Climate Change Management

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Climate Change and Health

Improving Resilience and Reducing Risks

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Climate Change Management

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Preface

It is widely known that climate change has multiple effects on human health: hot temperatures not only reduce productivity but are associated with problems such as blood pressure and discomfort especially among elderly people. Extreme events such as floods may spread water-borne diseases and lead to damages to property, which, in turn, sometimes leads to psychological problems among the affected population. In summary, climate change may affect our health in a far-reaching way than we may think.

Climate change is seen—and perceived—as being one of the most important challenges of modern times. The impacts of climate change to human and environmental health are significant: climate change is known to negatively influence the social and environmental determinants of health (i.e., poverty, clean air, safe drinking water, food supplies), and extreme events such as floods and hurricanes are associated with distress as well as with loss of property. Overall, it can be said that the negative health effects of a changing climate are likely to become more intensive in the future, especially in poor countries, where the ability to adapt is limited by a restricted access to resources and technology. There is therefore a pressing need to identify approaches, try new methods, and develop new tools to increase health resilience to climate change and reduce risks.

But despite the relevance of the topic, few publications have ever attempted to document and promote the wide range of initiatives and projects linking climate change and health, taking place today. Most publications are topic specific or sectorial oriented, which demonstrates a need for a forward-looking book, which holistically handles the links that exist between climate change and health.

This book addresses this perceived need. This book is therefore an attempt to contribute to the global debate on the climate change and health, by linking climate change science and the health implications of global warming. It meets a perceived need for a publication, which explores the strong links between climate change and health, providing a solid basis for further works in this field.

The growing of knowledge on the nature and the physics of climate change, its causes, consequences, and configuration is not currently matched by an equivalent understanding and scientific production of the societal challenges it poses, namely in health-related issues and well-being of populations.

The aim of this book is to create and share knowledge about the social, economic, political, and cultural dimensions of climate change implications on health and well-being of communities and the needed transformations in the policy, governance, and social-cultural strategies to mitigate, adapt, and prevent it, giving evidence to the ecology of produced knowledge, between scientists, politicians, policy makers, professionals, populations, and all the actors considered in these controversies.

Bearing in mind the broad field of Climate Change and Health, this book is divided into four main parts: The first part is more related to the direct links between Climate Change and Human Health (e.g., mental health, human thermal comfort, human cardiovascular system, air quality, food security, and environmental health). The second part focuses on Climate Change and Infectious Diseases (e.g., Ebola, malaria, mosquito-borne diseases, dengue, and waterborne diseases). The third part focus on education, training, and governance topics (e.g., public health, curriculum, training, and education; risk, risk management, multi-institutional network, resilience, vulnerability, environmental injustice, social transformative practices, climate governance, traditional communities and knowledge ecology, traditional knowledge), whereas the final part concentrates on regional experiences (health inequality, intersectionality, migrants, metropolitan governance and megacities, the Mercosur).

A total of 28 double-blind peer-reviewed chapters from Europe, Asia, Africa, North America, and South America afford this book a strong thematic and geographical coverage, with experiences from different parts of the world.

In the first chapter, Walter Leal Filho, Ulisses Azeiteiro, and Fátima Alves set up the scene for a scientific discussion on climate change and health and outline the major issues it entails. This introductory chapter also outlines the challenges of climate change to societies and its impacts on human health, considers the influence on various groups of stakeholders, and suggests some measures, which may lead to a better understanding of the connections between human health and ever-changing climate conditions.

In the first part of the book related to Climate Change and Human Health, readers can find eight chapters (Chaps. 2–9).

The second chapter, from Jyotsana Shukla, is entitled "Extreme Weather Events: Addressing the Mental Health Challenges." The purpose of the chapter is to take an overview of the mental health impacts of the major extreme weather events and emphasize the importance of preparedness in meeting these mental health impacts. The author looks into some of the best practices adopted by nations and cities, to deal with the mental health challenges thrown in the wake of such extreme weather events, and suggests measures, for governments and communities, to be better prepared to deal with mental health issues arising from future extreme weather events.

Paola E. Signoretta, Veerle Buffel, and Piet Bracke in the chapter "Mental Well-Being and the Eco-State: a Classification of Regions and Countries of the European

Union" report on exploratory research work on the link between mental well-being and the "eco-state" within the context of countries and regions of the European Union (EU).

Susana Oliveira Moço, José Eduardo Ventura, and Manuela Malheiro Ferreira in the chapter "The bioclimatic (dis)comfort and summer thermal paroxysms in Continental Portugal—intensity, frequency and spatial contrasts" analyze the variability of thermal (dis)comfort due to heat in summer, in Continental Portugal, between 1981 and 2010, based on an appropriate set of bioclimatic indicators. The authors conclude that the feelings of discomfort due to heat are quite frequent. Since 2000, the cities of Coimbra and Lisbon have revealed a trend for thermal sensations of greater intensity and intended to contribute to the identification of vulnerable areas and predict intense heat situations, preventing risks to public health and human welfare.

In the chapter "Effects of temperature variation on the human cardiovascular system: a systematic review," André Luís Foroni Casas, Gabriella Mendes Dias Santos, Natalia Bíscaro Chiocheti, and Mônica de Andrade conducted a systematic review concerning the effects of temperature variation on the human cardiovascular system in order to access evidence of how heat and cold waves are affecting health. The chapter concludes that high ambient temperatures are leading to increased incidence of cardiovascular diseases, mainly heatstroke, and the elderly is the most vulnerable age group.

Vittorio Sergi, Paolo Giardullo, Yuri Kazepov, and Michela Maione address the complex relationship between these two policy domains, their scientific background, and the related acceptability issue, which varies substantially among countries and social groups and is influenced by social and cultural factors, and pose a question "Can concern for air quality improvement increase the acceptability of climate change mitigation policies?" They state at the end that linking air quality to climate change could be a win-win strategy to increase the social acceptability of specific policies and their implementation if knowledge and communication gaps between citizens and policy makers will be reduced.

"São Paulo, Brazil, is a big city that suffers the effects of extreme climatic events like intense rains and droughts. In fact, these circumstances are outcomes of deficits accumulated for years in the production of an urban space that neglected environmental factors in their management, construction, and planning. As a coping strategy the municipality of São Paulo promulgated in 2009 the MPCC, whose original main objective was to mitigate the emission of greenhouse gases." Rubens Landin and Leandro Luiz Giatti in the chapter "The Health Sector in an adaptive dialectic strategy: The case of the São Paulo's Municipal Policy on Climate Change" analyze São Paulo's Municipal Policy on Climate Change (MPCC) until 2012 in terms of the Health Sector's convergence and intersectoral actions, considering a necessary dialectic between global and local toward adaptive measures in the urban scale concerning climatic variability.

"The global food system makes a significant contribution to climate change, affecting greenhouse gas emissions and other major environmental impacts, along the entire food chain." This topic is introduced by Beatriz Oliveira, Ana Pinto de

Moura, and Luís Miguel Cunha in the chapter "Reducing food waste in the food service sector as a way to promote public health and environmental sustainability." Authors evaluate the determinants and the consequences of food waste at the food service sector, while considering potential solutions. It takes into account the fact that reducing food waste is an important part of the effort to attain environmental goals and to promote public health.

Elvis Chabejong Nkwetta introduces the topic of malnutrition caused by food insecurity and writes the chapter "A Review on the Impact of Climate Change on Food Security and Malnutrition in the Sahel Region of Cameroon." The author also suggests measures to raise awareness on climate change, food security, and malnutrition.

The second part of the book is about Climate Change and Infectious Diseases (e.g., Ebola, malaria, mosquito-borne diseases, dengue, and water-borne diseases) (Chaps. 10–14).

In this context, Harris Ali, Barlu Dumbuya, Michaela Hynie, Pablo Idahosa, Roger Keil, and Patricia Perkins in the chapter "The Social and Political Dimensions of the Ebola Response: Global Inequality, Climate Change, and Infectious Disease" consider the wide ranging sociopolitical, medical, legal, and environmental factors that have contributed to the rapid spread of Ebola, with particular emphasis on the politics of the global and public health response and the role of gender, social inequality, colonialism, and racism as they relate to the mobilization and establishment of the public health infrastructure required to combat Ebola and other emerging diseases in times of climate change.

Vincent Nduka Ojeh and Sheyi Aworinde in the chapter "Climate Variation and Challenges of Human Health in Nigeria: Malaria in Perspective" address the potential impact of climatic variations in relation to human health with Malaria in perspective. Six years climate data and in- and out-patient malaria records from hospitals in Kosofe, Lagos, were used and analyzed and preliminary result shows that there is a strong relationship between climate variation in rainfall and malaria disease in Nigeria with seasonal cycles.

In the chapter "Climate change and mosquito-borne diseases," Teresa Nazareth, Gonçalo Seixas, and Carla A. Sousa illustrate the complex scenario where mosquito-borne diseases (MBD) develop and the myriad of consequences that climate may induce in the incidence of these illness. Different types of models used to predict forthcoming MBD scenarios are presented as well as the limitations that might preclude their use as tools for the design of surveillance or control strategies. Authors also presented the history of dengue prevention and reemergence. The evolution of this well-documented disease reveals that besides climate, the increase of human population density, the growth urbanized areas, the upsurge of international mobility, the discontinuity of sustainable source-reduction activities, and the emergence of insecticide resistance in mosquitoes are also determinants for an increase in dengue prevalence.

Paula Carvalho Pereda and Denisard Cneio de Oliveira Alves in the chapter "Climate Impacts on Dengue Risk in Brazil: Current and future risks" analyze the climate effects on dengue using a risk function for Brazilian data. Authors intended to link two relevant agendas: the identification of ways to manage the climate-related risks of today and improve the understanding of future risks in the country. The findings indicate that if climate change occurs as expected, there will be a potential added risk for central-southern areas in Brazil and a risk reduction for northern areas of the country. Short-term deviations from normal rainfall conditions in summer also increase the risk of dengue. Other relevant findings suggest the ineffectiveness of current local expenditures for epidemiological surveillance and the need for integrated actions to control the disease, which include the best use of climate forecast to predict dengue cases.

In the chapter "Climate Change and Health Vulnerability in Bolivian Chaco Ecosystems," Marilyn Aparicio-Effen, Ivar Arana, James Aparicio, Cinthya Ramallo, Nelson Bernal, Mauricio Ocampo, and Gustavo J. Nagy state that "Climate change and variability is impacting health, across different spatial scales, ecosystems, and water supply and quality. In Bolivia climate change is operating in a framework of poverty and inequality. This chapter focuses on the Bolivian Chaco ecosystems' water availability and indigenous health. An ecohealth research was launched to evaluate rural communities and their vulnerability and impacts to current and future climate conditions. The participatory-based approach incorporates community and indigenous organizations, local and national health, and meteorological services. Main observed impacts at Chaco are water stress and warming affecting watersheds, ecosystems, and health. Water-borne diseases (WBD) and diarrheal diseases (DD) affected most children evaluated. An average decrease in rainfall of 5–12 %, up to 25 % in winter, especially at the middle and low watershed, is observed. Future increases in temperature (+1 to 2 °C for 2030–2050), modified rainy patterns, and reduced water availability are expected. Both observed and expected warming and less rainfall are correlated with diarrheal vulnerability (VCCDD) and the number of DD cases at rural and indigenous communities. Thus, increasing trends of WBD and DD are likely for 2030–2050. This experience was useful to design Chaco region climate change policies and indigenous health adaptation strategies focused on WBD/DD. These included raising awareness about water and health climate vulnerability and impacts, increasing investments for water sources protection, establishing systems to compensate and protect watersheds and water springs, capacity building, WBD/DD prevention actions, and clean technologies for economic activities."

In the third part of this book, the focus is on education, training, and governance topics (e.g., public health, curriculum, training, and education; risk, risk management, multi-institutional network, resilience, vulnerability, environmental injustice, social transformative practices, climate governance, traditional communities and knowledge ecology, traditional knowledge) (Chaps. 15–21).

"A key component of adapting to climate change and variability is the creation of a new generation of professionals able to understand the role of climate on disease and to quantify its risk in public health. Capacity building in different regions of the globe will help strengthen the decisions made in the health sector and is reflected in the reduction of climate risk. A lot of knowledge remains to be built in climate and public health and the field efficiency of the new approaches implemented is yet to be assessed. It is critical to continue training professionals and to provide spaces for networking and also to create collaborative programs that allow professionals from different institutions, sectors, and disciplines to communicate and share their expertise to tackle climate risk." Gilma Mantilla, Carmen Ciganda, Graciana Barboza, Francisco Chesini, Laura Frasco, Silvia Fontán, Carolina González, and Celmira Saravia in the chapter "Training Institute on Climate and Health: Mercosur Experience" introduce the International Research Institute for Climate and Society (IRI), the InterAmerican Institute for Global Change Research (IAI), the Ministry of Public Health of Uruguay, the Intergovernmental Commission for Environmental and Occupational Health of (CISAT), and the Pan American Health Organization (PAHO) that joined forces to organize the first regional Training Institute on Climate and Health based on the curriculum on climate information for public health developed and implemented worldwide by the IRI. Training and ongoing Projects are described.

Marcos Barreto de Mendonça, Teresa da-Silva-Rosa, Tulio Gava Monteiro, and Ricardo de Souza Matos in the chapter "Improving Disaster Risk Reduction and Resilience Cultures through Environmental Education: a Case Study in Rio de Janeiro State, Brazil" discuss the contribution of environmental education projects as an example of strategy for landslide disaster risk reduction since they can motivate inhabitants to participate in disaster risk reduction activities and, hence, to practice participatory risk management, empowering citizenship and strengthening community resilience. The studied project consisted in a nonformal education experience and took place in a landslide risk community in Niterói, a city situated in the metropolitan area of Rio de Janeiro, Brazil. The project involved geotechnicians, researchers of different backgrounds, young residents, and members of a local nongovernment organization and aimed to analyze this experience as an effort to face climate impacts.

"The potential consequences of climate change to our health and well-being pose relevant questions and real challenges need to be tackled. These real challenges can be used as strong triggers to initiate action-oriented learning processes." In the chapter "Climate change and health related challenges as a trigger for educational opportunities to foster social knowledge and action," David Dueñas and Lídia Ochoa focus on the educational responses that are being developed to promote a generational transformation which can enhance social knowledge and bonding, having an empowering impact over communities, leading to their transformation and improvement. This chapter includes interesting initiatives and international trends that are worth disseminating.

"In January 2011, an extreme rainfall event took place in the Mountainous Region of the state of Rio de Janeiro causing a catastrophic landslide that resulted in more than 1500 deaths. This event marked a new challenge for disaster reduction in Brazil and introduced several measures for risk management." Leonardo Esteves de Freitas, Anderson Mululo Sato, Sandro Schottz, and Ana Luiza Coelho Netto in the chapter "Community, University and Government Interactions for Disaster Reduction in the Mountainous Region of Rio de Janeiro, Southeast of Brazil" discuss the dialogue gap between government and the local population that could possibly explain the failure of the current risk management model, pointing at the urgent need to integrate actions from the government, the civil society, and universities. Authors describe former procedures and local studies, which have guided the development of a multi-institutional network (called Córrego Dantas RIsk Management—CD-RIMAN) and the establishment of its main goals.

Andréia Faraoni Freitas Setti, Helena Ribeiro, Edmundo Gallo, Fátima Alves, and Ulisses M. Azeiteiro in the chapter “Climate change and health: governance mechanisms in traditional communities of Mosaico Bocaina/Brazil” address various socio-environmental challenges, health, and traditional communities in the context of climate change. The study regards a protected area, the so-called Mosaico Bocaina, in the municipalities of Angra dos Reis and Paraty, in the state of Rio de Janeiro, and Ubatuba, in the state of São Paulo, where traditional communities from three different ethnic groups live (indigenous, quilombolas, and caiçara). The knowledge of nature and of the physics of climate change (including its causes, consequences, and characteristics) is not always accompanied by the understanding and science of how climate change affects the well-being and health of populations. The analysis of the public policies and science production for the field concluded that the situation for the region in question is no different from that of other regions in Latin America: (1) public policies have not become effective interventions against climate change in general, and the interest in its implications over the health of populations is recent; (2) the science of climate change is insufficient, especially regarding its effects over the health of populations, whether in this specific region or more encompassing scales; (3) there is no information on how traditional communities perceive climate change, their impacts on health and well-being, and tackling strategies. This chapter seeks to contribute to the knowledge of the impacts of climate change on the health and well-being of traditional communities, focusing on the governance tools required to address it. What strategies have traditional communities been using to deal with it? How does the official agenda of efforts reflect the sociocultural perceptions and mitigation and survival strategies of traditional communities? Qualitative methods of participant observation that combined participation, observation, informal open interviews, and analysis of documents were employed. The results generated territorialized knowledge in the social, economic, political, and cultural dimensions of climate change and their implications on the health and well-being of traditional communities, as well as allowed the identification of governance mechanisms and sociocultural strategies that can be used to mitigate, adapt to, and help avoiding climate change.

In Chap. 20, “Observatory of Sustainable and Health Territories (OTSS) GIS—GEO-Information for the Sustainability of Traditional Communities in Southeastern Brazil,” Leonardo Esteves de Freitas, João Crisóstomo Holzmeister Oswaldo-Cruz, Anna Cecília Cortines, and Edmundo Gallo state that “The sustainability of traditional communities has a direct connection with the knowledge about their territories and the constitutive social practices of their territoriality. Building a Spatial Database generates knowledge about their territories and enables carrying out a range of geospatial analyses to support communication and decision making. This chapter describes the first step in building a Geodatabase to support the management, planning, and communication actions within OTSS, a partnership between FIOCRUZ and the Traditional Communities Forum of the Municipalities of Angra dos Reis, Paraty, and Ubatuba in Brazil. Three lines of work were developed: (1) Geodatabase Design—geodata was arranged in different scales, comprising basic and thematic secondary data, as well as primary data relevant for the management and the political action of the communities. The information contained in the system was selected together with representatives from the communities. (2) Geodatabase Analysis and Management. There was continuous data input from traditional populations and technical teams. Analysis of the geodata provided solutions to spatial questions posed by project members and by communities, especially about territorial disputes. (3) Geo-information Availability—preparation of maps, charts, spatial files, and other media to support the management of the project, the traditional communities, and the implementation of related projects."

In the chapter "Building Community Resilience and Strengthening Local Capacities for Disaster Risk Reduction and Climate Change Adaptation in Zongoene (Xai-Xai District), Gaza Province," the authors, Fialho Paloge Juma Nehama, Alberto Júnior Matavel, António Mubango Hoguane, Manuel Menomussanga, César António Mubango Hoguane, Osvaldo Zacarias, and Muhamade Ali Lemos, evidence extreme events in Mozambique. "The occurrence of extreme climate events in Mozambique constitutes a great barrier to swift sustainable economic development due to associated human and material damages. As a result, the population lives in a situation of threat and instability. The most vulnerable societies in Mozambique are those inhabiting settling areas along coastal or river plains and those whose economies are strictly related to resources highly sensitive to climate changes. The vulnerability factors of two communities in the lower Limpopo River were analyzed using a participative tool, the top mecca. The communities (Zongoene and Mahielene communities) in the lower Limpopo River basin lack essential adaptation elements that enable responses to climate change and natural disasters. These elements are required nationwide and include a highly diversified economy and access to new production technologies. In addition and in particular, the Zongoene and Mahielene communities rely directly on the services offered by the coastal ecosystems that have been affected by the impacts of floods, droughts, sea level rise, and tropical cyclones. Some activities for climate change adaptation were identified and discussed based on the weaknesses and strengths identified."

The fourth and last part of this book is about regional experiences (health inequality, intersectionality, migrants, metropolitan governance and megacities, the Mercosur) (Chaps. 22–28).

"Climate change is projected to further increase heat waves in number, intensity, and duration over most land areas in the twenty-first century. Among the urban population persons with migrant background are particularly considered to be at risk during heat waves due to the intersection of several risk factors: social status (poverty, manual labor), residential area (densely populated, disadvantaged urban areas, heat islands), and health condition." Laura Wiesböck, Anna Wanka, Elisabeth Anne-Sophie Mayrhuber, Brigitte Allex, Franz Kolland, Hans Peter Hutter, Peter Wallner, Arne Arnberger, Renate Eder, and Ruth Kutalek in the chapter "Heat Vulnerability, Poverty and Health Inequalities in Urban Migrant Communities: A Pilot Study from Vienna" pledge for a differentiated approach in studying heat-related health outcomes and present first descriptive outcomes of two explorative case studies of multi-generation families in Vienna, comparing a family with Turkish migrant background with a family without migrant background. The data consists of participant observation and in-depth interviews and has been generated in the course of the research project "Vulnerability of and adaption strategies for migrant groups in urban heat environments (EthniCityHeat)" between June and September 2014.

"Against the backdrop of Climate Change and the inevitable increase in the negative consequences which arise, there emerges the need to study their economic, socio-demographic, and environmental impacts." "Maria da Conceição Pereira Ramos, Natalia Ramos, and Ana Isabel da Rocha Moreira" in the chapter "Climate change and forced environmental migration Vulnerability of the Portuguese Coastline" discuss the "forced environmental migration" of populations due to environmental phenomena resulting from changes in the Earth's climate. As Portugal is a country with a considerably long coastline, it is extremely important to study the problems that such a shoreline faces, particularly those that arise from the increase in the average sea level. These problems resulting from climate variability associated with abusive and inappropriate use of the coastline increase its degradation and the vulnerability of the resident population. In some situations, the best solution involves implementing the planned withdrawal projects through the displacement of the population to an area more climatically stable, which can be considered "forced environmental migration."

In the chapter "Inequities and challenges for a metropolitan region to improve climate resilience," Ana Karina Merlin do Imperio Favaro, Natasha Ceretti Maria, Silvana Audrá Cutolo, Renata Ferraz de Toledo, Rubens Landin, Fernando Antonio Tolffo, Ana Cláudia Sanches Baptista, and Leandro Luiz Giatti analyze the inequities among municipalities in the Metropolitan Region of São Paulo—MRSP related to Human Development Index—HDI and the provision and demand for water as an environmental service. Metropolitan areas require a large flow of environmental services in order to maintain their structures and their population, especially considering the challenges associated with climate change, and the growth of metropolitan areas implies pressures for the production of wealth and supply for the population needs resulting in environmental and social pressures as well.

Sofia Lizarralde Oliver and Helena Ribeiro in the chapter "Water supply, climate change and health risk factors: example case of São Paulo—Brazil" introduce us to the Cyanobacteria blooms that are becoming an increasingly common phenomenon worldwide, especially in urban lakes and reservoirs. Authors want to demonstrate the potential relationship between cyanobacteria in the drinking water from the Guarapiranga Reservoir and climate change in the Metropolitan Region of São Paulo, as well as health risk factors associated and how climate change in the city of

São Paulo can worsen these problems related to drinking water once the ideal climatic conditions for the proliferation of cyanobacteria are increasing in frequency. Especially in the last 20 years, the maximum temperatures are higher and episodes of heavy rain are more frequent. This scenario can magnify a public health problem related to cyanobacteria in São Paulo and around the world. Climate change may increase public health risks related to drinking water quality as associated with land use.

"Climate change and ENSO events are increasing hydro-climatic risks and health impacts in Bolivia, Paraguay, and Uruguay, as well as social inequalities in Bolivia and Paraguay. Climate scenarios project increase in average temperature in the whole region, a slight decrease in precipitation, and modified rainy patterns in the Andean region and Paraguay for 2040. More hydro-climatic extremes are also expected, which will likely worsen health vulnerability without further adaptation measures." Marilyn Aparicio-Effen, Ivar Arana, James K. Aparicio, Pamela Cortez, Genaro Coronel, Max Pastén, Gustavo J. Nagy, Aida Galeano Rojas, Laura Flores, and Mario Bidegain in the chapter "Introducing hydro-climatic extremes and Human Impacts in Bolivia, Paraguay and Uruguay" introduce the research conducted by the Vulnerability, Impact and Adaptation Network on excessive rainfall, floods, and landslides from 2007 to 2014 in Bolivia, Paraguay, and Uruguay. Herein, a case study of the vulnerability and human impacts of an extreme rainfall and landslide in Callapa, La Paz, Bolivia, in 2011 is presented. Despite strong differences in socioeconomic and health status, the three studied countries are vulnerable to hydro-climatic extremes. EWS and preparedness based on climate and socioeconomic assessments and monitoring are crucial to increase resilience to extreme events.

Gustavo J. Nagy, Genaro Coronel, Max Pastén, Julián Báez, Roger Monte-Domecq, Aida Galeano Rojas, Laura Flores, Carmen Ciganda, Mario Bidegain, Marilyn Aparicio-Effen, and Ivar Arana in the chapter "Impacts on well-being and health by excessive rainfall and floods in Paraguay, Uruguay and Bolivia" explain how hydro-climatic anomalies are impacting the well-being of populations and increasing vector-, rodent-, and water-borne diseases (H-ID) in Bolivia, Paraguay, and Uruguay where extreme ENSO-linked floods have been frequent since 2007. Both well-being and health impacts are discussed as well as the development of adaptation plans after disasters. The evolution of Hepatitis A in Uruguay which was endemic and correlated with droughts where a sewage deficit existed is also discussed because mandatory vaccination strongly reduced the number of cases since 2007. Future climate scenarios show increases in average temperature and modified rainfall patterns, with increases in Uruguay and decreases in Bolivia and Paraguay for 2011–2040. There is high uncertainty with regard to river flow, floods, and health impacts, and more hydro-climatic extremes are expected. There is evidence of both an adaptation deficit to cope with current climate and a risk management learning process, the balance of which remains to be established.

Last but not least, Edmundo Gallo, Andreia Faraoni Freitas Setti, Tiago Ruprecht, Francisco Xavier Sobrinho, Patrícia Finamore, and Gustavo Carvalhaes Xavier Martins Pontual Machado in the chapter "Territorial Solutions, Governance and Climate Change: Ecological Sanitation at Praia do Sono, Paraty, Rio de Janeiro, Brazil" outline the context of climate change and water crisis in Brazil (particularly in the Southeast), which amplifies the vulnerability of traditional and coastal communities and influences the implementation of technological solutions.

Given the variety of research it entails, this book offers a diverse thematic/disciplinary and geographic overview of some current research and projects/action projects in Climate Change and Health. In addition, the chapters address some important challenges and future developments, also giving insights into the discussion around consequences at multiple spatial, temporal, and sociopolitical scales and the multiple dimensions of climate change, based on an interdisciplinary dialogue.

We would like to take this opportunity to thank all authors who submitted their manuscripts for consideration of inclusion in this book. And since the peer review was a double-blind process, we also thank the reviewers who have taken time to provide timely feedback to the authors, thereby helping the authors to improve their manuscripts and ultimately the quality of this book.

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Contents

Chapter 1
Climate Change and Health: An Overview of the Issues and Needs

Walter Leal Filho, Ulisses M. Azeiteiro, and Fátima Alves

Abstract This introductory chapter outlines some of the key issues related to climate change and health, as well as some areas where action is needed, so as to allow a more systematic approach towards the problem. It outlines the challenges of Climate change to societies and its impacts on human health; considers the influence on various groups of stakeholders and suggests some measures, which may lead to a better understanding of the connections between human health and ever changing climate conditions.

Keywords Climate change • Health • Societal challenges

Introduction: Setting the Scene

The global climate is changing. There are solid evidences about this and a broad consensus among the scientific community. Climatic factors are known to be of importance in the preservation of nature, biodiversity and human health and well-being. If current trends continue, increase in temperature, and in the frequency of extreme weather events may lead to serious consequences to the environment as a whole and to human health in particular.

All sorts of pressures characterize the modern world. In particular, many of the forms of economic organization and production, consumption or social organization are not very climate friendly. In addition, ecosystem services are not fully appreciated and their predatory management has led to some of the paradoxes that humankind face today, such as: how human species can survive and ensure the survival of future generations in the context of enormous changes in the functioning of natural systems? How can we live with dignity, health and ensure our well-being?

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The growing need for energy has led to increased consumption of fossil fuels, responsible for the emission of greenhouse gases. As a result of these actions, in which the various actors are integrated in complex biogeochemical cycles, the world has been witnessing climate change with increasingly visible impacts, which affect life on the planet, especially ecosystems and habitats. Global warming is at the base of the pyramid of these factors and it results mainly from anthropogenic action.

In modern societies, there are several aggravating factors of the situation in the context of a development model that makes extensive use of fossil fuels, causes problems in land use and production and interferes in the carbon cycle which in turn affects the availability of essential resources such as drinking water for example, as well as leads to melting ice caps and glaciers. Also, pollution—produced mainly by carbon dioxide—increases the acidity of the oceans and compromises the marine food chain.

If the current trend continues, the twenty-first century will witness climate change as an increasingly diverse and devastating phenomenon. It will also witness an unprecedented destruction of ecosystems, and the emergence of several diseases—old and new ones—that will affect many more people. In the last 100 years we have seen a rise in temperature of about 0.75 °C (WHO 2009a, b), which varies geographically. For example, rising sea level alone will put in danger a quarter of the world population, living near the sea or very close to it (see the location of large cities, for example). The health of populations is directly related to the environment.

Climate change interferes directly on the conditions of human life: affect economic development, ecosystems, food production, water and agriculture, shelter (Menne and Ebi 2005; Smith et al. 2014). The deterioration of these conditions has adverse effects on the health of populations.

The consequences of climate change to human health are directly proportional to the duration, frequency and intensity of exposure to situations, as well as to the vulnerability of exposed communities and populations, where social factors (which include social inequalities and lack of access to services—gender, income, social and medical services, cultural factors, and others) and environmental factors (geography among others) are determinant for this vulnerability. Effectively, we are not all affected in the same way. International trends have shown us that women (with their children), the elderly and the poor are, in this context, especially vulnerable groups (Tavares 2009; McMichael et al. 2012; Smith et al. 2014).

The Intergovernmental Panel on Climate change (IPCC) Fifth Assessment Report concluded that strong evidence exists for increases in some extreme events worldwide since 1950 (Stocker et al. 2013), especially more frequent hot days and heavy rainfall episodes (Herring et al. 2014). Despite the published literature about causes (Kerr 2013) and attributing weather extremes to climate change (Hulme 2014), it is consensual that climate and global warming are accompanied by an increased frequency and/or intensity of extreme events (extreme temperature and precipitation events: heatwaves, heavy rainfall, storms and coastal flooding) with the possibility that this large change could initiate nonlinear climate responses which lead to even more extreme and rapid (on the time-scale of decades) climate change (McMichael et al. 2006). Populations adapt to the local prevailing climate via physiological, behavioral, and socio-cultural and technological responses however, extreme events often stress populations beyond those adaptation limits which makes it very important to understand the health risks deriving from these events (McMichael et al. 2006).

These extreme weather events have been forcing the displacement of populations to other locations, caused by the rising sea level that has led to the destruction of cultivated fields and to the reduction of fish availability for large populations for example, forcing local population displacement and forced migration (Wilbanks et al. 2007). In this context we assist to the increase in infectious diseases and in the prevalence of mental problems caused by stress and anxiety.

Climate change affects all regions around the world differently. This causes several types of costs for society and economy, and entails risks for wildlife and human health. In fact, there is scientific consensus that global warming, Climate change and increasing climate variability (extreme events) have severe impacts on human health.

Climate Change and Health: Some of the Issues

It is widely acknowledged that climate conditions play a significant role in people's health, and can interfere with it in a number of ways. Even though some degree of uncertainty is related to Climate change (Swart et al. 2009), there are evidences of its connection to health issues (WHO 2009a, b).

Indeed, climate change, when considered at the macro level, can exacerbate a number of health problems, since an intensification of certain climate conditions such as intensive temperature increases may lead to discomforts or, in extreme cases, to decreases in levels of productivity. A study performed by Kovats and Akhtar (2008), for instance, has shown the links between Climate change and human health in Asian cities, whereas Keim (2008) looked at the role of public health preparedness and response as an adaptation to Climate change.

Climate change also puts pressure on existing health vulnerabilities and many prevalent human diseases are linked to climate fluctuations, from cardiovascular mortality and respiratory illnesses due to heatwaves, to altered transmission of infectious diseases and malnutrition from crop failures (Patz et al. 2005).

In some extreme cases, climate change and its consequences may negatively influence quality of life and livelihoods, being also a possible cause of death in specific contexts. For instance, some recent heatwaves in India (e.g. Akhtar 2007) have led to high levels of mortality—especially among the elderly a similar trend has been seen in Italy (Schifano et al. 2009).

According to some latest research on climate change there are documented increases in average temperatures, meaning that summer seasons are becoming hotter and winters are getting milder in some parts of the world (e.g. Andresen

Table 1.1 Some of the impacts of climate change on health

Item	Consequence
Impacts from heat, heat waves and drought	Discomfort, distress, cardiovascular and respiratory diseases, malnutrition, infectious diseases, malaria, exacerbation of chronic diseases (diabetes, lung disorders, psychiatric disorders)
Impacts from extreme weather events	Discomfort, distress, psychological problems due to loss of property
Impacts from reduced air quality and emission of gases	Breathing problems, higher incidences of allergy, skin cancer, ocular lesions, reduction of the immune system
Impacts from floods and flooding	Proliferation of water-borne diseases Malaria, dengue, transmissible diseases, stress and psychiatric disorders
Impacts from cold	Risk of respiratory infections, risk of allergic reactions, respiratory diseases, cardiovascular and cerebrovascular diseases

et al. 2012). There are also predictions, which states that average temperatures are likely to increase in the coming decades (IPCC 2014). As a result, one may expect the number of hot days to increase, and the occurrence of heat waves may intensify, which, in turn, may lead to some health problems. Table 1.1 outlines some of the impacts of climate change on health.

Apart from the direct effects on human physical health, increases in the frequency of extreme weather events—or in their severity—could increase the risk of diseases, as Table 1.1 outlines. Not only droughts but also floods are phenomena associated with Climate change, and Ahern et al. (2005) provide an analysis of the global health impacts of floods based on epidemiological evidence. In other words: floods may pose a direct threat to human beings, their property and the surrounding environment.

Increases in the number of climate-heat related ailments and illnesses are also more likely to occur, some of which may be quite serious to the more vulnerable groups, which are listed in Table 1.2.

Furthermore, it is often overlooked the fact that concentrations of unhealthy air and water pollutants may increase under specific conditions, leading to a further set of health problems.

In this context, attention may be paid to fine particulate matters (FPM), which characterize extremely small particles and liquid droplets suspended in the atmosphere. FPM include particles smaller than 2.5 μm, which may be formed in the atmosphere or may be released as a result of chemical reactions of gases such as sulfur dioxide, nitrogen dioxide, and volatile organic compounds. They are produced as a by-product of the operation of power plants, gasoline and diesel engines, but also from wood combustion or from high-temperature industrial processes such as smelters and steel mills.

The inhaling of fine particles may lead to a broad range of negative health effects, which may vary from cardiovascular and respiratory diseases, to the

Table 1.2 Overview of some vulnerable groups and how climate change impacts them (focus on increased temperatures)

Group	Influence of climate change due to increases in temperature	Impacts
Children	Discomfort, distress	Apathy, reduced ability to concentrate, lower learning performance
The elderly	Discomfort, variations in blood pressure	Less motivation to be outdoors, reduction in social contacts
Pregnant women	Sudden changes in levels of bloods pressure; sweat attacks	Lower ability to work, prolonged sick leave periods
Allergic people	Earlier release of pollen by some plants; longer pollination seasons	Worsening of symptoms of allergy

development of chronic lung disease, and decreased lung function growth in children and in adults. As stated by Apsimon et al. (2009), synergies in addressing air quality and Climate change may be beneficial in addressing this issue.

Extreme temperatures, particularly heat waves and pollution contribute to the onset of cardiovascular and respiratory diseases, affecting mostly children and the elderly (Bai et al. 2014). Rising temperatures lead to droughts and water shortages, affecting the agricultural crops and reducing food possibilities that underlie situations of malnutrition and consequent increase in infectious diseases (NRC 2010). A further element may be added to the list of negative impacts of Climate change on health, namely the increased spread of some diseases, whose genesis may be traced back to changes in temperatures.

The emission of harmful anthropogenic gases has increased the incidence of skin cancer, ocular lesions and reduced the activity of the immune system, as well as increasing incidence of allergic attacks (McMichael et al. 2011).

It is estimated that the mortality in Europe increases 1–4 % per each increase of one degree in temperature above a certain threshold (Matthies et al. 2008). These rates increase in the case of individuals with chronic diseases: patients with cardio cerebrovascular disorders, diabetes, lung disorders and psychiatric disorders (Bouchama et al. 2007). The elderly and children are the most affected by hot flashes (Matthies et al. 2008; Bai et al. 2014).

Lack of water leads to contaminated water consumption, which in turn contaminates the food chain and limits hygiene, responsible for virus and bacteria proliferation causing numerous diseases, which has been increasing and that can even lead to death. Also the temperature rise enhances the transmission of malaria and other diseases (Naidoo and Olaniran 2014).

The impact of the temperature on health is determined by the level of moisture and increases the risk of respiratory infections, the risk of allergic reactions and respiratory diseases, cardiovascular and cerebrovascular diseases (McMichael et al. 2003). The homeless are a highly vulnerable group in this context, since they often have no means to cope with very cold conditions.

Tropical cyclones and tornadoes, with destructive consequences for any habitat, have been a common phenomenon in recent years in various parts of the globe. The negative effects are more visible in poor populations, with the result of worsening inequalities and the difficult access to health services (WHO 2009a, b).

Apart from the economic effects and ecosystems, fires adversely affect health and social conditions of the concerned populations, including their health due to the smoke or produced combustion gases and the impacts on soil and ecosystem services (Nyamadzawo et al. 2013).

Floods and flooding in addition to the losses that also carry are responsible for habitat destruction and by favouring the increase of certain diseases. Malaria and dengue are strongly influenced by the floods caused by the Climate change as well as infectious diseases (McMichael et al. 2012). Also, stressful situations have impacts on mental health to which women are most vulnerable.

Climate Change's Impacts on Health: Some Intervention and Research Needs

The climate is a common good in which humanity is called to become aware of the urgent need to understand the causes of its change and deal with its consequences. Dealing with climate change requires profound changes in lifestyles, production and consumption (Giddens 2009). In terms of climate change impacts on health, it is important to mention that we need to move towards preventive action, requiring the organization of society, in terms of structures, services, and professionals who can respond timely and effectively to the disasters caused by extreme events and climate change, and the health problems they bring about (McMichael et al. 2015).

Climate change is a global problem that concerns everyone and requires a commitment from everyone. Since the late 1990s, climate change has been placed in the public, scientific and international agenda, with recommendations aiming to create global and regional policies to cope and address it. What has changed? How do we explain the ineffectiveness in the necessary change of human behavior and responsibility of the states?

The position on the world stage of peripheral or developing countries affects them strongly on the impacts of climate change on health and on biodiversity loss. This requires rethinking this issue in the light of international relations, in order to no longer penalize the poorest countries. Their livelihoods depend heavily on natural resources and ecosystem services such as fisheries, agriculture and forest resources. Furthermore their access to services (social, health, etc.) is tight and uneven (McMichael et al. 2015).

Climate change is also known to be one of the causes of migration among humans (Carraro 2015), and disruptions to animal and plant populations, whose capacity to adapt is often very limited (Parmesan 2006). In the case of human populations there are some problems with the national and international regulation of their status. They are not recognized as refugees by international conventions, presenting in turn a huge difficulty in having access to resources and services, including health (Williams 2008).

If we maintain the current production and consumption models, the situation will worsen further, and will bring probably irreversible consequences. It is therefore urgent to develop policies that compromise us all, individually and collectively, in a transformative change: reducing greenhouse gas emissions (replacing fossil fuels and developing renewable energy sources), changing patterns of production and consumption, changing social conditions and behaviors.

The creation of a strong legal-normative framework that ensures the protection of ecosystems is mandatory in a context where the logics of technology and economics are not in accordance. The policies of life must overlap the death's policies. The failures of world summits on the environment are revealing the alienation and irresponsibility of the countries and their political and economic groups that systematically devalue the environmental problem, hence worsening climate change impacts on health and well-being.

NGOs and social movements that have made a fundamental work at the local level and at national or international level, particularly in the areas of information, communication and awareness, which are known to be important in fostering and understanding of the impacts of climate change (Leal Filho 2009). They have faced enormous difficulties in the struggle with States and multinationals, which tend to regard climate change as a harmless phenomenon.

Some Courts have been asked to intervene and evaluate accountability processes of companies as well as their own states for the development of preventive measures in climate change, and the need to preserve the environment and maintaining and increasing biodiversity. Its performance can redraw new imbalances that destabilize the status quo of the current forces for environmental protection, the fight against climate change to ensure the right to a healthy planet and life for the future generations.

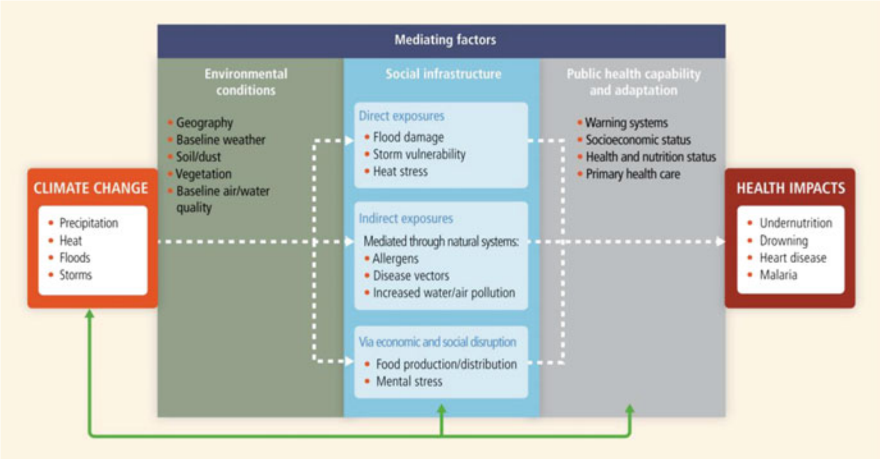
The ecological sensitivity of the population is still not enough to change behavior and attitudes that result from a society of consumption, which has systematically breached the limits of nature (Giddens 2009). The truth is that nature is prepared for all adversity. It will remain. We may not.

Future scenarios are complex and tend to polarize solutions: (1) on one hand it is considered that science and technology will find solutions for ecological problems (e.g. Cameron 2004); (2) on the other hand, human beings are seen as the cause of the major environmental problems, then we should reduce the human presence on the planet and prevent the action (e.g. Keller 2008).

In a paper on tools for developing adaptation policy to protect human health, Chalabi and Kovats (2014) developed a new generic conceptual framework for development-compatible climate policy planning, to evaluate policy options for middle and low-income countries that reduce the adverse health effects of climate change.

Perceptions and answers to climate change challenges, especially about the vulnerabilities to disease, are directly related to the social and environmental conditions of a region, a community, group, gender, age, and evidence social-

Table 1.3 Climate change, mediating factors and health impacts



Source: Smith et al. (2014: 716)

cultural and environmental inequalities, built between the relation of nature and human beings. Dealing with climate change and its consequences on health and well-being in current societies requires global strategies and local responses, considering both local governments and policies and the community lived experiences and lay rationalities (Alves et al. 2014). In order to achieve a global and total understanding of the phenomena and built effective solutions, it is necessary to continue to support research in each scientific area, but also to reinforce research that overcome disciplinary borders, in a global, dialogic and multidimensional approach, compatible with the evidenced complexity, as we may see in Table 1.3.

Conclusions

This overview and this book demonstrate that much can be gained by a better understanding of the connections between Climate change and Health. Therefore, more research on this theme is needed. This is not to say that current levels of research are not appropriate. The main message here is that there is—both quantitatively and qualitatively—a research gap, which has been preventing a better understanding of the implications of the impacts of Climate change on Human Health.

The examples outlined on this chapter show how much can be achieved by adopting a pragmatic approach, via which the various inconsistencies and gaps seen in Climate change research in relation to health—which have been common in the past—may be avoided. More research can not only fill in the gaps, but also guide future planning where aspects of climate, health and social sciences need to come hand in hand.

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Part I
Human Health and Climate Change

Chapter 2
Extreme Weather Events: Addressing the Mental Health Challenges

Jyotsana Shukla

Abstract There is an increasing body of evidence in India and across the world regarding the mental health impacts of the extreme weather events, along with other direct and indirect impacts. There is a strong evidence to suggest that these extreme weather events are occurring due to climate change resulting from global warming. The Climate Change debate does not talk much about dealing with the mental health impacts, preoccupied as it is in dealing with physical and economic impacts of climate change. Also, extreme weather events have been occurring in India for a while now. The Indian government has woken up to the fact that these weather events, bringing unprecedented devastation, are indeed “extreme”, only after the recent Kashmir floods. India has been an active participant in the climate change debate and discussions. The purpose of the present chapter is to take an overview of the mental health impacts of the major extreme weather events and emphasize the importance of preparedness in meeting these mental health impacts. The chapter looks into some of the best practices adopted by nations and cities, to deal with the mental health challenges thrown in the wake of such extreme weather events and suggests measures, for governments and communities, to be better prepared to deal with mental health issues arising from future extreme weather events.

Keywords Climate change • Extreme weather events • Mental health impact • Preparedness • Policy

Introduction

In 2014, researchers could finally perceive a strong relationship between climate change and some extreme weather events. The warming globe is seeing new records being set, in terms of climate variables, such as temperatures, over the last 10 years, including 2014 and now in 2015, both at the local and global levels

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(Thomson 2015). There is enough evidence to suggest that there may be more extreme weather events, than the world anticipates. In the case of precipitation changes, it has been observed that these changes are greater than those projected by the climate models (Gutowski et al. 2008; Allan and Soden 2008; Min et al. 2011).

It is easier to recognize extreme events, but it is not easy to define them, as there is no precise definition of the word “extreme”. Various definitions of the term are in vogue. It is said that the perceptions of the word “extremeness” are relative and context based. Words such as “rare”, “severe”, “high impact” have been used to describe “extremeness” (Stephenson 2008). Perhaps a better term would be an extreme event, or better still, an extreme weather (Climate, hydrological, etc.) event (Warakomski 1998). It has been said that extreme weather events may substantially increase in frequency and intensity, even with relatively small changes in the average distribution of climate variables such as temperature, rainfall, etc. (Trenberth 1999; Gutowski et al. 2008).

Climate change and global warming have already caused so many extreme weather events, still, there is much inertia, at the international level, in terms of policy formulations to tackle climate change. It appears that the developed countries of the world are evading the issue of tackling climate change by reducing their carbon emission (Levitt 2012).

All over the globe, global warming is causing intense, frequent, and lengthy periods of droughts, greater incidences of cloud bursts, heavy precipitation events, and the resultant flooding (IPCC 2007). The world has witnessed large-scale flooding in India, Pakistan, UK, Australia, Brazil, China; landslides in China; heat, drought, and wildfires in Russia; and record floods and heat waves, hurricanes in the US, all of which have left behind them a trail of death, destruction, displacement, and lost development (Union of Concerned Scientists 2010). These disasters are believed to have been caused by global warming (The Climate Institute 2011).

The increasing numbers of extreme events are a threat to the health and prosperity of the population of the world. The new and increasing number of extreme weather events can potentially subvert the ‘existing human systems and structures’ (Peterson et al. 2008). Such events will pose a threat to the eco system and adversely affect the human existence by having a fallout on the food production, transport systems, water management systems, etc. These events may also lead to much death and destruction, displacement, socio economic hardships, as has been observed in recent times when many parts of the world came face to face with hurricanes, floods, heat waves, droughts, or cyclones (Climate Communication 2015).

These impacts on human lives may be direct, short term, as well as indirect and long term. The impact on humans in terms of direct injury or psychosomatic complaints, vector borne diseases, etc. have been much studied and explored in the available literature on the subject. However, it is the indirect psychosocial impacts of the calamity brought by extreme weather, that have not received the due attention in the discussions, deliberations and policy papers that deal with climate change.

Connections Between Climate Change and Mental Health

There are numerous findings and experiences related to the mental trauma and psycho social suffering of populations affected by hurricanes like Katrina, typhoons like Haiyan, cyclones like Hud Hud, floods like Kashmir flash floods and Uttarakhand flash floods, in India. Such sufferings cannot wait for studies to keep on proving that the psychological harm is there. There is enough evidence relating to the psycho social impacts of these events, such as flash floods and droughts on farmers, on men, women, children, elderly, and the entire community life (Guenther and Balbus 2014; Gamble et al. 2013).

The psychological and mental health issues came to be highlighted mainly after disasters like tsunami and hurricane Katrina (Chand and Murthy 2008). The mental health issues relate to maladaptive responses in the form of trauma, chronic stress, anxiety or depressive disorders, co-morbidity with previous mental disorders or medical illness, acting out, or other defensive behaviors (Doherty and Clayton 2011). There may be an increase in the intensity and spread of mental health problems in the affected communities. Such events will also disrupt the social, economic, and environmental determinants of mental health, in these communities. All this will increase the responsibility of mental health institutions (Fritze et al. 2008).

The Scientific Evidence

The indirect effects of extreme weather events, also known as psychosocial impacts, are somewhat common across national and cultural boundaries (Rao 2006). The chronic mental health problems may get aggravated as a result of disruptions to health care service delivery caused by population displacement and infrastructure loss in the event of a disaster (Climate Change and Public Health 2010). The psychological distress, the unavoidable loss, and the displacement caused by weather related violent conflicts, have been found to be associated with a wide range of mental health impacts including anxiety, depression, and PTSD (WHO 2003a).

Studies have found a link between heat and violence and it is believed that the rising global temperatures may increase the incidents of violence (Anderson 2001), in the forms of assault, rape, robbery, burglary, and larceny (Rotton and Cohn 2003). Domestic violence also increases due to the experience of these unexpected events (Irfan 2011). Heat waves may also increase the incidence of alcohol and drug abuse (Bulbena et al. 2006).

For individuals who already have a mental illness, there are greater chances of getting a heat stroke, which may also result in delirium, neuropsychiatric syndromes, altered consciousness, agitation, restlessness, unconsciousness. These heat strokes may also lead to heat related deaths (Page and Howard 2009; World Health Organization 2008; Naughton et al. 2002).

Persons who already have schizophrenia or other serious psychological problems may suffer more in the aftermath of natural disasters and extreme weather events. People who already have mental illnesses may find it more difficult to cope than the normal residents (Fritze et al. 2008). Such persons pose a greater challenge for the public health delivery systems.

After such disasters, the admission rates for mental health problems in hospitals are also an indicator of mental health impact of disasters. A positive relationship was observed between prevailing temperatures and hospital admission rates for mental and behavioral disorders, such as dementia, mood disorders, stress related disorders, neurotic behavior and senility, during 1993–2006, in Adelaide, South Australia. It was also reported that the mortality due to these disorders, also increased in the event of heat waves for elderly people between 65 and 74 years of age (Hansen et al. 2008).

A long term mental health impact study of Katrina affected residents reported that anxiety-mood disorders prevailed in 49.1 % and Posttraumatic Stress Disorders (PTSD) and self harm in 26.4 % of the population, after 30 days of the disaster, in a sample of 815 pre-hurricane residents. There was high mental morbidity even 2 years of the disaster (Kessler et al. 2008).

Mental health problems also result from severe flooding, as a result of global warning. The risk for psychological distress increased fourfold following severe flooding in Lewes in southern England (Reacher et al. 2004). Similarly, posttraumatic stress disorder (PTSD) syndrome was reported in half of the children and adolescents, who were exposed to the "supercyclone" in the state of Orissa, even after 1 year (Kar et al. 2007).

Droughts, too, may affect family relationships, lead to stress, worry, and an increase in the rate of suicides. It may also result in loneliness and more work, due to the fact that fewer workers are willing to work, and the partners migrate to a new place for additional income or in search of school needs. The families may not get the needed social support at these times (Sartore et al. 2007; Raval and Vyas 2013).

Increased rates of suicides due to floods or droughts are another major area of concern. In case of India, these suicidal behaviors take place during droughts (Rao 2006), also witnessed recently in states of Maharashtra, Uttar Pradesh, etc. Such suicides are a characteristic feature in poor and agrarian economies of the world (Berry et al. 2008). Otherwise also, climate variations can itself be a reason for suicidal behaviors, as observed in the northern towns of Italy (Preti and Miotto 1998). Higher rates of suicides, violence, family break ups, drug and alcohol abuse after extreme weather events, were also reported in Australia, especially in its rural and semirural areas (The Independent 2011).

There are psychological consequences of physical diseases and infections caused by extreme weather related events, e.g. Schizophrenia and mood disorders were found to be associated with Borna virus infection outbreaks; Obsessive compulsive disorders with streptococcal infections and cognitive impairment with algal toxins (Sartore et al. 2007) in tropical countries.

There is also the risk of displacement from one's habitat due to extreme weather. It is speculated that the people who will thus migrate to other places will be seen as a threat to the culture and economy of that place, by the people already living there. They may also have to suffer from discriminations in these places, which might adversely affect their mental health (Myers 2005), in the form of place based distress, known as "solostalgia". This results from forced migration and from loss of connection to their home environments. Such displacements also result in population loss and disturbs the community life, affecting the mental health of those left behind in the affected community. It is estimated that around 200 million people might get displaced due to extreme weather events, by 2050 (Frumkin et al. 2008).

It has been reported that the likelihood of wars and conflicts increased twofold during years affected by the El Niño climate-warming phenomenon. It was concluded that despite the fact that the wars were not started by weather alone, El Niño might have played a role in 21 % of civil wars worldwide over the past 50 years (McCarthy 2011).

Children are highly vulnerable to severe distress after disasters as compared to adults, and especially prone to pre-disaster anxiety and post-trauma illness, as a result of either directly witnessing life-threatening situations or from getting separated from family and community support systems (Tucci et al. 2007; Searle and Gow 2010). It is also feared that future generations may have feelings of despair related to climate change (Goldwert 2011),as revealed in a survey of Australian children which showed that one fourth of these children, believed that the world would come to an end, before they became old (Australian Psychological Society (APS) 2007).

For people who are socially disadvantaged or are unemployed, there are greater psychosocial risks, such as, threats to their personal freedom, negative self perceptions and feelings of stress, insecurity, and seclusion (Shields and Price 2001; Keenan et al. 2004; Wang et al. 2008).

It has been found in an Australian study, that females, those under 35 years of age, and those who have a "pro-environmental orientation" and those high on "future anxiety" are more likely to be worried about changing climate, as reported in an Australian study (Australian Psychological Society (APS) 2007).

The affected people may cope by either denying the existence of the problem and thus minimize the threat perceived by them. They may also resign themselves to the situation and become cynical (Weems et al. 2007a). People may manage the thoughts and emotions related to potential threats from climate change through "adaptive protection motivation systems" and may reframe them through "social comparison with others and selective information exposure" (Weems et al. 2007b).

When an extreme weather event happens, the already available mental health services may get affected and the new cases may not receive the necessary treatment for long time to come. It has been found that even countries with very well-established mental health services may also not be well prepared to deal with the mental challenges that emerge after disaster (Morrissey 1995; Adams 2009; Patz et al. 2000).

Thus the mental health impacts of extreme weather events present an additional challenge, along with the challenge of dealing with physical injuries and infrastructure damages, for the governments, the public bodies, the NGOs, the insurance companies, the relief agencies, and for the communities affected. They need to prepare their capacities to meet this challenge, coordinate their efforts, and build the resilience of the community already affected and the ones likely to be affected in future by such events.

Future Trends

Communities around the world are adopting various strategies to meet the challenge of the extreme weather in the form of heat waves, cold spells, hurricanes, tornadoes, cyclones, floss, droughts, and other weather related calamities.

If people prepare themselves for severe weather, they will have lesser anxiety as has been reported in studies. For families and children, who are prepared for disasters, their anxiety levels are less (Osofsky et al. 2007). It will definitely be rewarding if there is planning and preparation for dealing with extreme weather events. Policymakers should aim at integrating mental health assessment into impact assessments carried out by non-health sectors. They need to understand the future risks and uncertainties and identify the vulnerable communities. There is also a need to develop and evaluate adaptive strategies and interventions so as to mitigate the current and possible future risks to mental health from climate change (Kovats et al. 2003). There needs to be coordination of policy and programs at local, national and international levels. The government needs to make necessary regulations in order to implement such coordination.

The government, public, and psychologists need to understand the studies and predictions about climate change with keenness so as to prepare their capacities and skills, to meet the mental health challenge. Besides the need to address the mental health impacts of disasters that have already happened, the governments needs to be prepared to meet the mental health challenge and invest in its preventive and mitigating measures (The Climate Institute 2011).

In Indian culture, it is believed that people have the ability to cope up with the disasters due to social cooperation. Nevertheless, the disasters do lead to psychological impacts on the affected populations, especially children. It has been suggested by psychiatrists in India that the parents need to involve themselves with children, and build a friendly environment, in order to help them "overcome the trauma" (Muzaffar 2014).

The health services in communities need to be prepared to deal with the psychological aftermath of any disaster like extreme stressor. They need to be equipped with the knowledge and skills necessary for offering specified help for specific problems of the affected victims. NSW (New South Wales) Health, of Australia, laid emphasis on mental health care, by suggesting psychological 'first aid', which would include assessment (i.e. risk factors screening), referrals, and interventions as part of an emergency mental health care response (Medicines Sans Frontieres (MSF) 2004).

The WHO (2003b), gave certain guidelines for meeting the mental health challenge post disasters. According to the report, national preparedness plans should incorporate a well organized mechanism of satisfactory social and mental health response in the wake of disasters. It should include training of people who are aware of the local realities. A very significant guideline is that heath care staff should receive supervised clinical on-the-job training, by mental health experts. The aim of all these activities, according to the guidelines, should be to develop long-term community mental health services and other social interventions. There have to be two phases of mental health care, one is the acute emergency phase and the other is the reconsolidation phase. Acute phase will involve 'managing urgent psychiatric complaints', and 'organising outreach and non-intrusive emotional support'. In the reconsolidation phase, 'longer-term social and psychological interventions' could be undertaken, such as, giving mental health skills to primary health care workers and doing a follow up of psychiatric cases. The WHO also suggested that such activities need not be exclusive, they could be interwoven into already existing coping mechanisms and traditional practices, wherever found acceptable and feasible.

Early warning systems against impending extreme weather events such as flooding, heat waves and droughts need to be widely installed in suspected areas (Sinisi and Aertgeerts 2011). Better surveillance and monitoring of health outcomes related to extreme weather events, in terms of both, the physical and mental health, is extremely important for preparedness.

It has been suggested that ther is a need to raise the concern of the general public, the policy planners and the decision making bodies, regarding the need to implement adaptation strategies required for dealing with extreme weather events and their impacts. It has been concluded that pointing to the personal adversities and emotional impacts experienced by people, during such events, could help in raising the societal concern and support for taking adaptation measures (Vasileiadou and Botzen 2014).

Research can play a key role in finding a global solution for mental health promotion. It can lead to mental health protection by recognizing the mental health risks and recommending primary prevention steps. Research looking at the mental health impacts of climate change on society needs to be encouraged (The Climate Institute 2011). Climate change research also needs to include social science and behavioral science research, in a big way, to bring the mental health impacts of these events into public knowledge and make the mental health services available to affected people on time (Crowley 2009).

The research perspectives need to take both, an extended time frame, in terms of decades, so that there is continuity and meaningful progress in data collection, policy development, implementation and analysis; and also a short term perspective, where there is quick information updating and 'rapid system evolution' (Rao et al. 2010).

There is need to carry out post disaster studies on mental health impacts post extreme events and the extent of mental health challenge posed must be assessed. For carrying out such studies, institutional mechanisms, such as dedicated centers and institutes for the purpose, need to be set up, as part of disaster planning (Shukla 2013).

Besides the basic physical risk mitigation measures, the activities aimed at raising awareness among common people about likely impact of extreme weather incidents and sensitizing of administrative officials need to be undertaken. Schools can get actively involved, by painting and debate competitions for school children, in vulnerable areas. Greater regional cooperation amongst countries for developing coordinated strategies to reduce/mitigate the impact of such events and to facilitate cross-learning among institutions and agencies, in both the government as well as academic and community domain, need to be encouraged (UNDP 2012).

Psychologists may learn from the findings of disaster psychology and help in the long term psychosocial adjustment of the affected people. They can employ individual and group therapies for those affected. They may use therapeutic tools such as "eco-psychology, grief/loss counseling, cognitive behavioral therapy, and interpersonal therapies, and group therapy" (Doherty and Clayton 2011). They can provide life skill in the form of "mitigation and adaptation behaviors" training, thus enhancing the ability of people to cope with the mental health impacts of climate change (Karlsson 2011).

The psychological and mental health services and interventions need to be country and culture specific. The services provided would differ from place to place, community to community, hence country to country. In India, it was found that issues such as inadequate number of mental health professionals, lack of institutional mechanisms for providing services and insufficient financial provisions, can be overcome by the community-based psychosocial support and mental health services. The community-based services are culturally approved, less stigmatized and much more viable. There is a need to learn from the best practices adopted in one country for which there should be regular experience-sharing platforms for countries to share their varied experiences (Satapathy 2012).

Media has a significant role to play in how people will respond to a disaster since media has an important role in providing information to people regarding the availability of psychological counseling and how to avail it (Karlsson 2011).

Government and various relief and aid agencies have increasingly emphasized psychological and psychosocial support and interventions in the wake of extreme weather events (Spickett et al. 2008). Skilled manpower is required for providing mental health services, and there is need to bring these services into the framework of other related services e.g. private and public health services, aid organizations, and the government agencies which provide essential services (Kabene et al. 2006). There is need for behavioral changes in consumption patterns and for realizing the risks involved in using or abusing the earth's resources. Psychologists have not yet understood the nature of the behavioral changes required (Corner 2009), however, they do agree that such changes are required, on a day to day basis, on an extensive scale, in the long run.

The consumption patterns, the risk perceptions, and the emotions related to climate change, need to be understood as these are very important factors in preventing and solving the threat to climate across the globe (PSYSR 2010). Large-scale global environmental change and policy change at the level of the government is required. “A cultural transformation—a new ‘industrial revolution’—is required” (Rao et al. 2010).

The need to invest in disaster risk reduction (DRR), to achieve climate change adaptation, has been recently felt. It is believed that for $1 spent on DRR, there can be a saving of $4 in terms of post disaster costs incurred in relief and rehabilitation. It has been suggested that the governments could introduce a scheme of “catastrophe bonds”, and “climate-induced disaster fund”, which could used for post disaster relief and help augment the resilience of communities in the face of changing climate and extreme weather events. Thus there is need to invest in disaster prevention—in infrastructure and on social development (Daily Times 2015).

Conclusion

Mental health has been much ignored in development and environmental management planning. Evidence-based and relevant tools of communication need to be adopted to increase awareness about climate change and its mental health impacts and measures to deal with them.

The extreme weather events are going to be increasingly witnessed by the world due to a changing climate. The damages from such events are going to be ecological, physical and psychological. There is lot of effort being made the world over to manage the infrastructural losses and to provide timely treatment for the injuries caused to people in the wake of such events. However, the need for addressing the mental health gaps is somewhat missing from the plans and policy documents, being prepared by national and international bodies. There is dire need to address these gaps. The psychologists and behavioral scientist need to be future oriented and get prepared to deal with the mental health challenge. Psychologists need to organize themselves, so that they may respond during these events. There is need to address the free floating anxiety and worry among the populations regarding the climate change related extreme disasters that might happen in future. The government needs to take initiative and create institutions, which could provide psychological support services before, during and after such extreme weather events, so that people may deal effectively with the adverse mental health impacts. When the countries of the world will act in unison, on the issue of preventing further climate change, and work together on building the resilience capacity of their populations to face any extreme weather event, can the world meet this mental health challenge.

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Chapter 3
Mental Well-Being and the Eco-State: A Classification of Regions and Countries of the European Union

Paola E. Signoretta, Veerle Buffel, and Piet Bracke

Abstract This chapter reports exploratory research work on the link between mental well-being and the 'eco-state' within the context of countries and regions of the European Union (EU). For the purpose of this chapter, the 'eco-state' is defined—paraphrasing Meadowcroft (2005: 3)—as "a state that places [climate change] considerations at the core of its activities". It is hypothesized that regions with higher levels of mental well-being are located in eco-states with a good ecological performance. For the purpose of this work, ecological performance in the area of climate change is measured using the Climate Change Performance Index 2013, while mental well-being using the WHO-5 scale derived from the third wave of the cross-sectional European Quality of Life Survey for the year 2011. Using exploratory spatial data analysis (ESDA) and regression analysis, regional clusters of mental well-being are identified and classified according to eco-state typologies of EU countries. While it emerges that the better a country performs in ecological terms, the better the levels of regional mental well-being are, the mechanisms of this association remain to be determined. The chapter concludes by suggesting future directions for research on mental well-being and the eco-state.

Keywords Mental well-being • WHO-5 • Climate change • Eco-state • Exploratory spatial data analysis

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Introduction

Changes in the climate are occurring (Moughtin et al. 2009) as a result of human activities releasing greenhouse gases, and this in turn raises climate temperatures. The concentration of carbon dioxide (CO_2) in the atmosphere today is a cause for concern. It is increasingly recognised that climate change and the policy actions implemented to control this increase will have consequences for health and mental well-being (Fritze et al. 2008; Berry et al. 2010). To stay below the 2 °C threshold in order to avoid climate change—with all its expected social, economic and environmental impacts—urgent action by governments around the world is needed. Currently, countries have taken action with different degrees of commitment (Burck et al. 2012; Christoff and EcKersley 2013).

With this background in mind, this chapter reports research work on the link between mental well-being (MWB) and the 'eco-state' within the context of countries and regions of the European Union (EU). The definition of an eco-state is still in its infancy but it refers to a new configuration of a country welfare state due to actions taken in order to mitigate the effects of climate change or more widely environmental degradation. For the purpose of this chapter, the 'eco-state' is defined—paraphrasing Meadowcroft (2005: 3)—as "a state that places [climate change] considerations at the core of its activities". The aim is to assess whether high levels of positive mental well-being at the regional level are associated with specific eco-state typologies.

This chapter argues that the eco-state, as the welfare state—term used to indicate the role of the state in providing social services in areas such as education, health and employment in developed capitalist countries (Eikemo and Bambra 2008; Alcock 2008)—is an important determinant of health (Bambra and Eikemo 2009; Bambra et al. 2014) and by extension mental well-being (Levecque et al. 2011).

Positive mental well-being is a very important and relevant condition for EU citizens, Member States, stakeholders and the EU economy as stated in the 2005 Green Paper (EC 2005) and in the European Pact for mental health and well-being (EC 2008), a joint EU strategic agreement which calls for action in the area of mental health. A recent estimate of the total costs of mental disorders—for health and social welfare systems and the EU economy—is more than 450 billion euros (Borg 2013). Consequently, it is of interest to explore levels of MWB in relation to emerging eco-states in the EU as already done in comparative health research (Bergqvist et al. 2013). Moreover, while comparative health research is normally conducted at country level using multilevel techniques (Arcaya et al. 2012), in this chapter a regional spatial perspective is proposed (Arcaya et al. 2012) so that in addition to regions' membership to a specific eco-state, their similarity/dissimilarity to neighbouring regions is taken into account.

There is an extensive literature in the social sciences on the theme of 'well-being', however the focus is often discipline-specific and a number of other terms are sometimes used interchangeably. In this chapter, mental well-being refers to positive psychological well-being as assessed by the World Health Organization measure of mental well-being (WHO-5) often derived from population survey data, in this specific case the European Quality of Life Survey (EQLS).

The rest of the chapter is divided into four sections. The following section focuses firstly on the concepts of well-being, eco-state and welfare state; then it argues for the use of eco-state typologies to assess mental well-being outcomes in a regional spatial framework in comparative health research. The second section reports the methodological approach, while results and findings are presented in the third section. The last section reports conclusions and recommendations for future research.

Literature Review

There is extensive literature in the social sciences on the theme of ‘well-being’. Moreover, well-being has entered the policy sphere, as a complement to economic growth (Stiglitz et al. 2009). While this term indicates the state of being or doing ‘well’ in life (Moughtin et al. 2009), it is a contested concept (Atkinson 2013), defined very differently in research work across a range of disciplines and research areas (Schwanen and Atkinsons 2015; Cronin de Chavez et al 2005). In particular, the economics literature uses the term ‘happiness’ (Layard 2005) with a focus on measuring utility in relation to a set of explanatory variables (Ballas and Tranmer 2012); sociological studies look at well-being in relation to the social determinants of (ill) health (Bambra et al. 2014), lifestyles and subjective health dimensions (Blaxter 1990, 2010; Van de Velde et al. 2010, 2013; Warwick-Booth et al. 2012); while quantitative geographical, public health and epidemiological studies provide evidence of the (unequal) geographical distribution of well-being (Copeland et al. 1999; Ballas and Dorling 2007) and subjective well-being (Schwanen and Atkinson 2015). The latter term refers to mental (or psychological) well-being and includes two dimensions: the hedonic dimension, with a focus on happiness, and the eudaimonic dimension (Deci and Ryan 2008), with a focus on the achievement of the best in one’s life (Schwanen and Atkinson 2015).

One of the most extensive research areas regarding health and well-being looks at the association between income inequality and various health outcomes (Wilkinson and Pickett 2009). Supporters of the income inequality hypothesis argue that beyond a certain level of Gross Domestic Product per capita, the unequal distribution of income across a society is a more important determinant of health outcomes than absolute income (Wilkinson 1996; Layte 2012). While the association between income inequality and health is not disputed (Layte 2012) and has been investigated from different theoretical frameworks (Mackenbach 2012), there is still little agreement on how this association might be explained at different geographical scales (Wilkinson and Pickett 2006). In addition, some researchers set this association within the wider context of the welfare state. This body of research recognises that the welfare state is an important determinant of health and MWB (Brennenstuhl et al. 2012; Bambra and Eikemo 2009; Coburn 2004) because its policies in areas such as employment, education and healthcare have an impact on people's life chances.

Based on the two dimensions of 'decommodification' (i.e., the extent to which social welfare is provided by the state as opposed to market providers) and social stratification (i.e., the extent to which the social welfare is a system of social class), Esping-Andersen's seminal work (1990) shows that western states, can be grouped in three distinct welfare state regimes (liberal, conservative, social democratic). Esping-Andersen's and other alternative typologies (Ferrara 1996; Huber and Stephens 2001; Eikemo and Bambra 2008) developed as a critique or extension to his work (Alcock 2008; Brennenstuhl et al. 2012; Bambra and Beckfield 2012), have been utilised to explore health outcomes within a comparative welfare state regime approach (Bergqvist et al. 2013). Within this context, it was found that social democratic regimes—characterised by income redistribution, and wide-ranging social security policies (Coburn 2004)—perform well on health outcomes compared to liberal (characterised by a minimal welfare state provision) and conservative (characterised by a welfare provision linked to earnings) regimes (Mackenbach 2011).

In addition, a growing body of literature looks at the environmental impacts of climate change on health and mental well-being and identifies the risk posed by: (1) immediate direct impacts of climate change such as extreme weather events on mental well-being; (2) indirect impacts on the social, economic and environmental determinants of mental health which are being felt by disadvantaged communities and populations; (3) the emotional distress and anxiety caused by the appreciation of the long term social and environmental challenges posed by climate change (Fritze et al. 2008; Berry et al. 2010). This literature is well developed and climate change is identified as a risk for mental well-being.

However, this chapter argues that an extension of research work undertaken on health and mental well-being should focus on the association between health and mental well-being and the eco-state. This development can build on extensive research available on comparative welfare state research and health [see Bergqvist et al. (2013) for a review]. Welfare state typologies are constructed on the basis of social and economic dimensions [see for instance Brennenstuhl et al. (2012)] but exclude environmental considerations, since these typologies mirror the fact that welfare states and associated social policies have been developed long before and without any integration with environmental policies (Gough 2014; Meadowcroft 2005). However, since the emergence of an environmental crisis in the 1960s, there has been a rise of state intervention in order to mitigate the environmental costs of the market economy (Gough 2014: 2), in a similar fashion as "the welfare state took on gradually increasing responsibilities for mitigating the social and human costs of the market economy" (Gough 2014: 2). Environmental and climate change mitigation policies will thus determine the most extensive implications for social policy and western welfare states (Gough 2010). Despite the increasing transformation of the welfare state due to the take up of environmental responsibilities, comparative cross-national health research has neither recognised the impact of climate change on health nor questioned the use of welfare state typologies which classify states only in relation to social policy [for a review see Brennenstuhl et al. (2012)].

The ‘traditional’ welfare state typologies are becoming obsolete as “the growing salience of environmental problems has led some analysts to speculate about the possible genesis of an ecological state, a state that places ecological considerations at the core of its activities” (Meadowcroft 2005: 3). In the same way as ‘welfare state regime’ typologies were constructed, “environmental state regimes [can be used] to describe and categorize the different ways in which specific states have begun to handle environmental demands” (Christoff 2005: 26), and a range of ecological or eco-social typologies and environmental regimes have emerged (Duit 2009; Koch and Fritz 2014; Jahn 2013).

Focusing solely on a states’ response to climate change (Christoff and Eckersley 2013: 431) there is no single classification available. Moreover, the approach taken in measuring this response will determine a different ranking of eco-states. For instance, a Climate Change Performance Index (CCPI) developed by German Watch (Burck et al. 2014) classifies countries around the world according to their ecological performance in four categories highly relevant for the mitigation of climate change effects. The CCPI, developed using standardised criteria, assesses and ranks the climate protection performance of 58 countries responsible for more than 90 % of global energy-related CO_2 emissions (Burck et al. 2014). However, the advantage of this approach is to provide a clear indication of states’ response on a set of transparent indicators.

Another issue is the appropriate geographical scale of study. Welfare and eco-state typology studies normally focus on the national level because it is at this level that welfare and environmental policies are developed and implemented. Also, in comparative health research (Brennenstuhl et al. 2012) the unit of analysis utilised is often the country. However, these analyses often hide wide regional differences within and between countries in levels of population health and health inequalities. Studies found that (1) national indicators of well-being and exclusion in Europe disguise geographical inequalities in health (Stewart 2002), (2) the relationship between income inequality and social expenditure in European regions shows a significant heterogeneity among regions of the same country (González and Deza 2008), (3) happy and unhappy European regions tend to cluster together (Okulicz-Kozaryn 2011), and (4) regional mortality in European regions varies widely within the same country (Shaw et al. 2000; Bonneux et al. 2010). Thus, a geographical (epidemiological) and spatial perspective approach to the study of mental well-being within a national and comparative context can provide a better understanding of geographical variation and help identify different clusters of mental well-being in EU eco-state.

The implications for mental well-being of a transition from a welfare state to an eco-state cannot be predicted at this stage. However, given the extensive literature on the socio-economic determinants of health (Wilkinson and Marmot 2003; Marmot 2005; Muntaner et al. 2011), it is expected that these changes will have significant impacts on mental well-being, especially for the less well-off (Muntaner et al. 2007). Consequently, an investigation into current levels of mental well-being across EU regions in the context of (emerging) climate change eco-states can contribute to an understanding of the current situation. This understanding will better equip policy actions in a regional EU context through the development of a regional policy in the area of health and mental well-being, as for instance envisaged by the project Healthy Regions (Hansen 2007).

With this background in mind, the work reported in this chapter explores the association between regional MWB and the eco-state in the context of EU states' responses to climate change. Specifically, taking into account regional income inequalities and GDP levels, it will be explored whether EU regions with higher levels of MWB are located in countries, which based on the CCPI 2013, are classified as providing a 'good' response to the climate change challenge.

Methodology

This section is divided in three parts as follows: (1) data; (2) measurements; and (3) analytical approach. The latter uses an exploratory spatial data analysis (ESDA) approach, with the aim to explore both overall clustering of mental well-being in the regions of the EU and the detection of regional clusters of high/low values and outliers (Haining 2003).

Data

Mental well being information was obtained from micro data of wave 3 (2011–2012) of the European Quality of Life Survey (EQLS). The EQLS has a random sample of adult population resident in 34 countries including the 28 EU member countries and covers multiple dimensions of quality of life. The relevant weight was applied and the sample size equalled 36,113 respondents in the 28 EU countries. In order to assess the robustness (Betti et al. 2012) of the data, further check on the results were undertaken using European Social Survey (ESS) and similar results to those presented in this chapter were obtained.

For the regional level, the first and second levels of the Nomenclature of Territorial Units for Statistics (NUTS 1 and NUTS 2) are used. For some countries NUTS level 1 and 2 correspond to the country as a whole. There was a certain degree of discrepancy between the regional information included in the EQLS dataset and the other data sources (Eurostat, the EU statistical service; ESS; and OECD statistics). Consequently, an ad hoc matching was undertaken. After recoding, a total of 132 regions (a mix of NUTS 1 and NUTS 2) that have more than 20 respondents were retained. The base map (Fig. 3.1) shows the regions of the countries of the EU included in the analyses. A better way to represent the data would be to use cartograms [see for instance Dorling and Thomas (2011), Ballas et al. (2014)] in which the area of regions is proportional to the population living

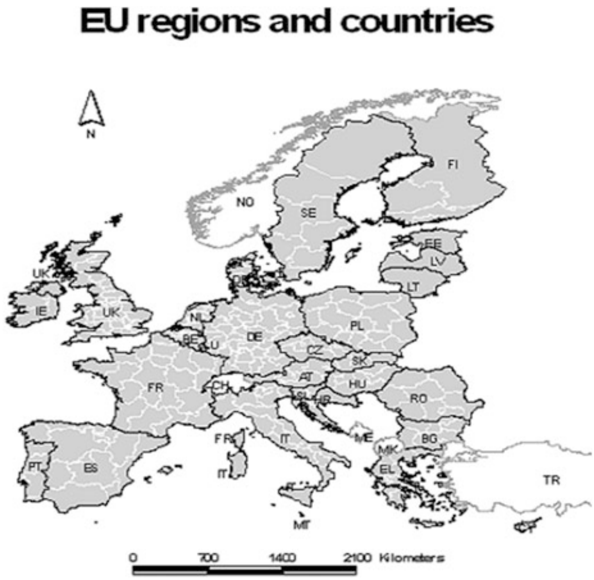

Fig. 3.1 Base map of EU regions and countries (coloured in *grey*). Regional boundaries are *white*, whilst country boundaries are *black*. Country codes are placed within the country boundaries (Administrative boundaries: © EuroGeographics)

there. However, because of time constraints, it has not been possible to use cartograms for this submission. The maps in this chapter are based on boundary data provided by GISCO, EuroGraphics.

The regional GINI values are partly retrieved from the OECD regional statistics (OECD 2015), as they are not available from Eurostat. For the countries not included in the OECD statistics, GINI values at regional level were calculated using household income micro data of the six waves (2002, 2004, 2006, 2008, 2010, 2012) of the ESS. Gross domestic product data were retrieved from Eurostat.

Measurements

Mental Well-Being

The measure of mental well-being utilised is the WHO-5 developed by World Health Organization and available in the EQLS data set. WHO-5 is a composite measure of responses to five questions which combined form a measure of positive psychological well-being. This measure reflects both hedonic and eudaimonic dimensions (Deci and Ryan 2008). The five items assess positive mood, vitality and general interest over the past 2 weeks and is an effective tool for revealing the frequency of depressive symptoms in the general population (Layte 2012). Each answer is scored from zero to five and summed to produce a score out of 25. The scores in the EQLS data set are available rebased between 0 and 100. The relevant weight (w5) was applied to the individual level EQLS data before aggregating it at the regional level (EQLS 2014).

The Climate Change Performance Index

German Watch developed the Climate Change Performance Index (CCPI) for 58 countries responsible for 90 % of global energy-related CO_2 emissions (Burck et al. 2014). For this work, data for the 28 EU countries were used for the year 2013 (Burck et al. 2012). CCPI is measured via 15 different indicators that are combined into one single composite indicator. They are classified into four categories (weighting in brackets): (1) Emissions: Emissions Level (30 % weighting) Emissions Development (30 % weighting); (2) Efficiency (10 % weighting); (3) Renewable Energy (10 % weighting); (4) Policy (20 % weighting) [For more details see Burck et al. (2014)].

The CCPI ranking is used in relative terms (better–worse) rather than absolute terms (good–bad). Since the development of the index, the first three rank positions have not been awarded, consequently ranking starts from the third position. As the focus of the present work is on climate change, this index was used to identify the performance of EU countries in tackling climate change instead of the eco-social typologies defined by Koch and Fritz (2014). The geography of EU countries based on the CCPI 2013 is presented together with the rest of the analysis in section "Results and Findings".

Measures of Income Inequality

The GINI coefficient is the most standard measure of income inequality. In order to have an adequate number of respondents per region (GINI coefficients are quite stable during a relatively short periods such as 2002–2012), the regional GINI was calculated using equivalence household income information from the six waves of the ESS. The calculations were performed in R statistical software. The GINI values at the regional and country level were calculated on the disposable household income (i.e., the income available to households after taxes and transfers).

Gross Domestic Product by NUTS Regions

Data on Gross domestic product (GDP) expressed in purchasing power standards (PPS) by NUTS 2 regions were retrieved from Eurostat. This is an indicator of the output of a region. It allows the comparison of price levels between the economies of countries and regions which differ significantly in absolute size.

Analysis

In order to address the research question as to whether regions with higher levels of mental well-being are located in countries with a good ecological performance, data are needed at an aggregate level for the relevant unit of analysis (EU regions and countries). A Geographical Information System (GIS) of the data was set up in ArcGIS 10 (ESRI 2015), an integrated suite of advanced GIS applications. Spatial analyses, instead of the common used multilevel analyses, were utilised because in this way similarities in levels of MWB of nearby regions were taken into account and local regional clusters identified.

The analysis proceeded as follows: firstly, a regional map of MWB was produced (in deciles) in order to show the (unequal) distribution of MWB in the EU; secondly statistically significant clusters of high/low MWB values were identified; thirdly, Ordinary Least Squares (OLS) regression and spatial regression were used to test whether there is an association between mental well-being at the regional level and the ecological performance of the corresponding country.

The regional map of MWB is produced using a decile classification (10 % of regions in each class). The map identifies the worst and best deciles using a colour ramp in order to assign colours to different levels of the mental well-being for regions of the EU.

The Moran's I and local Moran statistic (Anselin 1995; Okulicz-Kozaryn 2011) were used to summarize the degree of association between MWB values in neighbouring regions and the presence of clusters of MWB in the EU. These two measures are based on a weight matrix, which is a mathematical representation of the spatial relationship in the data (Haining 2003). In this specific case, a queen contiguity matrix was constructed to represent the geography of EU regions. This matrix determines neighbouring units as those that have either common boundaries or common corners. For each region its neighbours are coded as 1 while all other regions as 0. This matrix is then row-standardized so that each row sums up to one (Haining 2003).

A Moran's I creates a scatter plot with the spatial lag (that is the average of the values for the neighbouring regions) of the variable under consideration (in this specific case MWB) on the vertical axis and the variable itself on the horizontal axis. Both are standardized internally (such that their mean is zero and variance one), and the spatial lag operation is applied to the standardized variables. The slope of the regression line shows the degree of linear association between the variable on the horizontal axis and the values for the variable on the vertical axis at its neighbouring locations (as defined by a spatial weights file). A conditional randomization approach is used for determining statistical significance (Anselin 1995). The local Moran statistic identifies clusters of similar (i.e., regions of high/low MWB values surrounded by regions of high/low MWB values) and dissimilar (i.e., regions of high/low MWB surrounded by regions of low/high MWB) values. In other words the values show positive/negative spatial autocorrelation (Anselin 1995), that is the value of a variable at one location is similar/dissimilar to the value of the same variable at nearby locations (Haining 2003). Clusters were retained if $p < 0.01$.

Ordinary Least Squares (OLS) and spatial regression models were implemented, with the aim to explore the association between regional MWB and the ecological performance of the country of appurtenance. Dummy variables of the CCPI were created. The three groups were: (1) good, (2) moderate and (3) poor/very poor. The 'good' group was the reference category. The spatial models were used in order to take into account the spatial nature of the data used, including: (1) a spatial lag model of regional MWB variable (spatial autoregressive model SAR) which assumes that processes affecting regional MWB in one region are similar to those affecting MWB in neighbouring regions; and (2) a spatial error model (SE) in which spatial dependence is due to unknown factors.

Two potential confounding factors—which the literature showed to be most relevant for this analysis—were included in the models, namely regional income inequalities and regional GDP. Given the exploratory nature of this work no further variables were used.

Results and Findings

The Geography of EU Eco-States

From a purely ecological performance perspective, as measured by the CCPI 2013 (Burck et al. 2012), the 28 countries of the EU are distributed equally in three groups (Fig. 3.2):

- Nine countries including Ireland, UK, Denmark, Belgium, Hungary, Malta, Germany, Sweden and Portugal are classified as 'good';
- Ten countries including France, Slovakia, Slovenia, Czech Republic, Romania, Cyprus, Lithuania, Luxemburg, Italy and Spain are classified as 'moderate'; and
- Nine countries including Latvia, Austria, Finland, Croatia, Bulgaria, Poland, Estonia, Greece, Netherlands are classified as 'poor/very poor'.

It is notable the good and moderate performance of southern countries—specifically Portugal, Spain and Italy—in comparison to countries such as Finland and Austria. This better performance is due to their action in lowering their emissions in recent years as a consequence of the global economic crisis (Burck et al. 2012). In addition, Portugal has performed well in terms of climate policy and is therefore placed among the best performing countries. While these achievements have been recognised by the panel of CCPI experts, economic growth is expected to drive the economic recovery of these countries (Cassidy 2015), with a consequent increase in CO_2 emissions (Gough 2014). The very poor performance of the Netherlands stands out among the other neighbouring countries and is explained in relation to its inadequate climate policy (Burck et al. 2012), while Lithuania moderate

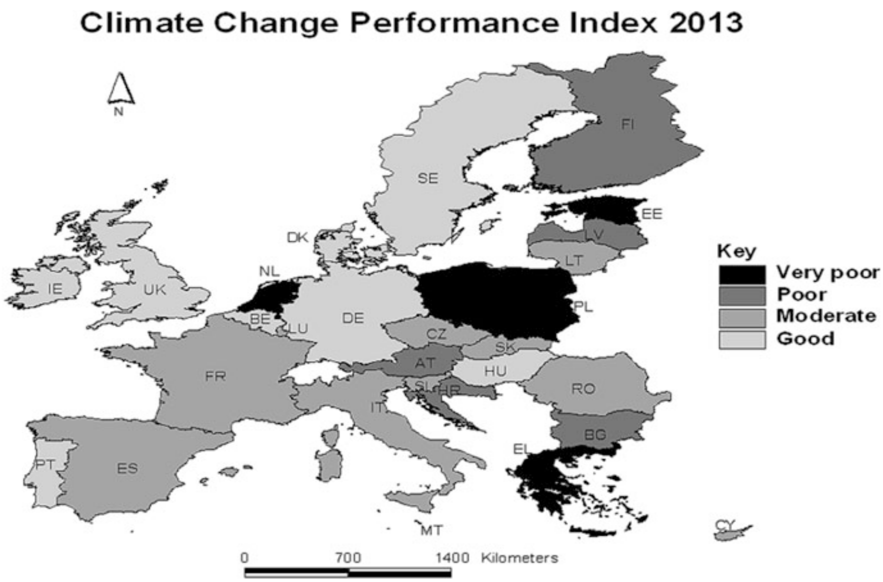

Fig. 3.2 Classification of the 28 EU countries, as quantified by the Climate Change Performance Index (CCPI) for the year 2013 (Administrative boundaries: © EuroGeographics)

performance stands out among (the poor performance) of the surrounding Eastern European countries.

The Geography of Mental Well-Being by EU Regions and Countries

As far as WHO-5 at the national level is concerned, the best performing countries (25 %) includes Austria, Belgium, Germany, Denmark, Finland, Spain and Portugal (Fig. 3.3). With the exception of Austria and Finland, these countries present good or moderate climate change performance indicators. The worst WHO-5 performing countries (25 %) include Greece, the geographical block of Lithuania, Latvia, Estonia, then Romania, Slovenia and Malta. Greece performance might be connected to the deep economic crisis afflicting the country (Economou et al. 2013; Kentikelenis et al. 2011).

The geographical distribution of WHO-5 for EU regions is displayed using a decile classification. It shows multiple regions of the top and bottom 10 % (Fig. 3.4), the dark areas on the map are the regions in the 10 % worst decile while the regions lightly coloured are in the best decile.

The best 10 % consists of regions in the north-west of Austria (1), Germany (6 out of 16), Denmark (4 out of 5), north-west and north-east of Spain (3), with the exception of Austria all regions are located in countries classified as good or

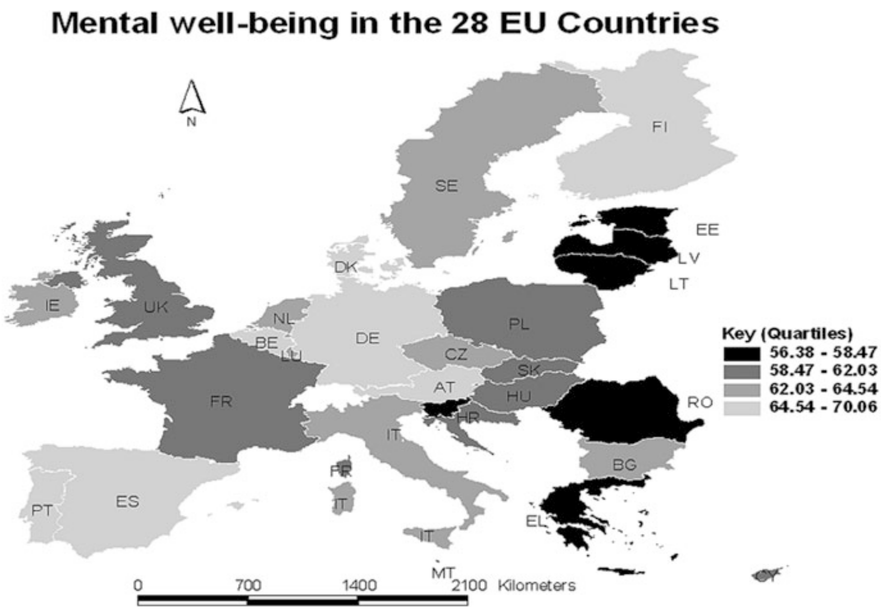

Fig. 3.3 Geographical distribution of mental well-being in EU countries, as quantified by the World Health Organization measure of mental well-being (WHO-5). The classification is based on quartiles (25 % of countries in each class). Theoretically, values can range from 0 to 100, in this distribution from 56 to 70. *Letters* within boundaries indicate country code (Administrative boundaries: © EuroGeographics)

moderate on the CCPI index. The worst 10 % consists of regions located in Estonia (1), Greece (1), Latvia (3), Lithuania (4), Poland (2), Romania (1) and Slovakia (2). As far as their ecological performance is concerned, the picture is split into two groups: three countries perform moderately on the CCPI index and four perform poor or very poorly. While it is difficult to make a connection between levels of regional MWB and country ecological performances, it seems that regions with better MWB are found in countries classified as 'good' or 'moderate', while there are no regions falling in the 10 % worst decile in countries classified as 'good' based on the CCPI 2013.

Exploratory Spatial Data Analysis of Regional Mental Well-Being

As far as clusters of MWB are concerned, the Global Moran I is 0.425 (scatter plot shown in Fig. 3.5), indicating a strong positive correlation, i.e., there is a high degree of similarities of MWB values in neighbouring regions. Using Local Moran, four different types of core regions of mental well-being clusters (Fig. 3.6) were

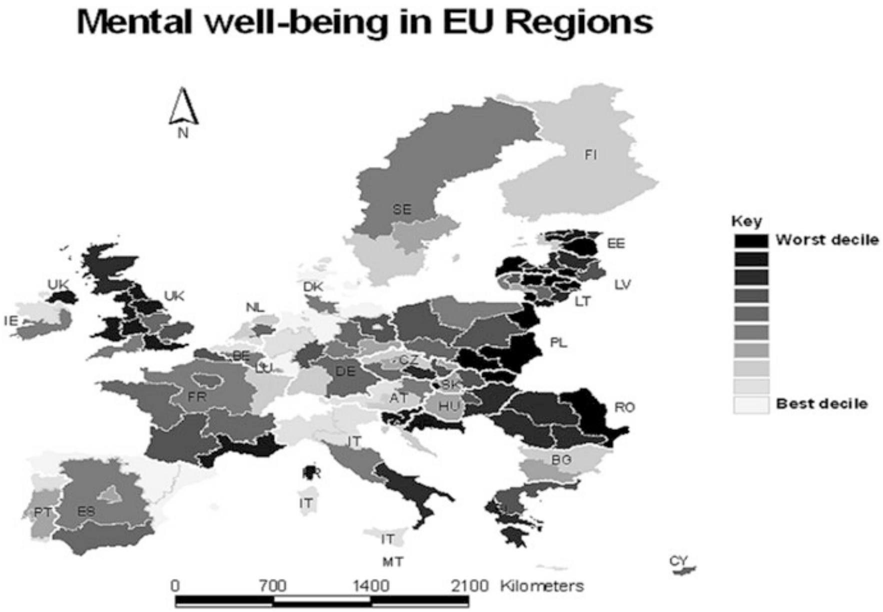

Fig. 3.4 Geographical distribution of mental well-being in EU regions, as quantified by the World Health Organization measure of mental well-being (WHO-5). The classification is based on deciles (10 % of regions in each class). *Darker shades* indicate worst levels of mental well-being. *Letters* indicate country code (Administrative boundaries: © EuroGeographics)

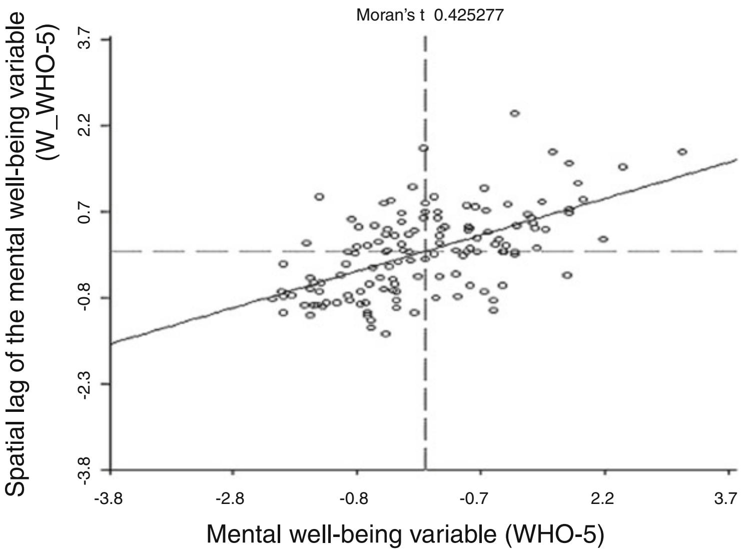

Fig. 3.5 A Moran I scatter plot of mental well-being (quantified by the WHO-5 variable) and the spatial lag of mental well-being (i.e., the average of the values for the neighbouring region) at regional level (NUTS 1 and NUTS 2). There are 132 data (*circles*), each representing a region of the EU. A trend line has been fitted by ordinary least *squares*. The slope of the regression line shows the degree of linear association between the values of the variable on the *horizontal axis* and those on the *vertical axis*

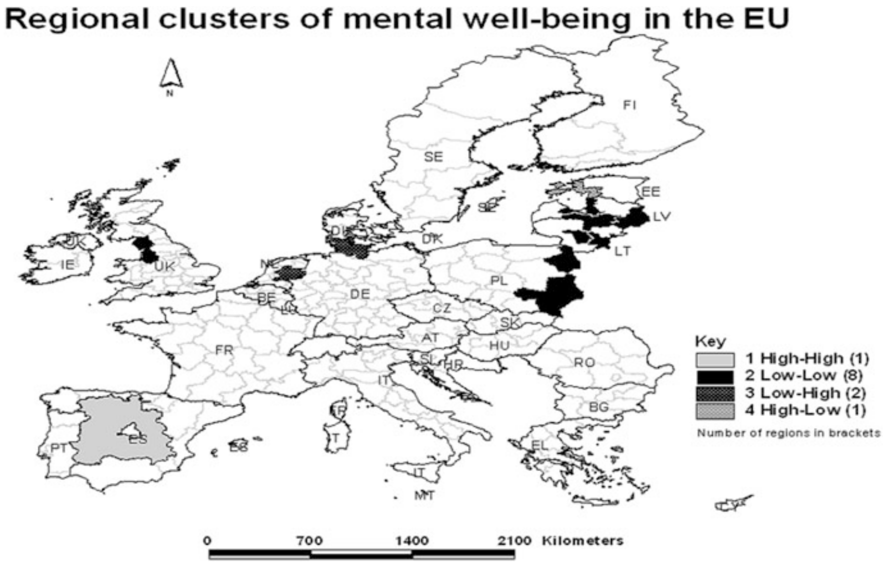

Fig. 3.6 Results of a cluster analysis, based on the Local Moran statistic, for the mental well-being variable (as quantified by the WHO-5 variable) for the regions of the EU. A *light grey* region indicates that it has neighbouring regions with similar high attribute values (high mental well-being); while a *black* region indicates that it has neighbouring regions with similar low attribute values (low mental well-being). Regions in *dotted grey* and *dotted black* indicate that it has neighbouring regions with dissimilar low/high attribute values. A *colourless* region indicate no statistical significance, islands are omitted from the analysis (Administrative boundaries: © EuroGeographics)

identified. The Centro region in Spain is the only core region of high MWB surrounded by regions with high MWB values. The Centro region is in fact surrounded by better performing regions. The eight regions that form clusters of low MWB surrounded by regions with low MWB are located in Latvia (3), Lithuania (3), Poland (1) and the UK (1). With the exception of the North West region in the UK, all regions are among the worst 10 % decile. The North West region in the UK is identified as at the centre of a cluster of low WHO-5 regions indicating that although its regions are not among the selected threshold of 10 %, they nonetheless form a statistically significant cluster ($p < 0.01$).

Finally, there are two outliers of core regions. The first outlier includes two clusters of low MWB surrounded by high MWB regions: Schleswig-Holstein in Germany and bordering Denmark and Oost-Nederland in the Netherlands and bordering Germany. While these core regions do not appear among the 10 % worst decile, they are surrounded by regions which perform well on WHO-5 and are included in the best 10 % decile. This indicates a regional variation in countries performing well on MWB overall. The other outlier is a region of high MWB surrounded by regions with low MWB and located in Estonia (Lõõne-Eesti), a country among the worst performing in terms of MWB and ecological performance.

This provides evidence of a regional variation within countries that perform worst on MWB overall.

Regression Results

Further analysis was undertaken in order to answer the question as to whether levels of mental well-being in EU regions are associated with the ecological performance of their country of appurtenance.

The OLS model reported (table not included) significant coefficients for the dummy variables and the correct signs. However, it also showed evidence of spatial autocorrelation (Moran's $I = 0.36$) which required, as expected the further exploration with the use of spatial lag and spatial error regression models. Based on the model measures of fit, the spatial lag model was not an improvement on the OLS. However, the spatial error model indicated that once the variables GDP and regional GINI were introduced, the coefficient of a country performing moderately on the CCPI was still significant and showing the right sign, while the coefficient for the countries performing poor/very poor showed the right sign but was not statistically significant. Also, neither the GINI nor the GDP variables were statistically significant in this model. The lag parameter was statistically significant indicating 'neighbouring' effects from omitted variables. The result for the spatial error model indicated that spatial autocorrelation was removed. The log likelihood and the AIC score (measures of model fit) also indicated that the spatial error model performs better than the spatial lag and OLS.

In conclusion, these further analyses undertaken in order to answer the question as to whether levels of mental well-being in EU regions are associated with the ecological performance of countries, indicate that countries that perform moderately or poor-very poor show a reduced mental well-being score compared to countries that are classified as 'good'. However, the SE models indicate the need for further investigation due to omitted variables.

These overall results seem to indicate an association between high MWB regions and good performance eco-states. However, additional data and further research are needed in order to undertake a more extensive investigation.

Conclusions and Recommendations for Future Research

The association between mental well-being and the eco-state is complex. While it emerges that the better a country performs in ecological terms the better its levels of mental well-being are, the mechanisms of this association remain to be determined. Regional income inequalities and GDP reduce the strength of this association when their regional levels are taken into account.

Within this overall picture, taking into account levels of regional mental well-being and regional income inequalities, four different types of mental well-being clusters within eco-state typologies emerged. Furthermore, regional clusters of high MWB are found in countries classified as good or moderate in relation to their ecological performance. Regional clusters of low MWB are instead located in countries with diverse ecological performances, ranging from good to very poor. One of the clusters is found in the UK, which is classified as 'good' on the basis of the CCPI 2013. However, this good ecological performance goes hand in hand with poor levels of MWB and high income inequalities, as found in further tests undertaken for this work but not reported in this chapter. High and growing income inequalities in the UK are widely reported in research work (Dorling 2006) and this finding seem to confirm this trend.

It must be recognised that the short-lived nature of some EU countries' ecological performances make this an unstable picture. For instance, countries affected by the deep economic and financial crisis have performed moderately on the CCPI 2013, a case in point is Italy. However, these good performances might deteriorate rapidly following the push for economic growth (Cassidy 2015) resulting in an increase of CO_2 emissions. While a link between a good ecological performance and high levels of mental well-being is apparent from this analysis, more work on the social, economic and political determinants of mental well-being would shed more light on the reasons for this association. This will provide sound evidence on which eco-states can continue to develop integrated environmental and health and mental well-being policies.

Finally, the results should be interpreted with care due to some limitations of the study, including the use of cross-sectional data, which can only provide a snapshot at one particular point in time, and the use of regional GINI developed from two different data sets. Also, the analysis could be strengthened with the use of spatial dependence multilevel models, while cartograms could be used to display the data [see for instance Dorling and Thomas (2011), Ballas et al. (2014)]. However, this chapter provides a novel contribution in an underdeveloped research area, that is the association between the ecological performance of a country and levels of mental well-being. In addition, it employs spatial analyses, an innovative method in sociological comparative health inequality research. Further research work in this underdeveloped research area is highly recommended in order to address the unequal levels of mental well-being across EU countries and regions in the context of emerging eco-states.

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Chapter 4
The Bioclimatic (Dis)comfort and Summer Thermal Paroxysms in Continental Portugal: Intensity, Frequency and Spatial Contrasts

Susana Oliveira Moço, José Eduardo Ventura, and Malheiro Ferreira

Abstract The effects of the changing climate system have become increasingly important in recent years, leading to a need to better understand, among other things, what impact they have on population health and human thermal comfort.

This research analyzes the variability of thermal (dis)comfort due to heat in summer, in Continental Portugal, between 1981 and 2010, based on an appropriate set of bioclimatic indicators. It also addresses the prevailing synoptic situations during climate paroxysms, namely heat waves, by applying the Heat Wave Duration Index formula. The synoptic classification used is an adaptation proposed by Ramos (1987).

We conclude that the feelings of discomfort due to heat are quite frequent. Since 2000, the cities of Coimbra and Lisbon have revealed a trend for thermal sensations of greater intensity.

The results show evidence of spatial contrasts, with the north-west of the country being thermally more comfortable.

On the basis of the occurrence of paroxysms, the position of the Atlantic anticyclone is connected, at altitude, with situations of meridian circulation and the dominance of wave regime and blocking.

Here, we intend to contribute to the identification of vulnerable areas and predict intense heat situations, preventing risks to public health and human welfare.

Keywords Climate change • Climate variability • Thermal comfort • Climate vulnerability • Climate risk • Welfare

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Introduction

The scientific literature reveals concern about the effects of climate system change and increased vulnerability to risks. In this sense, assessments of human thermal comfort should be considered in relation to spatial planning, especially within a context where global climate projections point to a rise in average air temperatures, which can lead to temperature extremes that are adverse for the human health, well-being and quality of life.

This article is based on human bioclimatology treating the problem of discomfort caused by heat during the summer in Portugal and the occurrence of certain paroxysms, in particular, heat waves and associated synoptic causes.

This approach aims to contribute to the knowledge of how frequent this phenomenon is and its possible impacts on a regional scale, thus contributing to improving the population's quality of life in bioclimatic terms.

State of the Art

Scientific studies on the urban climate began in nineteenth century Europe with the Howard's work (1833) on London's climate. Using an analysis of meteorological records for the period between 1797 and 1831, Howard found that air temperature values are often higher in the city than in the rural areas around them. Also in the nineteenth century, Emilien Renou published a work on climate change in Paris, analyzing, besides the temperature problem, the question of ventilation in the city (Landsberg 1981).

In the 1920s Vienna, Wilhelm Schmidt was the first to use the urban transects technique, which uses vehicles to carry out meteorological measurements at different points in urban areas and outskirts. Until then, studies were based on a comparison of data from urban and rural weather stations.

After the Second World War, the growth and expansion of metropolitan and urban areas encouraged studies on urban climate, mainly in the United States, Japan and certain European countries. Important references are the work of Chandler (1985) on the climate of London, of Landsberg (1981), which systematized the main changes in climatic factors in urban areas and that of Oke (1978) on the urban boundary layer. Olgyay (1963) and Givoni (1981) also did research related to climate impact on the built environment and human comfort.

In the late 1960s and early 1970s, researchers involved in climatology turned to outer space, where energy and water balance concepts became central themes. Many of these works were associated with major observation programs that have occurred in American and Russian cities since 1994. The high number of works produced in this period led the World Meteorological Organization (WMO) to sponsor a series of reviews on the subject.

In the last two decades of the twentieth century, methods, research techniques and the monitoring of urban climate were consolidated (Oke 1984), focusing on processes and atmospheric conditions over the city as a base for physical and numerical modeling. During this period, studies of urban climatology in the tropics were still very limited, highlighting those of Jáuregui (2000).

While research in developed countries has been concentrating on physical and numerical modeling, most studies in tropical areas still focuses on a descriptive approach of heat islands and air quality, paying little attention to the energy balance, modeling and development applications for urban planning.

Madrid was the site of numerous climate studies initiated in 1982 by Fernández García and carried out during 1990 and 1996 with special emphasis on pollution and urban climate. López-Gómez and Fernández García (1984) also participated in other studies on urban climate. In Barcelona, important studies were conducted by Carreras et al. (1990) and Clavero (1990), while Valencia had those of Caselles et al. (1992). Later studies were conducted in other Spanish cities.

In Portugal, the first study addressing this issue was conducted by Alcoforado (1988) in the Lisbon region. In 1994, Andrade studied the urban climate and air pollution and, in the same year, Lopes made a study dedicated to topoclimatology, relating land use and its effects on climate. In Coimbra, the study of urban climate (topoclimatology) came about with Ganho (1992). Porto's climate was studied by Monteiro (1993). In 1996, Freire's work about comfort and discomfort develops a bioclimatic classification and the researcher found that there is a very positive correlation between the variation in the bioclimatic comfort and mortality, whether monthly or annual, cardiovascular diseases, respiratory and death by suicide, which was followed by other publications in this area (1997, 1998, 2000, 2005, 2006, 2009a, b). Freire and Vasconcelos' study (2012) and that of Andrade (2004) should also be mentioned.

Studies that relate meteorological variables with health, particularly temperature with health, have gained importance as a contribution to the understanding of the effect of urban environmental change on population health and possible vulnerabilities regarding global climate change, highlighting the influence of extreme events.

In this context, and in relation to heat situations, we have the work of Calado et al. (2003 cited by Silva et al. 2014), which calculates excess deaths associated with the 2003 heat wave; Nogueira and Paixão (2008), which contributed to updating the ICARUS model (Surveillance System for heat waves, since 1999) and to increasing knowledge of the mechanism and impact of heat waves on mortality; (Silva et al. 2014) and Almeida et al. (2010), who discovered that the variation in mortality in Lisbon and Porto during the warmer months of the year, with modeling of the mean apparent temperature and daily mortality during the summer; Monteiro et al. (2013a), who studied the impact of heat waves in the Metropolitan Area of Porto in 2006, and concluded that, during the heat wave, excess mortality from all causes and morbidity was due to respiratory illnesses, pneumonia and chronic obstructive pulmonary disease.

In 2012, Monteiro et al. studied the relationship between episodes of cold and excess of hospitalizations related to Chronic Obstructive Pulmonary Disease (COPD) in the Metropolitan Area of Porto. The authors (Silva et al. 2014) calculated excessive admissions in the period leading up to and following the cold waves, finding that there is a gap of at least 2 weeks between the occurrence of cold waves and increased hospitalizations for COPD patients. They also identified that the persistence of low temperatures (T min ≤ 5 °C) for periods of at least 1 week may be more important to increased COPD morbidity than very low temperatures for very short periods of time (Tmin $\leq$ 1.6 °C).

Monteiro (2013); Monteiro and Carvalho (2013); Monteiro et al. (2013b, c, d); and Monteiro and Velho (2014) studied climate and health in Porto using a set of bioclimatic indices, including, among others, Physiological Equivalent Temperature and Average Temperature Radiant. In relation to Portugal, Vasconcelos (2012 cited by Silva et al. 2014) studied cold exposure as a risk factor for hospital admissions related to cardiovascular disease, while Vasconcelos et al. (2013) concluded that, in Lisbon and Porto, cold contributes to the increase in daily admissions for myocardial infarction.

In order to minimize the effects of thermal discomfort on people's health, numerous investigations have been developed at academic level that make it possible to identify the contribution of spatial planning to the population's health. This work, due the scale of analysis (mesoscale) and the specificity of the indices used, make an innovative contribution that can be applied to regional planning.

Data and Methodology

Spatial and Temporal Framework

To study the summer bioclimatic variability, weather stations from the Portuguese Meteorological Institute used in the daily weather forecast were selected, as exemplify the country's climatic diversity. The chosen stations were Bragança, Porto, Coimbra, Lisbon, Beja and Faro (Table 4.1 and Fig. 4.1) (Moço 2005).

The analysis of discomfort originated by heat assumes, first, the use of a reference sample at the time this occurs more frequently; i.e. the summer months: June, July, August and September. A 30-year period was considered (1981–2010).

The period considered in the study is 3524 days (97 % of the total days of the selected period and the remaining 3 % correspond to 106 days without or with incomplete records of variables at one or more weather stations).

We used daily data of 06 and 18 UTC, related to climatic variables: wind direction and speed, average, minimum and maximum temperature, and relative humidity published in the Portuguese Meteorological Institute's daily weather forecasts at weather stations considered during the summer periods of 1981–2010 (June, July, August and September).

Table 4.1 Network of weather stations used

Location	LAT (N)	LONG (W)	ALT (m)
Bragança	41°48′	06°44′	690
Porto/P. Rubras	41°14′	08°41′	70
Coimbra/Geophysical	40°12′	08°25′	141
Lisbon/Portela	38°46′	09°08′	123
Beja	38°01′	07°52′	246
Faro/Airport	37°01′	07°58′	8

Source: Climatological Yearbook of Portugal (Moço 2005)

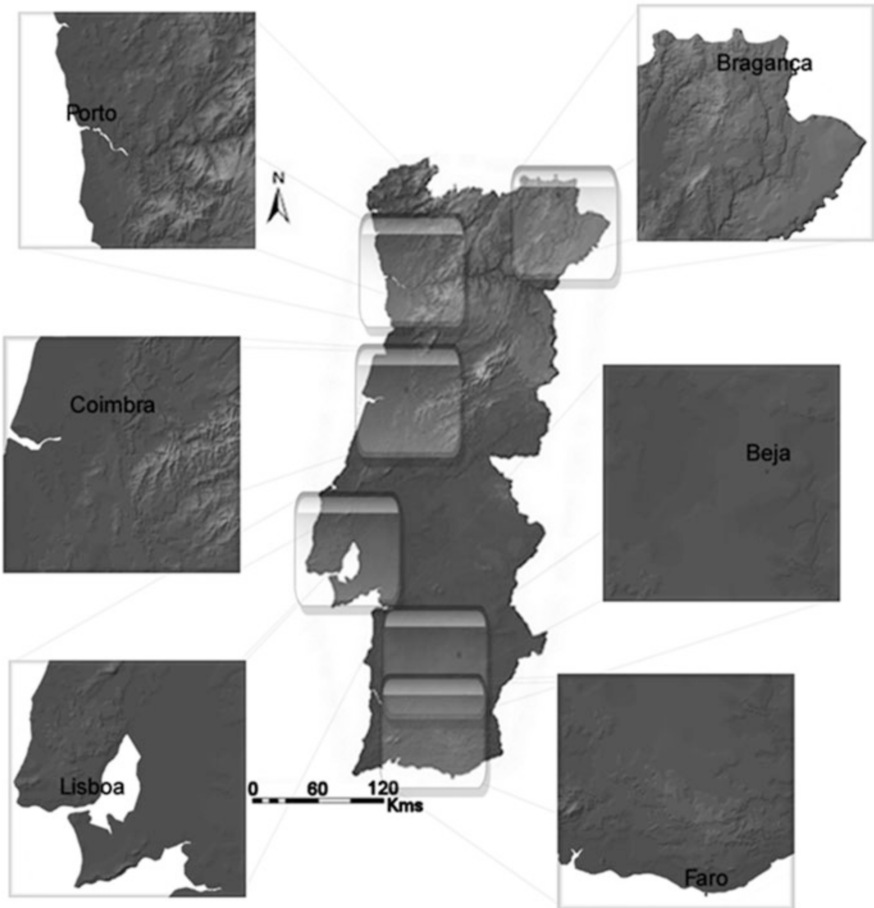

Fig. 4.1 Location of Bragança, Porto, Coimbra, Lisbon, Beja and Faro weather stations [*Source*: Moço (2005)]

Bioclimatic Indexes

In this study, the wide range of indexes selected were those best suited to the objectives of the analysis and best reflected the feelings of discomfort related to heat.

The calculation of the temperature-humidity index (THI) of GILES (Ganho 1998), Effective Temperature (ET) and Equivalent Effective Temperature (EET) of BROOKS, mentioned by BÚTIEVA in 1984 (León et al. 2003) was considered appropriate to achieve the proposed objectives.

The THI index is calculated using the following formula: where T is the air temperature in °C and RH the relative humidity expressed in % (Ganho 1998):

$$\mathrm{THI} = \mathrm{T} - 0.55\ (1 - 0.01\ \ \mathrm{RH})\ (\mathrm{T} - 14.5).$$

Considering that the THI index is a mathematical calculation that, in principle, will be not an integer value (as opposed to actual values), there may be values that are not included in any of the classes in question. As such, a slight adjustment to comfort classes was made:

- <21: absence of discomfort heat
- $\geq 21 < 24$: less or 50 % of the study population expresses feelings of discomfort
- $\geq 24 < 27$: more than 50 % of the population feels discomfort
- $\geq 27 < 29$: most individuals feel discomfort
- $\geq 29 < 32$: all individuals feel strong bioclimatic stress
- ≥ 32: medical emergency

The other ET and EET indicators incorporate the combined effect of temperature and relative humidity (ET), adding the effect of wind (EET) on people with summer clothing, under outdoor conditions, in the shade, performing light physical activity (León et al. 2003). These are empirical indexes, which subjectively evaluate the actual thermal state of individuals. They express the sensation perceived with any combination of the considered variables, which is equal to the feeling one gets with the expressed temperature, with 100 % relative humidity and no wind under controlled conditions (León et al. 2003).

The calculation of these indexes is made from the following expressions:

$$\mathrm{ET} = \mathrm{t} - \frac{G}{80}\,(0.00439\ \mathrm{T}^2 + 0.456\ \mathrm{T} + 9.5)$$
$$\mathrm{EET} = \mathrm{ET} + \mathrm{W}\ ((0.11\ \mathrm{T} - 0.13) - 0.002\mathrm{TG})$$

Where:

t: air temperature in °C

(continued)

T: t – 37 difference between the air temperature and the human body temperature expressed in °C
W: wind speed at a height of two meters, from the relation 0.67 V, where V corresponds to the wind speed at a height of ten meters, in m/s.
G: 100 – RH
RH: air relative humidity expressed in %

The evaluation of thermal sensations in the case of the results obtained by these two indexes was accomplished through the use of classes (°C) proposed by León et al. (2003) and an approach for the Portuguese case (Moço 2005), resulting in the following classes:

- <22: absence of discomfort heat
- $\geq 22 < 25$: slightly warm
- $\geq 25 < 28$: hot
- ≥ 28: very hot

According to León et al. (2003) and Moço (2005), these classes cover the majority of the population who feel discomfort.

The average monthly performance of the bioclimatic indexes involved was analyzed, as well as the frequency and intensity of heat discomfort at each selected station. The contribution of each climate variable was also discussed for each of the indices by determining the Pearson linear correlation coefficient (add reference). The trend of bioclimatic indices for the period 1981–2010 was determined accordingly.

In the case of heat waves, after the analysis of various indexes, it was considered appropriate to use the following formula (Tank 2002):

$$\text{HWDI }(\textit{Heat wave duration index}) = \text{TX}_{ij} > \text{TX}_{inorm} + 5$$

In which TX_{ij} corresponds to the maximum temperature of the day i during the j period and TX_{inorm} corresponds to the maximum average daily temperature corresponding to a 5-day period filter used as reference (1971–00). A heat wave is considered to be happening when the abovementioned conditions occurred for at least 6 consecutive days.

Analysis and Discussion of Bioclimatic Summer Comfort in Portugal

The Influence of Climatic Elements in THI, ET and EET Indexes

To investigate the importance of the temperature, relative humidity and wind speed variables taken at each weather station, according to each of the bioclimatic indexes used, correlation matrices were constructed concerning significance levels between the daily average values of the climatic elements and the comfort indexes in the two time periods (06 and 18 UTC) used in this study.

Thus, the evaluation of the Pearson correlation matrix (Fig. 4.2) for each of the weather stations, which corresponds to the interdependence between the bioclimatic indexes and the variables that compose them, defines their importance in the value of the index and, hence, the variation of thermal sensations.

As you would expect at any weather station, and in any of the bioclimatic indexes, the role of temperature seems more prominent compared to humidity and wind speed in the case of EET.

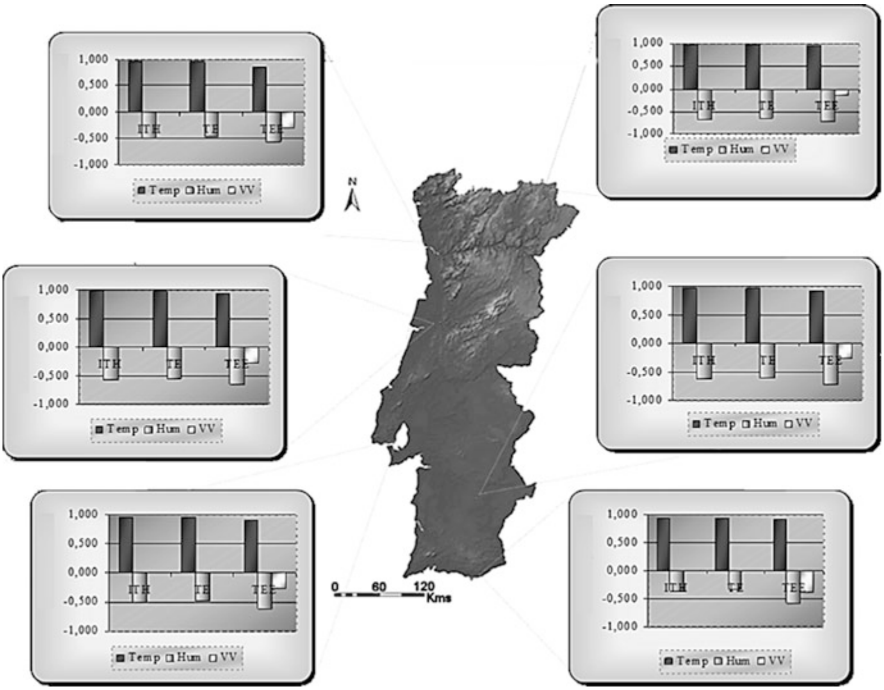

Fig. 4.2 Correlation coefficients (r) between the values obtained by THI (ITH), ET (TE) and EET (TEE) and climatic elements. *Temp* temperature, *Hum* relative humidity, *VV* wind speed (at a height of 2 m)

Temperature variations directly influence sensations of comfort/discomfort. In the case of relative humidity, it appears that thermal comfort varies inversely to this variable. This is justified because of the heat exchanges through evaporation, depending on the outdoor relative humidity—in a very humid environment, evaporation is limited, greatly reducing the potential of the heat dissipation inherent to perspiration and increasing thermal discomfort. Increased relative humidity reduces the capacity for water evaporation and the potential for heat dissipation, the only mechanism that, under particular environmental conditions, is capable of balancing the body heat gains.

In the case of EET, the temperature and humidity variables also have a particular significance in comparison to the role of the wind. Although wind has some cooling power, it is not the most significant variable in the variation of thermal comfort, which explains why the cooling effect of the wind in summer is not as significant as in winter.

Thermal comfort is primarily dependent on temperature; relative humidity and wind reinforce or reduce the sensation given by temperature.

The wind speed of the monthly average values are higher at 18 UTC in all weather stations; however, it has little influence on the index result when compared with temperature and relative humidity.

At the Porto and Faro weather stations, the effect of the wind seems to have more influence on the variation of thermal comfort than at other weather stations. In contrast, was in the weather station of Bragança, where this variable has less significance on the variation of thermal comfort.

The Spatial and Temporal Distribution of the Monthly Values of THI, ET and EET

The examination of Figs. 4.3 and 4.4 show that, at any of the weather stations, bioclimatic average values translated by THI and ET indexes are always higher compared to the average values of the thermal sensation translated by EET during the period of the sample.

The conclusion is that with decreasing latitude there is a tendency for situations to be more thermally uncomfortable.

Examination of the monthly mean values of bioclimatic indexes at 18 UTC (Fig. 4.4 and Table 4.2) at the Coimbra, Lisbon, Beja and Faro weather stations shows that, according to THI, thermal sensations fall into the class ranging between 21 and 23.9, where 50 % of the study population expresses feelings of discomfort. The situation is similar for the ET index, where the values obtained correspond to slightly warm thermal sensations. The Porto and Bragança weather stations boast greatest latitude and are less exposed to tropical high pressure that advance north at this time of year and influence our mainland, especially the most southern latitudes

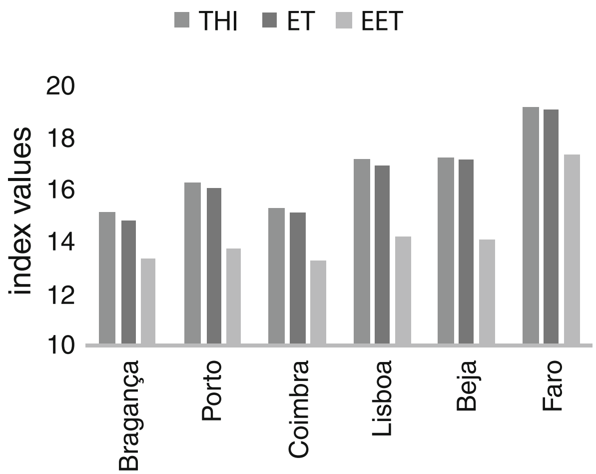

Fig. 4.3 Average monthly values of THI, ET and EET in the summer months during the period 1981–2010 at 06 UTC

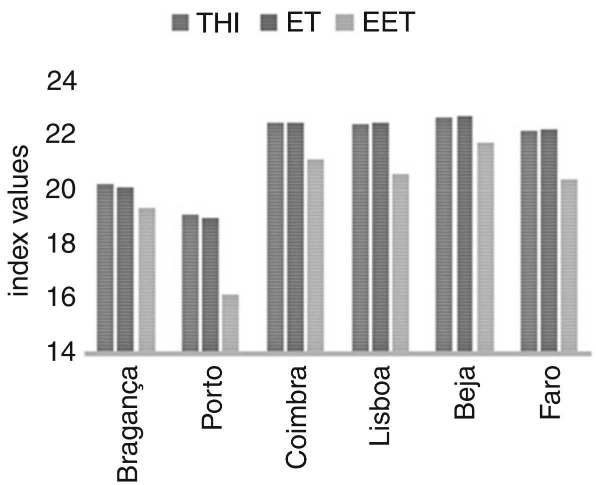

Fig. 4.4 Average monthly values of THI, ET and EET in the summer months during the period 1981–2010 at 18 UTC

(Table 4.2). In Bragança, it is worth highlighting the altitude at which the weather station is located.

Considering the average values of EET, Beja weather station shows slightly warm thermal sensations, resulting from the combined effect of latitude and continentality, being located in a sheltered position in relation to the sea breezes and north winds.

Any of the bioclimatic indexes used indicate lower values (more thermally comfortable) in June and September, both at 06 UTC and 18 UTC. The months of July and August, with average values of higher temperature, show higher values in the three indexes (Fig. 4.5).

Table 4.2 Total average of indexes at 18 UTC

Average 18 UTC	THI	ET	EET
Bragança	20.2	20.1	19.4
Porto	19.1	19.0	16.2
Coimbra	22.5	22.5	21.1
Lisbon	22.4	22.4	20.5
Beja	22.6	22.7	21.7
Faro	22.2	22.2	20.4

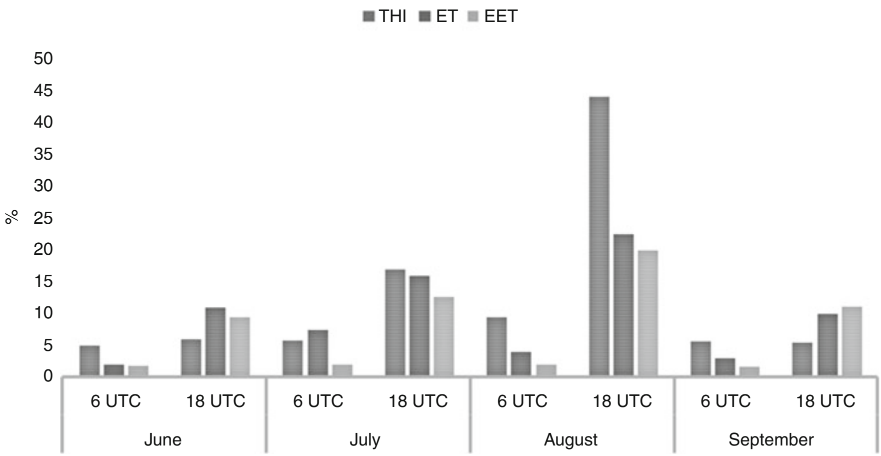

Fig. 4.5 Total percentage of days with discomfort in the summer months during the period 1981–2010

In this sense, without devaluing the role of relative humidity or wind speed, in the case of EET index, the values obtained from the bioclimatic indexes seem to change more closely in line with air temperature values.

The temporal distribution of annual average indexes values (Figs. 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, and 4.17) shows an intra and inter annual irregularity of values of thermal sensation in the two time periods. THI and ET years 1981 to 1990, 1998, 2000, 2003, 2004, 2009 and 2010 show the highest average values at most weather stations.

The examination of the trend lines at 06 UTC (Figs. 4.6, 4.7, 4.8, 4.9, 4.10, and 4.11) denotes an increase, albeit not a significant one, of the thermal sensations at all the weather stations, with the exception of Coimbra, which shows a decrease, and Lisbon, which boasts a relatively constant tendency to increase. Matching the results obtained with the global climate models, there may be some parallels pointing towards an increase in thermal sensations, along with the forecasts for the rise in global temperature. However, in view of the above, and given the natural decline in temperature at night in Coimbra, there is a tendency for reduced feelings of discomfort related to heat. As such, there is a tendency for more thermally comfortable situations, which may be indicative of a strong degree of urbanization,

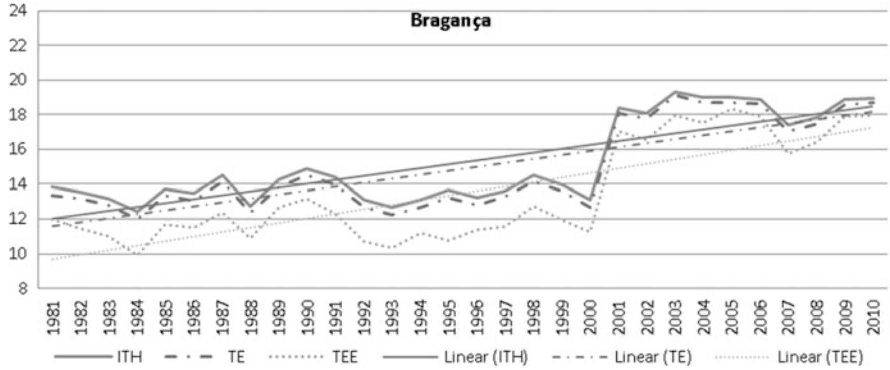

Fig. 4.6 Temporal evolution and linear trend of average annual values of THI, ET and EET at 06 UTC in Bragança during the summer period (1981–2010)

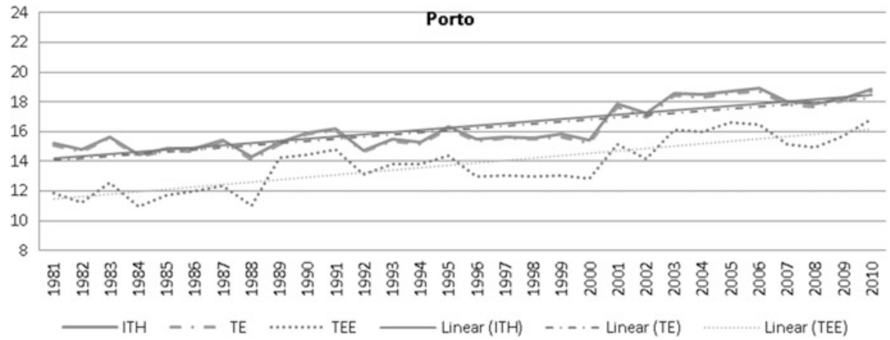

Fig. 4.7 Temporal evolution and linear trend of average annual values of THI, ET and EET at 06 UTC in Porto during the summer period (1981–2010)

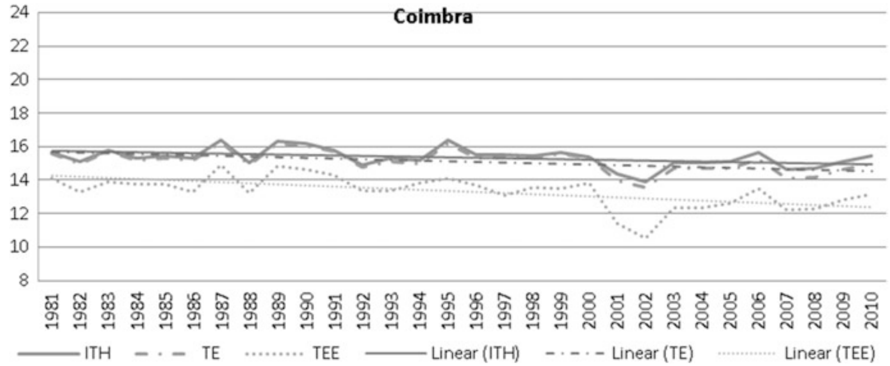

Fig. 4.8 Temporal evolution and linear trend of average annual values of THI, ET and EET at 06 UTC in Coimbra during the summer period (1981–2010)

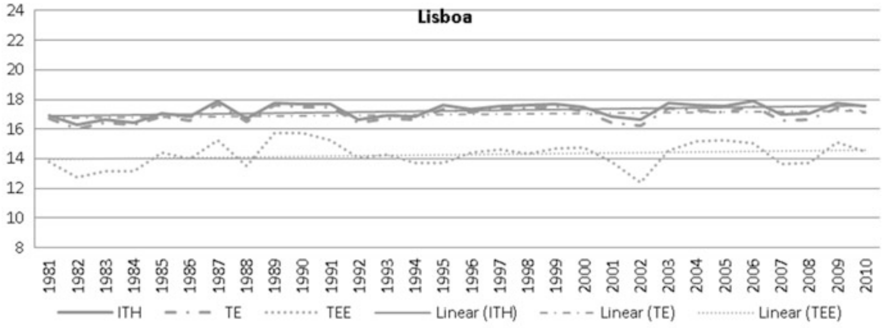

Fig. 4.9 Temporal evolution and linear trend of average annual values of THI, ET e EET at 06 UTC in Lisbon during the summer period (1981–2010)

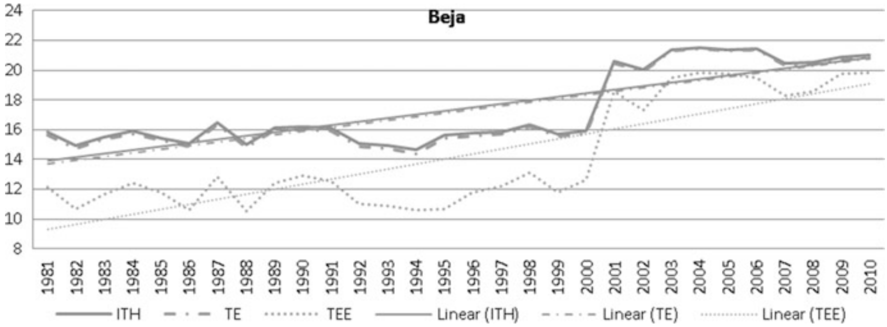

Fig. 4.10 Time evolution and linear trend of average annual values of THI, ET e EET at 06 UTC in Beja during the summer period (1981–2010)

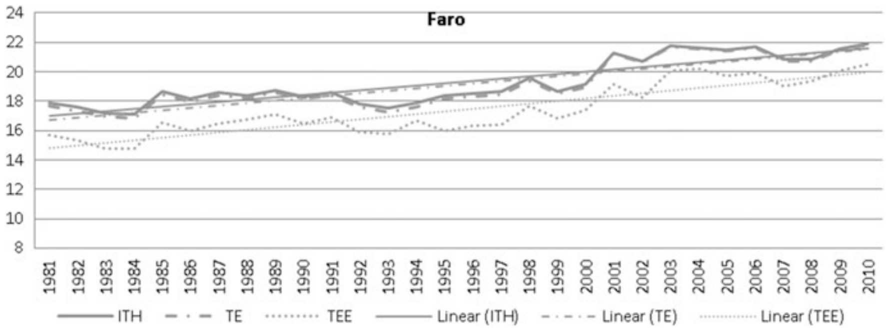

Fig. 4.11 Time evolution and linear trend of average annual values of THI, ET and EET at 06 UTC in Faro during the summer period (1981–2010)

boosting the nuclei of heat islands occurring during the day and which are strongly attenuated overnight due to the accumulation of cold air originating in the Katabatic

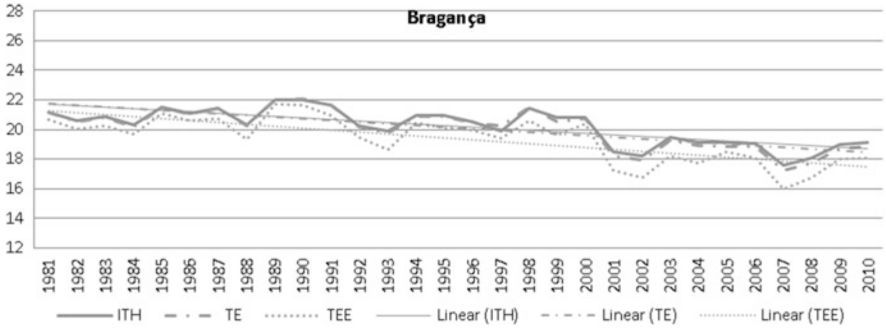

Fig. 4.12 Time evolution and linear trend of average annual values of THI, ET and EET at 18 UTC in Bragança during the summer period (1981–2010)

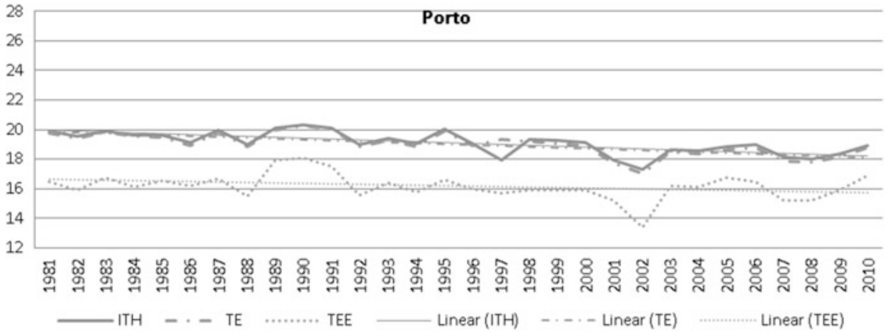

Fig. 4.13 Time evolution and linear trend of average annual values of THI, ET and EET at 18 UTC in Porto during the summer period (1981–2010)

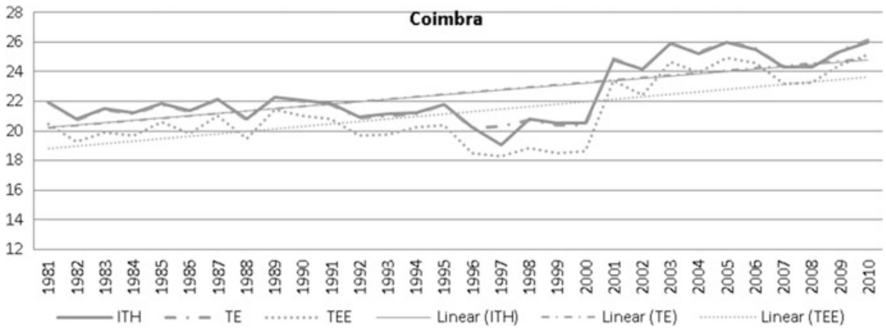

Fig. 4.14 Time evolution and linear trend of average annual values of THI, ET and EET at 18 UTC in Coimbra during the summer period (1981–2010)

(Ganho 2009). Given the proximity of the ocean and the river (Mondego), night breezes improve thermal comfort during the early hours of the day.

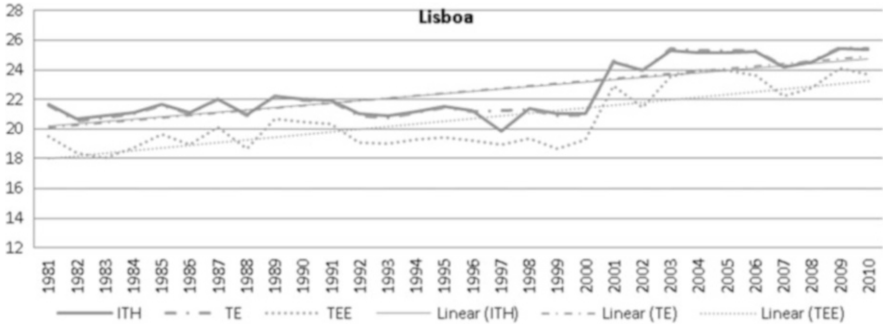

Fig. 4.15 Time evolution and linear trend of average annual values of THI, ET and EET at 18 UTC in Lisbon during the summer period (1981–2010)

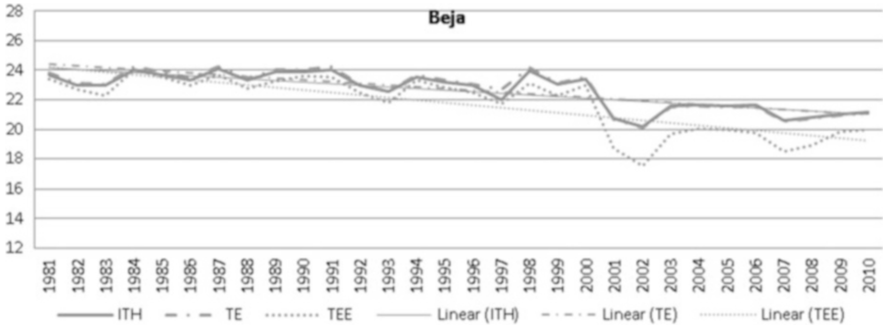

Fig. 4.16 Time evolution and linear trend of average annual values of THI, ET and EET at 18 UTC in Beja during the summer period (1981–2010)

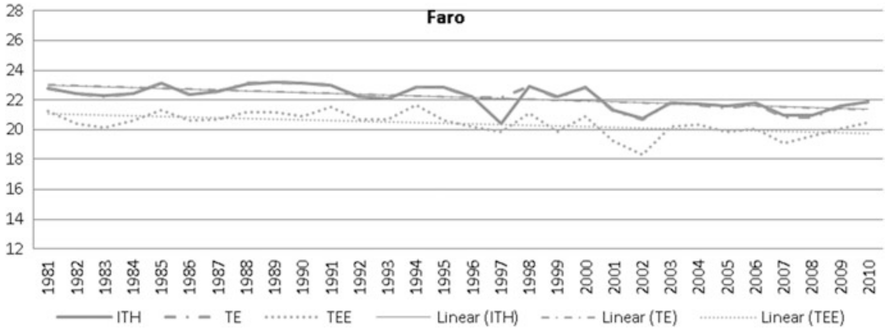

Fig. 4.17 Time evolution and linear trend of average annual values of THI, ET and EET at 18 UTC in Faro during the summer period (1981–2010)

The strong correlation between the variation of temperature and thermal comfort, as proved in section Spatial and Temporal Framework of this chapter, should also be noted.

At 18 UTC (Figs. 4.12, 4.13, 4.14, 4.15, 4.16, and 4.17), Coimbra and Lisbon boast slight increase in the values of bioclimatic indexes, particularly from the year 2000. There may be several causes for this phenomenon, particularly the higher average temperatures recorded in recent years. At the remaining stations, the linear trend lines are relatively constant, with the exception of Bragança and Beja, which may be indicative of the peri-urban character of these stations.

For Coimbra and Lisbon, their own internal urban microclimate dynamics, associated, for example, with the intensification of the urban heat island, can explain the abovementioned increase of bioclimatic indexes.

The analysis performed at this point shows that the evolution of the average annual values of bioclimatic indexes varies at the different weather stations, with many fluctuations over the period-sample. The results obtained for the THI index at 18 UTC, regarding the intensity of sensations, show significant contrasts between the different weather stations.

According to the intensity values obtained for situations of discomfort, Porto is the most comfortable, while Beja and Faro, the stations located at the lowest latitude, have a greater number of uncomfortable days and where, according to the intensity classes, more than 50 % of the population frequently feels discomfort. In Coimbra and Lisbon, there are even situations that generate strong bioclimatic stress and, consequently, medical emergencies (Fig. 4.18).

Results show that there are potential risks arising from this situation in Lisbon and Coimbra. Consequently, it is necessary to undertake studies that considered the importance of micro-climatic characteristics in these territorial units and their changing metabolism, units that this study does not consider because it was undertaken on a regional scale.

The distribution of mean values of EET in each of the sample years adheres to variation of the average of the previous two indexes but with lower values.

Heat Waves in the 1981–2010 Period

Identification of Heat Waves

Through the data obtained by applying the HWDI formula, it was observed that the total number of heat waves occurring at each weather station is distributed unevenly in temporal and spatial terms (Fig. 4.19). With regard to spatial variation, the Bragança weather station recorded the most waves during the period-sample (26), followed by the weather stations of Beja, Coimbra, Lisbon, Porto and, finally, Faro.

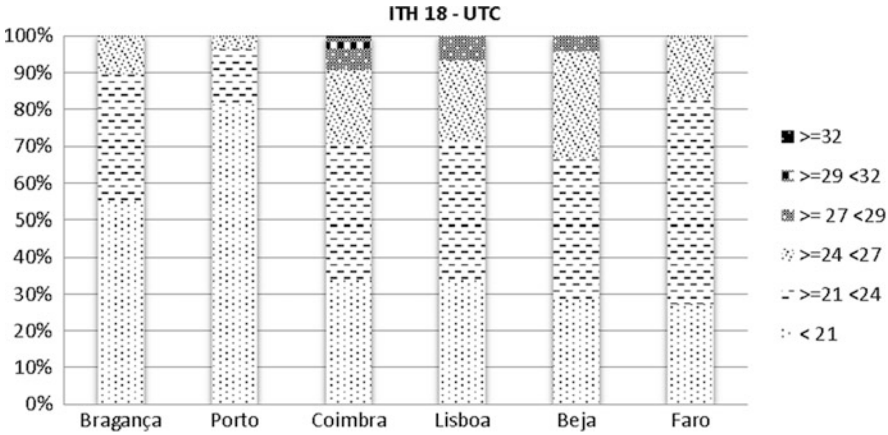

Fig. 4.18 Distribution of classes of THI at 18 UTC in Bragança, Porto, Coimbra, Lisbon, Beja and Faro during the summer period (1981–2010)

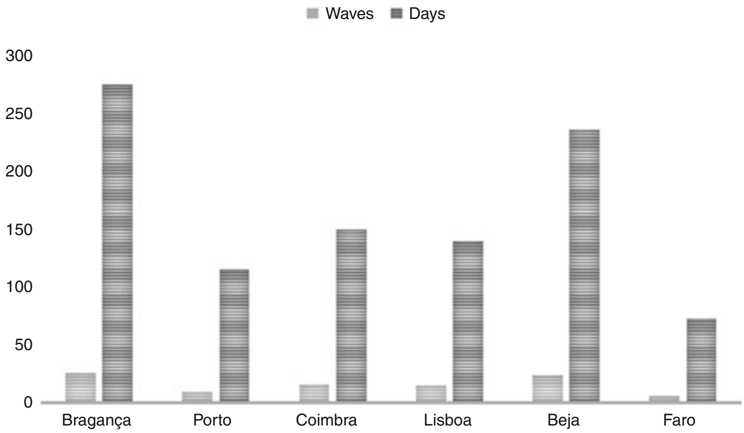

Fig. 4.19 Total number of heat waves and associated days in the study period

The Atmospheric Circulation Associated with the Occurrence of Heat Waves

This analysis used surface synoptic charts (level pressure on sea water and wind to 10 m) and 500 hPa at altitude (geopotential and wind at 500 hPa). For each selected situation, the day before and after the heat wave was considered, in order to contextualize the synoptic situation.

The terminology used in this study was proposed by Ramos (1987) and used by several authors. For all studied episodes, a synoptic classification of surface and altitude was made. To catalogue synoptic situations in surface and altitude, the criteria and classification codes proposed by Ganho (2000) were employed.

For the classification of surface synoptic situations, the distinction between anticyclone situations and synoptic disturbances was made, and, in relation to the latter, between frontal disturbances and depression centers related to cold pool situations.

With respect to situations at altitude, zonal circulation schemes, wave circulation and blocking circulation that reached the Western and Eastern Atlantic sector were considered.

Examining all heat waves days recorded from 1981 to 2010, we see that surface circulation corresponds to anticyclones, 95.5 % of the time, while the remaining days (4.5 %) indicate situations related to thermal origin depressions.

In relation to the typology of anticyclones (Fig. 4.20) causing heat waves, we can see the predominance of mixed Atlantic anticyclone (60 % of days). This type of anticyclone is also the most frequent in the summer, providing a westerly or northwesterly flow that mainly affects the coastal area. Mixed Atlantic anticyclones extending to Western Europe were also very significant in relation to the occurrence of heat waves (24 %).

Despite being less frequent, the Iberian-Mediterranean and Iberian-African anticyclones (Fig. 4.20) should be highlighted, due the extent of thermal discomfort they caused.

At altitude, during the occurrence of heat waves, meridian circulation clearly prevailed (Fig. 4.21), accounting for 65.8 % of the days (38.4 % in wave regime and 27.4 % in blocking scheme).

Zonal circulation occurred on the other 34.2 % of heat wave days. In the case of zonal circulation, disturbed circulation occurred in most situations (20 %). The remaining situations occurred under anti-cyclonic conditions (14.2 %), which is characteristic of this time of year.

Despite the predominance of zonal circulation during the summer period, the most intense heat waves occurred in meridian situations that were associated with wide-range anticyclone ridges, which extend from North Africa to southern Europe.

Given the above, it is concluded that the study of atmospheric generators of heat-related extreme event systems is both very important and urgent, due to climate change scenarios and associated consequences. Research combining several fields of knowledge and spheres of action can contribute to more effective risk anticipation or risk communication.

Conclusions

Situations of thermal discomfort are a common feature of the summer season in Portugal. Studying six weather stations located in climatically distinct areas allowed the observation of spatial contrasts, as well as the factors explaining them.

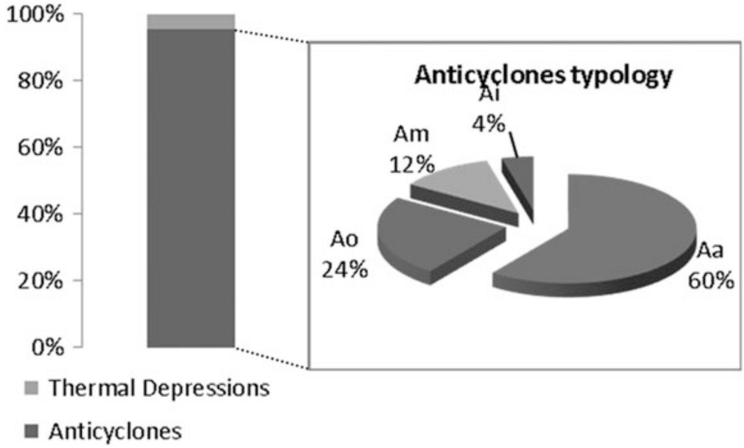

Fig. 4.20 Synoptic situations surface (n, m, m). Legend: *Aa* mixed Atlantic anticyclone, *Ao* mixed Atlantic anticyclone extending to Western Europe, *Ai* anticyclone Iberian-African, *Am* anticyclone Mediterranean

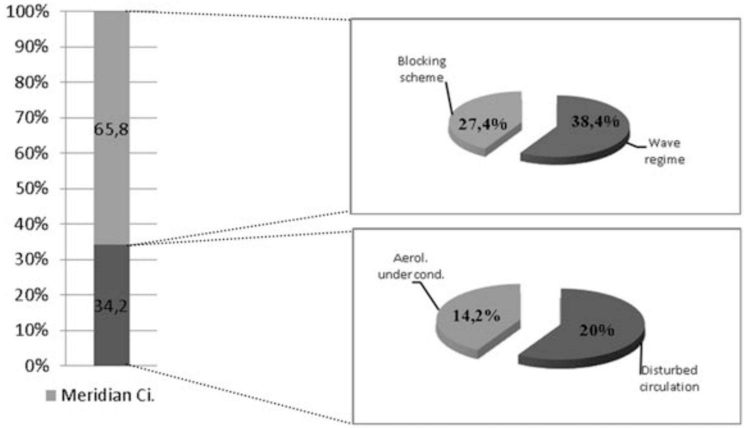

Fig. 4.21 Frequency of different types of anticyclone and situations at altitude (500 hPa) during heat waves (1981/2010)

Situations of discomfort in summer (1981–2010) are, primarily, the result of high temperatures, but also influenced by relatively high humidity (particularly at 06 UTC) at most of the weather stations studied. The combination of high levels of these two elements was the main cause of thermal discomfort. The role of wind speed as a moderator of thermal discomfort recorded by EET index is felt most at 06 UTC, slightly mitigating the intensity of the discomfort caused by heat.

In bioclimatic terms, the months of June and September are less uncomfortable at 06 and 18 UTC, while July and August, which boast higher average temperatures and a slight drop in relative humidity, are the most uncomfortable. However, the temporal distribution of greater bioclimatic discomfort (frequency and intensity) is quite irregular.

The number of heat waves occurring at each of the weather stations was considered relatively high, with the exception of Faro. In the case of Bragança and Beja, the high frequency of heat waves can be explained by the continental character of the regions where they are located.

Synoptic causes of these episodes are due almost exclusively to the Atlantic (Azores) anticyclone position, which, with the migration of the polar jet to the north during the summer, allows this high pressure cell to increase its latitude and reach mainland Portugal with greater frequency and intensity.

It is therefore vital to take relevant and efficient action in order to mitigate risks, reduce their effects and make the population aware of the need to adapt to such paroxysms. To this end, knowledge of specific risks, the identification of elements at risk and the assessment and quantification of vulnerabilities are essential for effectively planning prevention and protection, thus improving people's quality of life in bioclimatic terms.

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Chapter 5
Effects of Temperature Variation on the Human Cardiovascular System: A Systematic Review

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Abstract In recent years, extreme weather has been recorded on every continent demanding adaptation of health care services to climate change. The aim of this chapter was to conduct a systematic review concerning the effects of temperature variation on the human cardiovascular system in order to access evidence of how heat and cold-waves are affecting health. A systematic search was conducted between December 15th and 25th via health-related databases: PubMed, Medline, LILACS, SciELO and Cochrane Library, using combinations of the DeCS/MeSH terms "ambient temperature", "health" and "cardiovascular system" and their equivalent in Spanish and Portuguese, published between 2004 and 2014. A total of 47 publications were retrieved, 9 of which met the inclusion criteria. Some studies reported the potential effects of temperature on human health, mostly from high temperatures. The main effect of ambient temperature variation on human systems is abnormalities in blood vessels and homeostatic mechanisms, which trigger a series of responses that may affect the cardiovascular system. Papers from different countries report that changes in ambient temperature alter the profile of hospitalizations, with an increased incidence of cardiovascular disorders, particularly in individuals with predisposing factors or comorbidities, such as being elderly and having Type 2 diabetes. The conclusion is that high ambient temperatures are leading to increased incidence of cardiovascular diseases, mainly heatstroke, and the elderly is the most vulnerable age group.

Keywords Ambient temperature • Health • Cardiovascular system

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Introduction

The World Health Organization estimates that the warming and precipitation trends due to anthropogenic climate change of the past 30 years already claim over 150,000 lives annually. Many prevalent human diseases are linked to climate fluctuations, from cardiovascular mortality and respiratory illnesses due to heatwaves, to altered transmission of infectious diseases and malnutrition from crop failures. Existing quantitative studies of climate–health relationships were used to estimate relative changes in a range of climate-sensitive health outcomes including: cardiovascular diseases, diarrhea, malaria, inland and coastal flooding, and malnutrition, for the years 2000–2030. These estimates should be considered as a conservative, approximate, estimate of the health burden of climate change (Patz et al. 2005).

The aim of this study is to provide a link between health care service and mitigation and adaptation to climate change, using as its subject cardiovascular disease. We want to know how the patterns of knowledge, practice and values need to change in order to address the increasing demand for health care during events of abnormal temperature changes.

The chapter presents: a theoretical reference about the effects of climate changes on human health; the methods and research questions guiding the systematic review; the findings concerning the effects of temperature variation on the human cardiovascular system and evidences of the effects of heat and cold-waves on health.

Theoretical Referential

Climate change affect human life through three main mechanisms: extreme climatic events, environmental changes and changes in pattern of infectious disease transmission. Extreme climatic events can affect health by influencing the body's physiology (e.g., heat weaves or extreme cold) or by causing physical or psychological trauma triggered by natural hazards, such as storms, floods, or droughts. The environmental changes can also affect the production of food, impact air and water quality, and the ecology of infectious agent vectors, such as mosquitos transmitting endemic diseases (e.g., Malaria and dengue). These mechanisms have effects on social processes determining important socioeconomic, cultural or demographic ruptures (Confalonieri and Marinho 2007).

Climate change research has also frequently identified vulnerable groups who may be differently affected by climate change, often within socioeconomically disadvantaged populations, such as older citizens or indigenous peoples (Woodward and Scheraga 2003).

Currently, there has been increased concern over the implications of meteorological factors for human health, due to evidences that increases in air temperature can be associated with an immediate increased risk of respiratory mortality (Liu et al. 2011). The Intergovernmental Panel on Climate Change (IPCC) has recommended that change in air temperature in the short term is one of the main markers for analysing associations between climate and mortality or morbidity (Confalonieri et al. 2007).

Climate changes, both extreme heat and extreme cold, may favour the onset of diseases with early death, especially among population subgroups presenting limited adaptive capacity (Michelozzi et al. 2009).

Diverse epidemiological studies have shown that extreme ambient temperatures (heat or cold) are associated with increased mortality and morbidity among humans (Basu 2009; Turner et al. 2012; Ye et al. 2012). There is also growing evidence reported by recent studies suggesting that individuals with pre-existing pathological conditions (e.g., Diabetes Mellitus, heart disorders, and respiratory diseases) are at higher risk of death during episodes of extreme temperatures (Zanobetti et al. 2013; Madrigano et al. 2013).

In 2003 there was a heat wave in Western Europe reaching Portugal, Spain, France, Italy, Germany and the UK, with a large number of deaths. At that time the Institut de Veille Sanitaire estimated 14,802 deaths only in France (Marto 2005). After this fact, some institutions involved in public health on the continent have shown greater interest in preventing effects from heat. Certain public entities started research and sought bases for the beginning of an action plan to combat the heat. A survey of cities that have battle plan to the effects of heat was performed by World Health Organization, and found that of 51 European Region member countries included in the evaluation, only 18 developed heat action plans (Bittner et al. 2014).

As a result of the large number of deaths, several strategies to reduce preventable deaths from heat waves are being created, as public education with recommendations to seek air-conditioned places (cinemas, libraries, transport and museums), decreased physical activities during the heat, and increase fluid intake and monitor vulnerable populations such as the elderly. Portugal uses a heat wave alert system called ÍCARO project, which began in 1999. The project aims to identify heat waves that can cause death 3 days in advance. The value of ÍCARO index and its significance are reported daily to the Health General Directorate, the National Service for Fire and Civil Protection. Thus alert levels are generated (blue, yellow, orange and red) in ascending order. Each alert signal triggers a plan (Marto 2005).

Recent studies have provided estimates of climate effect through correlations of air quality with meteorological variables; however few studies assess the effects of ambient temperature on specific pathologies such as cardiovascular diseases. Even though older studies have not shown a correlation between ambient temperature and cardiovascular diseases, various recent studies, using diverse statistical analyses, have shown this association either through GAM analysis (Schwartz et al. 2004; Jie et al. 2014), Poisson regression models (Bayentin et al. 2010) or systematic reviews (Bhaskaran et al. 2009).

Methods and Research Instruments

A systematic literature review was conducted relating environmental thermal effects and their implications for human health, especially on the cardiovascular system. The questions guiding the search for papers were: How does ambient temperature affect human health? What relationships can be established between ambient temperature and the cardiovascular system?

The following electronic databases were included: PubMed, MedLine, LILACS (Latin American Literature on Health Sciences), SciELO (Scientific Electronic Library Online), and the Cochrane Library. The following DeCS/MeSH descriptors were used: temperature, health and cardiovascular system including their equivalents in Portuguese and Spanish, always in this order and using the additive conjunction “and” between words. Exclusion criteria were publications with abstracts written in languages other than Portuguese, English or Spanish or publications predating 2004.

The titles and abstracts of the papers identified in the electronic search were reviewed and selected by professors working in the human medicine field from the University of Franca—SP—Brazil. The full texts (PDF format) of those studies that met the inclusion criteria were obtained to enable a greater understanding of the effects of ambient temperature on the cardiovascular system.

The selection of papers followed the Critical Appraisal Skills Programme (CASP) and criteria suggested by Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).

This review includes all papers that met the inclusion criteria.

Results and Discussion

A systematic review addressing the effects of temperature variation on the human cardiovascular system was performed. A total of 47 publications were retrieved. Of these, 43 were found in PubMed, and four in the remaining databases (SciELO, LILACS, MedLine and Cochrane Library). Two of these papers appeared twice and their duplicates were excluded.

Of the 45 papers submitted to title assessment, 30 were excluded, with 15 papers remaining for further analysis. After complete assessment of abstracts and the respective full texts, six papers were excluded, leaving nine papers that met the inclusion criteria (Table 5.1).

Of the nine papers selected, one was published in 2009, one in 2010, one in 2011, two in 2012, and four in 2014. The *Environmental Health Perspectives* journal published two of the papers selected, while the others journals published one paper each: *Gerontology, American Journal of Epidemiology, PLOS ONE, Medicine & Science in Sports & Exercise, Revista de Saúde Pública, Environmental Health* and *Zhonghua Liu Xing Bing Xue Za Zhi* journals.

Table 5.1 Studies that met the inclusion criteria by year of publication, authors, titles and journal

Year	Author	Title	Journal
2009	Guo et al.	Association between temperature and hospital emergency room visits for cardiovascular diseases: a case crossover study	*Zhonghua Liu Xing Bing XueZaZhi*
2010	Hampel et al.	Altered cardiac repolarization in association with air pollution and air temperature among myocardial infarction survivors	*Environmental Health Perspectives*
2011	Ren et al.	Ambient temperature, air pollution, and heart rate variability in aging population	*American Journal of Epidemiology*
2012	Blatteis	Age dependent changes in temperature regulation—a mini review	*Gerontology*
2012	Silva, Ribeiro	Impact of urban atmospheric environment on hospital admissions in the elderly	*Revista Saúde Publica*
2014	Mehta et al.	Association between changes in city and address specific temperature and QT interval—the VA normative aging study	*PLOS ONE*
2014	Li et al.	Association between high temperatures and mortality in metropolitan areas of four cities in various climatic zones in china: a time series study	*Environmental Health*
2014	Zanobetti et al.	Brachial artery responses to ambient pollution, temperature, and humidity in people with type 2 diabetes: a repeated measures study	*Environmental Health Perspectives*
2014	Kenney, Craighead, Alexander	Heat waves, aging, and human cardiovascular health	*Medicine & Science in Sports & Exercise*

Guo et al. (2009) studied heat thresholds for mortality outcomes in four cities in China in different climatic conditions. The results show strong association between mortality and a rise in daily maximum temperatures in all the cities under study. The effect of the temperature was estimated as the percentage of increased daily mortality in relation to an increase of 1 °C in the daily maximum temperature. There was a significant increase in association between high temperatures and mortality due to cardiovascular diseases. Exposure to high temperatures may lead to dehydration, salt depletion, and failure of thermoregulation by increased superficial blood circulation. Additionally, significant association was found between temperature and mortality due to metabolic and endocrinal causes, and diabetes mellitus (higher temperatures seem to increase the absorption of insulin by diabetes mellitus patients treated with insulin). Lastly, higher mortality rates were observed among the elderly. There was significant increase in all causes of death, especially cardiovascular, endocrinal, and metabolic causes due to changes in temperature.

A study of non-smoking myocardial infarction survivors (Hampel et al. 2010) was conducted to assess the influence of air pollution and air temperature on cardiac repolarization, for parameters, the study had the QT interval and temperature-wave amplitude (Tamp) in Augsburg, Germany, between May 30, 2003 and February 1, 2004. Heartbeat did not appear to alter according to changes in the temperature:

during the study period of 24 h, though, the average temperatures never exceeded 28 °C, which is similar to temperature conditions before participants were exposed to heat in other studies. Tamp decreased in association with both low and high temperatures; maximum Tamp was approximately 5 °C. Non-linear associations were detected between temperature and Tamp. In general, changes in heart rate and repolarization parameters associated with exposure to air pollutants and temperature changes were detected, which are potential precursors of additional cardiovascular problems in individuals who had previously experienced a myocardial infarction.

Blatteis (2012) performed an integrative review of an elderly population exposed to the effects of changes in ambient temperature. Epidemiological studies show that regulation of body temperature depends on almost all bodily systems. The body temperature of men and women aged from 60 to 65 years old is generally lower than that of their younger counterparts. The author concluded that elderly individuals have greater difficulty maintaining thermal homeostasis when exposed to extreme temperatures.

The study by Ren et al. (2011) was initiated in 1963 with 694 individuals living in Boston, MA, USA, aged from 21 to 80 years old who underwent physical assessments and laboratorial exams every 3–5 years to measure variation in their heart rates which was correlated with temperature, pressure and the presence of ozone. The authors concluded that, during the hot season, there was a decrease in heart rate variation in the elderly group; no such variation occurred during the cold season. The human body may be able to maintain a stable average temperature at the expense of physiological stress activation, which may alter physiological responses to exposure to toxic agents in many environments. Higher temperatures may modify the generation, dispersion, and degeneration of toxic substances, including ozone.

A cross-sectional study was conducted with hospitalizations of 60-year-old or older individuals, between 2003 and 2007 São Paulo, Brazil, in order to analyse the impact of intra-urban atmospheric conditions on circulatory and respiratory diseases (Silva and Ribeiro 2012). The authors concluded that thermal discomfort was associated with an increased risk of developing cardiovascular system conditions among individuals over 60 years old. An increase in hospitalizations due to problems in the circulatory system was observed on cold days with wide thermal variations, regardless of the socio-environmental conditions. Areas with lower socio-environmental indicators have populations that are the most vulnerable to atmospheric conditions in both cold and hot temperature extremes. Physiological Equivalent Temperature (PET), a complex index that reflects interactions between humans and their thermal environments, revealed a 12 % higher risk of hospitalizations with a decrease of 1 °C in the comfort index and approximately 1.12 the relative risk for every increase of 1 °C in maximum temperatures.

Mehta et al. (2014), studied elderly male volunteers aged between 21 and 80 years old and found associations between corrected QT interval and moving averages (1–7, 14, 21 and 28 days) and temperature standard deviation. The authors found that an increase in the mean temperature is associated with a wider QT interval. A larger standard deviation of 24 h for temperature was associated with a wider QT interval. These associations were stronger in colder months and among participants with Diabetes Mellitus or cardiac coronary disease.

Another study was performed in Beijing, China (Li et al. 2014) with individuals hospitalized due to cardiovascular diseases in order to explore the relationship between ambient temperature and emergency room visits. After adjusting the data on air pollution, 1 °C increase in average ambient temperature was associated with increased emergency room visits. The authors concluded that an increase of 1 °C in ambient temperature increased emergency room visits due to cardiovascular diseases in the spring and summer and decreased visits in the fall and winter. The authors recommended that patients with cardiovascular diseases pay attention to climatic changes, especially during spring and summer, because higher temperatures in these seasons caused an increase in the number of visits to emergency rooms.

Zanobetti et al. (2014) conducted a longitudinal study of individuals with type 2 Diabetes Mellitus living up to 25 km from the Boston monitoring station between 2006 and 2009 in order to assess responses of the brachial artery to environmental pollution and weather (measuring humidity and temperature and water vapour pressure). The results show that pollution particles are associated with mid-sized brachial artery vasoconstriction in individuals with type 2 Diabetes Mellitus, while an increase in temperature, humidity and pressure can cause vasodilation. This finding shows that individuals with type 2 Diabetes Mellitus present a reduced ability to effectively respond to environmental changes, increasing the risk of cardiovascular diseases.

Kenney et al. (2014) performed an integrative review based on the American College of Sports Medicine's Annual Meeting in 2013 to analyse the effects of climate change and consequent increased environmental heat stress on the cardiovascular system in old age. The authors found that during heat waves, elderly individuals accounted for most visits to emergency rooms and that thermoregulatory mechanisms may overload the cardiovascular system. More frequent and more severe heat waves associated with the rapid growth of the at-risk elderly population increase the likelihood of undesirable outcomes.

All nine studies included in this chapter corroborated the fact that changes in temperature have a determinant impact on physiological changes in the thermoregulatory system, which mainly predispose individuals with a compromised adaptive capacity to the risk of cardiovascular lesions. Additionally, there was greater association between temperature and mortality due to metabolic, endocrinal, and especially, cardiovascular causes (Li et al. 2014; Hampel et al. 2010).

In the next section we present how temperature can influence cardiovascular systems in different ways.

Physiological Changes in Thermoregulation

The regulation of body temperature involves almost all systems and decreased bodily functions significantly impact the maintenance of thermal homeostasis, with significant consequences, especially among the elderly. This possibly explains the greater vulnerability of this population when exposed to extreme temperatures (Blatteis 2012).

The human body can be divided arbitrarily into two thermal compartments: a core compartment (trunk and head), with precisely regulated temperature around 37 °C, and a peripheral compartment (skin and extremities) with less strictly controlled temperature, and lower than the core temperature (Sosnowski et al. 2015).

During exposure to hyperthermia, peripheral vascular resistance usually decreases due to cutaneous vasodilation (Li et al. 2014). Exposure of the population in general to high temperatures may lead to dehydration, salt depletion, high blood viscosity, increased cholesterol levels, and sweating (Li et al. 2014). Cardiac output (heart rate multiplied by stroke volume in 1 min) tends to increase to maintain blood pressure. Patients in this situation are either unable to maintain their blood pressure or unable to promote proper cutaneous vasodilation for thermoregulation and, as a consequence, cardiac lesions may occur (Oktay et al. 2009). In other words, the body is unable to sustain the level of cardiac output necessary to meet the combined demands of skin blood flow for thermoregulation and blood flow for the metabolic requirements of exercising muscle and vital organs (Carter et al. 2005).

The mechanism by cold induced thrombogenesis might involve a combination of factors, including haemoconcentration, an inflammatory response, and a tendency for an increased state of hyper coagulability (Heppell et al. 1991). Exposure to cold has been associated with increases in arterial pressure and blood viscosity. Red cell counts, plasma cholesterol and fibrinogen concentrations, all of which may be thrombogenic, seem to be raised after exposure to cold (Keatinge et al. 1984). The density distribution of blood platelet subpopulations may be affected, with an observed increase in less dense platelets that were more sensitive towards agents that induce aggregation (Opper et al. 1995).

Changes in the metabolic profile may also occur during cold days, the biological mechanisms that take place include a rise in blood pressure (both systolic and diastolic), in serum LDL-cholesterol levels, heart rate, increased concentration of plasma fibrinogen, increased platelet stickiness and peripheral vasoconstriction, in addition to a decrease in HDL-cholesterol, which is associated with protection against atherosclerosis (Rocklov and Forsberg 2008; Hong et al. 2012).

According to many authors, the systems that regulate body temperature allow individuals to cope with variations in ambient temperature. When an individual faces low or high temperatures, there is an increase in heart rate so that blood flow to the skin also increases, leading to thermoregulatory responses such as sweating or shivering. On hot days, the need to regulate body temperature imposes an additional tension on the cardiovascular and respiratory systems and there is an increase in blood stickiness and cholesterol. Hence, the number of deaths caused by cardiovascular, respiratory or cerebrovascular diseases is higher on days in which the temperature is high. In turn, exposure to very low temperatures causes cardiovascular stress because of changes in blood pressure, vasoconstriction, increased blood stickiness, and increased levels of blood cells, plasma cholesterol and plasma fibrinogen. Additionally, inspiration of cold air can lead to bronchoconstriction, increasing one's susceptibility to pulmonary infections; thereby, the main causes of mortality on cold days are cardiovascular and respiratory diseases (Cesarino et al. 2013).

Murara and Amorim (2010) analysed atmospheric variations and their relationship with deaths due to pathologies of the circulatory system in Presidente

Prudente, SP, Brazil. The results showed that the days with a higher number of deaths due to circulatory diseases were related to periods of drought associated with greater temperature ranges and days with low relative humidity, showing a higher concentration of problems when the stable atmospheric systems (Tropical and Polar Atlantic Air Masses) operated on the area or when they suffered basal heating.

The relationship between atmospheric weather conditions and hypertensive crises in the urban population of the city of Areia, PB, Brazil was investigated. The results showed that the climatic parameters (temperature, relative air humidity, and days without rain) played an important role in the incidence of hypertensive cases, since the days with a higher number of hypertension events were related to rainy and cold days, mainly those in which there was a sudden thermal variation. The number of hypertension cases exacerbated in the dry season, with low relative air humidity, showing the importance of further research on Bioclimatology to plan actions intended to improve the quality of human life (Souza et al. 2011).

Souza et al. (2012) showed the relationship between climatic change and its effects on the health of the population, especially on the incidence of coronary diseases. Its results present three main reasons that potentially explain the relationship between weather conditions and variations in the number of infarcts: respiratory inflammations that contribute to cardiovascular conditions; blood-clotting factors, which become more active on cold days and favour the closing of coronary arteries and the formation of blood clots; and vasoconstriction, since to avoid heat loss in low temperatures, blood vessels contract, causing an elevation in blood pressure and obstruction among people with some type of fatty plaque impeding their arterial circulation. The authors suggest the relationship between weather variations and cardiovascular diseases guide the planning of actions intended to improve quality of life.

Souza et al. (2013) addressed the relationship between seasonality, weather changes, and their implications for cardiovascular diseases. They verified that the development of coronary heart diseases depends on individuals' genetic predispositions in combination with environmental factors. According to the authors, the early identification of cardiovascular risk associated with lifestyle and weather conditions can encourage preventive practices of health education.

There is a clear deleterious effect on the heart when temperatures fall under 22 °C. Harmful effects were also verified when the temperature ranged from 21.6–22.6 °C to 23.8–27.3 °C. It is possible that thermal changes account for 10 % of all myocardial infarction (Danet et al. 1999).

Evidence of How Heat and Cold-Waves Are Affecting Health: Co-morbidity

Individuals with pre-existent pathologies are at risk and are more prone to suffer the effects of climatic change. People with Diabetes Mellitus are at a greater risk of cardiovascular diseases due to chronic endothelial dysfunction, atherosclerosis and anatomical disruption Individuals with type 2 Diabetes Mellitus presented compromised ability to efficiently respond to environmental variations, which makes this group more susceptible to the effects of temperature, and increases the risk of morbidity and mortality due to cardiovascular diseases (Zanobetti et al. 2014).

Patients with pre-existing cardiovascular diseases should pay attention to climatic changes, especially during spring and summer, as a rise of 1 °C in temperature increases visits to emergency rooms due to cardiovascular diseases during these seasons of the year, while visits to emergency rooms are more stable during fall and winter (Wang and Lin 2014). Hampel et al. (2010) show that thermoregulation-related physiological functions decrease with aging, especially when elderly individuals are exposed to extreme temperatures, either cold or heat. During periods of heat weaves, seniors more frequently seek emergency care whether due to physiological and/or pathological factors (e.g., hypercholesterolemia, hypertension, and medication use more frequent and severe heat waves associated with the rapid growth of this at-risk-population are causes of great concern (Kenney et al. 2014).

Health Care Demand Under Extreme Weather: Adaptation and Mitigation

High temperatures have been associated with increased hospitalizations due to acute myocardial infarction and clinical worsening of congestive heart failure (Koken et al. 2003). Extreme cold also causes increased hospitalizations due to heart disease in patients with a history of a heart condition (Lavigne et al. 2014).

Deaths caused by cardiovascular diseases related to extreme temperatures were greater in number when compared to other causes of death. Some studies found association between ambient temperature and hospitalization due to ischemic injuries on days or even weeks subsequent to the increase in temperatures (Berginer et al. 1989; Basu et al. 2012) or decrease (Feigin et al. 2000; Ohshige et al. 2006; Hori et al. 2012) and differences between minimum and maximum daily temperatures (Ebi et al. 2004; Magalhães et al. 2011).

One study performed in China, show that low temperatures (14 °C) raised the rate of hospitalizations due to cerebrovascular diseases and hypertensive disorders (Wang and Lin 2014).

Murara et al. (2010) analysed meteorological influence on hospitalizations caused by cardiovascular conditions in the population older than 45 years old in Presidente Prudente, SP, Brazil, from 2000 to 2005. The authors observed a seasonal tendency of hospitalizations due to cardiovascular conditions in both months with high and with low temperatures. They emphasize that climatic elements by themselves do not cause the disease or individuals' behavioural changes, but act together with other factors such as nutrition, genetics, behaviour, and lifestyle.

These studies evidence the need to development of preventive measures in order to reduce the effects caused by climatic changes. Strategies should contain a plan to adapt to such changes with an evaluation concerning the vulnerability of infrastructure and populations to extreme climatic events and devise plans to reduce such impacts.

After the heat wave from 2003 in Europe, many people involved with public health in the continent showed greater interest in preventing the effects caused by heat, especially because other, even more severe, events were expected. Thus, public entities initiated studies and sought to ground a plan of action to prevent the effects of heat (Bittner et al. 2014).

Some countries, such as Yugoslav Republic of Macedonia due to intense climatic changes expected for the period between 2025 and 2100 has sought to devise policies and interventions to minimize risks and to adapt over the long term. Hence, an integrated and efficient approach is sought to prevent and warn the population in advance, in addition to efficient management to overcome the effects of climate change related to floods and fire (Kendrovski et al. 2014).

The impact of heat is site-specific and may change over time, so that the collection of recent data is important to assess the impact of temperature, mortality and morbidity. These data may be used to plan urban adaptation, identify locally relevant temperature thresholds and thus, warning can be issued to address vulnerable populations enabling preventive strategies.

It is also relevant to sensitize the population in regard to the effects of excessive heat, improve communication, enable individuals to have air conditioning, implement heat warning systems, and urban planning. It is important to observe that temperature enables “thermal comfort” for individuals and use heating systems when experiencing low temperatures and cooling systems during periods of high temperatures and also to encourage the use of proper clothing for each of these situations to protect health (Rogot et al. 1992; Danet et al. 1999).

Changing the height and density of buildings, using light painting on walls, installing insulating materials, and providing guidance in regard to the size of windows are recommended measures in addition to planting trees and creating parks to increase shadow areas. Another very efficient protective factor when facing heat weaves is air conditioning, which should be installed in every public space and be mandatory in hospitals, nursing homes and shelters (Petkova et al. 2014).

As recommendations, countries should improve its ability to monitor and evaluate the ongoing local effects of climate change by monitoring climate-health indicators, such as emergency room visits and hospital admissions for heat illness, or deaths due to extreme weather events.

Conclusion

Considering the papers included in this review, a progressive increase in the number of studies in the period reflects the growing interest of authors from different countries in the effects of temperature change. It is, however, noteworthy that this subject still requires information, particularly in respect to actions adopted by countries to combat the effects of climate change.

Human being has adaptive mechanisms to reduce the consequences arising from climate change; however, these mechanisms are often unable to impede undesirable effects on human health.

The vulnerability of elderly individuals is widely discussed in many of the papers, showing a concern in devising temperature-related preventive strategies and health-promoting measures directed to this population and those at risk, such as individuals with diabetes mellitus.

There are urgent need to perform health vulnerability assessment due to climate change in order to develop resilience and capacity to prepare for changing climate conditions and extreme weather events.

Limitations

Systematic reviews may be performed as an exploratory analysis between seemingly similar studies or to identify risk factors for further study, which is particularly useful for designing future studies, by systematically identifying key vulnerable groups and study characteristics from previous work. However, the restriction of databases chosen to carry out the search, the exclusion of monographs, dissertations and thesis and the fact that the articles were published in medical journals, could have limited the number of retrieved studies.

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Chapter 6
Can Concern for Air Quality Improvement Increase the Acceptability of Climate Change Mitigation Policies?

Vittorio Sergi, Paolo Giardullo, Yuri Kazepov, and Michela Maione

Abstract Air quality and climate change policies are finding new common grounds today as increasing social complexity requires better integration of separate knowledge domains. This chapter addresses the complex relationship between these two policy domains, their scientific background and the related acceptability issue, which varies substantially among countries and social groups and is influenced by social and cultural factors. The first section of this chapter describes the relationship between air quality and climate change policies. Indeed, global CO_2 reduction objectives require complex adaptations of socio-economic behaviours that might not directly appear to be related to pollution reduction or to improvement the exposure of citizens to harmful pollutants. Recent studies, however, have confirmed that air pollution and its impacts are one of the main environmental concerns for citizens, even if relevant differences in public perception between countries still remain. This section also addresses the ambiguities and conflicts that characterise communication between experts and citizens. The second section briefly describes recent scientific evidence that shows the possibility of coupling air quality and climate change mitigation benefits with policies targeted at specific pollutants called *short lived climate forcers* (SLCF). The third section spells out some preliminary research questions on the acceptability of these policies and their complex relationship with individual interests and cultural contexts. Linking air quality to climate change could be a *win-win* strategy to increase the social acceptability of specific policies and their implementation if knowledge and communication gaps between citizens and policy makers will be reduced.

Keywords Air quality • Climate change • Policy acceptability • Social perception • Eurobarometer

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Introduction

The European Union has been described as a leading actor in the international climate change policy arena (Wurzel and Connelly 2011). Indeed, the EU Climate and Energy Package, issued in 2008, was a major step in evidence-based policy implementation. However, along with the policy planning, the day-by-day implementation of policies has strong implications for individuals and collective actors (Leiserowitz 2012; Atran et al. 2005). Even though, in general terms, climate change is a growing concern for 40 % of European citizens (this figure was 22 % in 2008) (Eurobarometer 2008, 2011), there are still strong variations among countries (Bucchi and Saracino 2012; Running 2012; Leiserowitz 2012; Bulkeley 2000). Moreover, climate change policies face different degrees of social acceptability (Leiserowitz et al. 2013; Whitmarsh 2011; Shove 2010). Along with the increase in the share of populations living in urban environments, we have witnessed a global concern for the rising risks and health impacts linked to air pollution (Graham 2015). Recent scientific findings have increasingly linked air quality with climate change, highlighting the possibility of implementing win-win policies to efficiently tackle both problems. These developments opened a complex field of interactions between hard atmospheric sciences, social research and policy studies. They also provide a new scenario for addressing policy-makers activities and citizens' perception about environmental issues. In order to disentangle the complex relationship between scientific evidence, policy domains and the social acceptability of these issues, this chapter is divided into three sections. The first section describes the relationship between air quality and climate change policies and the ambiguities that mark the communication between experts and citizens. The second section briefly describes recent scientific evidence showing the possibility of coupling air quality and climate change mitigation benefits with policies targeted at specific pollutants called *short lived climate forcers* (SLCF). The third section spells out some preliminary research questions on policy acceptability based on the analysis of the Eurobarometer data. The essay will conclude by assuming that even if linking air quality to climate change may be a *win-win* strategy, as shown by scientific evidence, it has to pass the test of social acceptability. The analysis of our indicators will show that a *win-win* approach cannot be taken for granted and is not easily translated by policy makers both at the European and national level.

Between Experts, Common Sense and Acceptability

Air quality management policies were kicked-off with the *Clean Air Act* of 1956 in the United Kingdom. Air quality (AQ) legislation has been further developed in European countries since the 1970 EC Directive (70/220/EEC) (Uekoetter 2009). While the EU Directive does address national policy, its translation into national and local plans or interventions has been affected by differences in interpretation and varying levels of coherence (see Giardullo et al. 2015). Furthermore, the translation into policy of research findings related to air quality has been gradual but extensive (Williams 2004) and the social awareness of air pollution risks for health seems to increase as well (Eurobarometer 2013). On the other hand, although climate change (CC) has been studied since the 1980s, its complexity and debated impacts means that it did not influence specific policy initiatives till 1994 when the United Nations' Framework Convention on Climate Change was signed. At the European level, the Directorate-General (DG) for Climate Action was established in February 2010, adding a new specific department for CC, which was previously part of the DG Environment of the European Commission. More recently, the EU has encouraged attempts to unify the efforts: the Joint Research Center (JRC) set up a specific research unit about the integrated assessment of air quality and climate change policies.[1] Beyond the socio-political complexities and implications of the relationship between AQ and CC research and policy, we need to recognise, as advisers (Irwin et al. 1997; Jasanoff 1990) and citizens who can express forms of resistance (Jordan and Lifferink 2004; Jordan 2012), a deeper complex relationship between expert knowledge which contributes to policy-making. The relationship between experts and the public has always been at a crossroads between trust, distrust and misunderstanding, while environment problems have been perceived for a long time as issues to be solved through a top-down transmission of knowledge from experts to citizens.[2] In the last three decades, environmental policy making has been the site of growing conflicts, and policy makers have often come under public scrutiny or been openly criticized or contested (Pellizzoni 2011; Pellizzoni and Ylonen 2012). Today, governance over AQ and CC has become more complex due, for instance, to the coexistence of multiple perspectives and the need to:

1. Develop and present multiple arguments taking into account different points of view
2. Inform public opinion
3. Establish compromises with multiple social groups and stakeholders in order to achieve main public goals
4. Avoid serious damage to the interests of any of those groups (Viegas and Macario 2002)

Such challenges are exactly what public communication of science and technology (PCST) debates have already stressed (Peters et al. 2008). In particular when scientists advise policy-makers and scientific knowledge becomes public (Jasanoff 1990) it needs to cope with these extra-scientific challenges. It is not merely a

[1] More details on the website of the Joint Research Centre Unit of Air Quality and Climate of the EU http://ccaqu.jrc.ec.europa.eu/acu.php and on the national environmental agencies. The earlier approach was established in the UK; see: http://uk-air.defra.gov.uk/assets/documents/reports/aqeg/fullreport.pdf

[2] One important example is the "Bodmers report" (Royal Society Report 1985).

matter of recognising environmental problems and their consequences (problem perception): scientists have to answer the crucial question of whether the efforts required of citizens are appropriately effective and efficient. A general mismatch between the public acceptability of a measure and an expert's appraisal of their effectiveness opens space for multiple micro and macro conflicts (Pellizzoni 2011).

There is broad consensus that acceptability is crucial for a successful introduction and operation of policies; nonetheless, only a few authors have attempted to formulate a clear and systematic definition of acceptability (Schade and Schlag 2003; Viegas et al. 2000; Vlassenroot et al. 2010). According to Schade and Schlag, the term 'acceptance' defines "respondents' attitudes including their behavioural reactions after the introduction of a measure" (2000, p. 15), while 'acceptability' "describes the prospective judgment of measures to be introduced in the future" (ibid.). Moving from an individual to a collective perspective on acceptability, since 1991 the 'public (or social) acceptability' (Stankey and Clark 1992) concept has been used, although there is currently an inadequate understanding of its meaning. Usually, acceptability is related to specific measures or regulatory schemes in order to identify which drivers affect the (public) acceptability of a specific policy. Schade and Schlag (2003) stated that the acceptability of a system has primarily been seen as determined by attitudes and influenced by additional system-specific characteristics. In many cases, the social psychological attitude theory of planned behaviour (Ajzen 1991), which describes the relationship between attitudes and behaviour, has been used as a theoretical basis, considered useful for investigating public favour of policy interventions. This might drive policy-makers to be mostly interested in schemes and measures which do not question the wider logic of the whole social system and its ecological implications. This common sense assumption, which equalises high problem awareness with increased willingness to accept (unpopular) solutions in order to cope with environmental problems, has not been confirmed by empirical findings: for instance, the proofs of problem perception's influence on acceptability are still inconsistent or controversial. Although some studies found a relationship between problem perception and the acceptability of various pricing measures (De Groot and Schuitema 2012; Rienstra et al. 1999), some other research outcomes show that groups which recognise specific problems can refuse a proposed intervention. This is the case with traffic congestion, which was identified as one of the biggest problems by a group of participants in a study (Harsman et al. 2000) who rejected the road pricing solution and did so even more strongly than other groups who perceived the problem differently (Ibidem).[3] Further, research on environmental awareness has established that knowing the "right action" is a necessary but not sufficient prerequisite for conservation-conscious behaviour (e.g. Bell et al. 1990). Thus, while any new measure or policy depends on the level of information available, it is not entirely dependent on it. Among other issues, the background of the problem, the

[3] The authors suggest that this pattern might reflect doubts about the efficiency of road pricing. Nevertheless, respondents' attitudes in the survey differ significantly between cities.

aims of the measure and its concrete implementation have to be clearly explained to and understood by the public (Schlag 1998). Although this causal relation is not straightforward, previous studies have shown that well-known demand management measures meet a higher rate of acceptability than unknown measures. However, findings are, once again, inconsistent. The information level has either not been proved definitively to be a positive driver, as Steg and Vlek (1997) found, or it has been found to produce a negative effect. While a lot of information leads to a higher assessment of effectiveness, it also leads to a significantly lower acceptability of the restrictive measures compared to a less informed control group. Similarly, in the case of biotechnologies controversy, Bucchi and Neresini (2002) demonstrated that people who have the highest level of information about such a topic also have the highest levels of aversion. Hence, a differentiation is made between the so-called objective knowledge and the subjective assessment of both the problem and the proposed solution (Schade and Schlag 2000). For instance, the upfront costs of mitigating CO_2 emissions for people's health or of building dams to reduce the effects of sea level rise loom large due to loss aversion,[4] while the uncertain and future benefits of such actions are more heavily discounted than can be predicted by normative models. This is true both at the local/community and national level. Such accounting of present costs against long-term benefits for the consumers may complicate the justification for these expenses (Weber 2013). As the IPCC summary for policy makers states:

> Behaviour, lifestyle and culture have a considerable influence on energy use and associated emissions, with high mitigation potential in some sectors, in particular when complementing technological and structural change (medium evidence, medium agreement). Emissions can be substantially lowered through changes in consumption patterns (e. g. mobility demand and mode, energy use in households, choice of longer-lasting products) and dietary change and reduction in food wastes. A number of options including monetary and non-monetary incentives as well as information measures may facilitate behavioural changes (IPPC 2014, p. 23).

A further factor affecting individuals' behaviour is the perceived (social) fairness of the measure. However, this concept is imprecise and overlaps with related definitions of equity, justice and fairness, which also require clarification (Shade and Schlag 2003). First, we need to distinguish between three different perspectives: a normative, an individual and a descriptive perspective. The normative perspective (usually the economic approach) asks which distribution of outcomes should be considered fair from a societal viewpoint. Giuliano (1994) reports that equity as an economic concept primarily refers to the real distribution of costs and benefits within society. From an individual point of view, perceived justice is of major concern as a basic requirement for acceptability. Justice, as people perceive it, may differ from the objective distribution of costs and benefits, but it surely

[4] "Loss aversion is an important property that distinguishes prospect theory (Tversky and Kahneman 1992) from expected utility theory (von Neumann and Morgenstern 1944) by introducing a reference-dependent valuation of outcomes, with a steeper slope for perceived losses than for perceived gains" (IPCC 2014, p. 162)

depends on it as one major parameter influencing individuals' perceptions. This differs not only in different situations and among different people in the same situation but even between people with comparable objective costs and benefits. Therefore, besides rational cost-benefit calculations, additional variables must be taken into account. Viegas (2001) tentatively operationalizes equity as a personal outcome expectation. The more people perceive advantages following the introduction of a given measure, the more they will be willing to accept that measure. Apart from intangible individual characteristics (e.g. perceptions, evaluations, etc.), policy acceptability depends on individual socio-economic status and additional characteristics related to the implemented policy. Socio-economic relations of agency and power, as well as spatial and social distribution of risk, have an impact on acceptability and related social behaviour as well (Buzzelli et al. 2003; Kenis and Mathijs 2012). In summary, in order to capture how and if environmental policies can reach their objectives, it is important to understand the correlation between the different dimensions of acceptability and policy design.

Integrating Air Quality and Climate Change Policies: The Path Towards a *Win-Win* Option?

Until the first decade of the new century, air quality and climate change policies, both in Europe and at the international level, were dealt with according to different policy frameworks. Such distinctions produced different action plans and policy agendas, given the separation of goals and competences: typically, energy ministries dealt with climate change (e.g. the United Kingdom), while environment ministries and agencies dealt with air quality. As a consequence, the relationships between these two policy areas have often been ignored or underestimated, despite part of the scientific community arguing that climate change and air quality are actually two faces of the same problem (Pleijel 2009; Fuzzi and Maione 2009). Nowadays, an integration of both policy areas is being supported by increasingly stronger scientific arguments (Barker et al. 2007; Bollen et al. 2010; Rao et al. 2013; Maione and Fuzzi 2013; Stocker et al. 2013). Furthermore, since major *greenhouse gases* (GHGs) originate from the same sources as air pollutants, a coordinated abatement strategy is emerging as the more effective and rational choice (Williams 2012). This has also been shown by a recent study undertaken by the *International Institute for Applied System Analysis* (IIASA) at the request of the European Parliament's Committee on *Environment, Public Health and Food Safety* (Amann et al. 2014). This study provided a complementary impact assessment, exploring the interactions between the European Union's air quality policy and the proposed EU climate and energy policy. It showed that reduced consumption of polluting fuels resulting from the climate and energy targets that have been put forward by the European Commission in early 2014 (i.e. a 40 % reduction in GHGs, a share of 27 % renewables, and a 30 % improvement of energy efficiency compared to the

2007 baseline) would reduce premature mortality from fine particulate matter in the European Union and make further air quality improvements less costly. In short, its authors say: "Climate and energy efficiency policies will reduce the consumption of polluting fuels, which in turn will lower air pollutant emissions and costs for further air quality improvements" (Amman et al. 2014, p. 8).

Further steps towards such integration have been made at the transnational level where, until recent times, emissions of GHGs and air pollutants have been regulated separately. The Kyoto Protocol sets internationally binding emission reduction targets for a set of well-mixed GHGs including methane. On the air quality side, the Gothenburg Protocol sets emission ceilings for reactive pollutants; its revision, agreed in 2012, included an emission ceiling for primary $PM_{2.5}$, requiring the reduction of sources with high proportions of black carbon (BC). This, together with the inclusion of emission reduction obligations for methane, created the first legislative link between air quality issues and so-called *short-lived climate pollutants* (SLCPs) like BC, tropospheric ozone and methane. BC is an air pollutant that causes major health impacts and is also a major contributor to global warming. Tropospheric ozone reduces crop yields and damages human health and is also the third most important greenhouse gas. Methane, besides being a potent GHG with a relatively short lifetime, affects air quality and climate as a precursor of tropospheric ozone. It has been estimated that reducing global methane and BC emissions by 2030 could prevent about 2.4 million air pollution related deaths and save 50 million tonnes of crops, substantially reducing, at the same time, the risks of crossing the 2 °C threshold during the twenty-first century (UNEP 2011; Shindell et al. 2012). Indeed, policies aimed at fighting climate change represent a long-term commitment. Meanwhile, as already shown by the decrease in atmospheric levels of the reactive pollutants in the developed countries (where timely actions have been taken), air quality policies can have an immediate effect (Shindell et al. 2012; Raes and Seinfeld 2009).[5]

Relationships Between Air Quality and Climate Change Perceptions in Europe

The growing scientific consensus on the need for integration of AQ and CC policies as a win-win option, together with the limits of public acceptability studies, opens new challenges for social research on environmental policy. We argue that exploring public perceptions and attitudes to these environmental challenges represent a basic starting point in order to plan strategies for fine-tuned policy intervention and communicative efforts.

[5] However, measures reducing SLCPs have to be seen as complementary rather than a substitute for early and stringent CO_2 mitigation (Rogelj et al. 2014).

With the aim of verifying the win-win option, we investigated the links between air quality and climate change in terms of perception, using Eurobarometer's data. As argued by Nissen (2014), Eurobarometer is one of the most up-to-date sources of data representative of the European population and can be considered a valid tool for investigating the relationship between the two issues. We opted to use the most recent 2011 Eurobarometer wave 75.2, which investigated both air quality and climate change within the same questionnaire.[6] Our goal is to answer the following questions:

- Are people concerned by both climate change and air quality?
- Are these differences in concern the same in different countries?
- Do people share the same attitudes about drivers for social acceptability of environmental policies?

In order to answer the first research question, respondents' attitudes about the two matters of concern have been crossed. The hypothesis was: "if respondents are concerned about the same issue, they might be likely to share preferences for policies that are able to tackle both".

The data[7] in Table 6.1 show that we have to reconsider this hypothesis. The two concerns do not coincide: it seems unlikely that people are worried by both climate change and air quality. People worried about both concerns represent only 8.69 % of the sample, while 43.53 % of the respondents were not concerned by climate change or air quality.[8] Such an outcome suggests the need to investigate the topic further. We opted to work on the remaining 47.77 % of the sample by splitting it between the two matters of concern we are interested in. The differences between people concerned about air quality (from now on, AQC) and climate change (CCC) were investigated by clustering the 27 EU countries by the classical social policy

Table 6.1 Cross analysis of respondents' concerns about air quality and climate change (% values)

		Air quality	
		Non concerned	Concerned
Climate change	Non concerned	43.53	16.68
	Concerned	31.09	8.69

Source: Own calculations on Eurobarometer (2011). n = 26,825; Phi = −0.066; p = 0.000

[6] In September 2014, a new wave about Europeans' environmental attitudes has been published by Eurobarometer (Special Eurobarometer 416/Wave EB81.3), but, as they report, "the list and number of concerns presented to the respondents has been modified from the previous survey" (p. 12). Two alternatives have been deleted, namely: climate change and man-made disasters.

[7] The questionnaire allowed multiple answers to the same question (*From the following list, please pick the five main environmental issues that you are worried about*). For this analysis, we opted to use respondents as a unity of analysis, rather than the answers, as Eurobarometer normally does.

[8] The most quoted concern in 2011 was man-made-disaster followed by water pollution. See Eurobarometer EB75.2, available at http://ec.europa.eu/environment/pdf/EB_summary_EB752.pdf

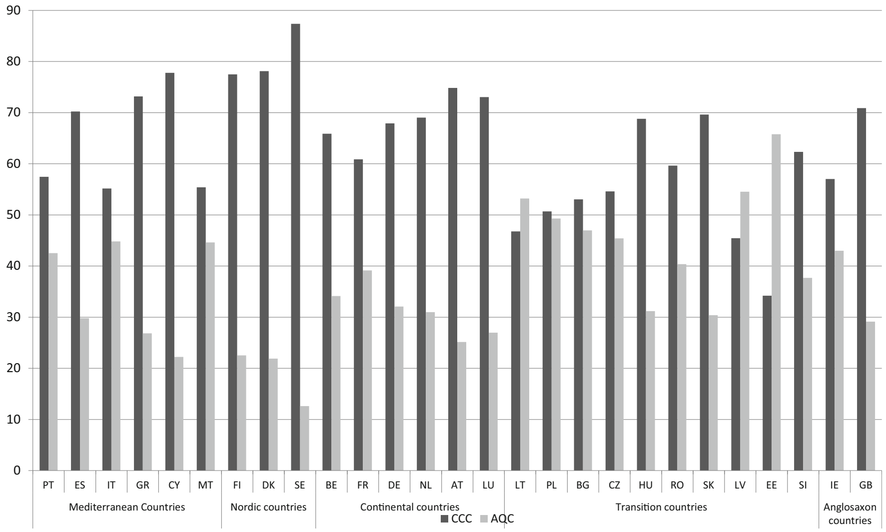

Fig. 6.1 Comparing concerns in EU + 28 countries (% values) [*Source*: Own calculations on Eurobarometer (2011)]

regimes description (Esping-Andersen 1996) according to the model suggested by Jahn (1998), introducing further questions.

In Fig. 6.1, we divided the countries into five clusters to identify regularities between countries with similar cultural and welfare heritages. Apparently, there are too many exceptions to consider a clear correlation: for instance, if we consider transition countries, three of them have higher levels of AQC compared to CCC, three others have almost the same levels and four others have a reverse situation. The lack of regularity confirms how complex the scenario that European authorities have to work with is and how difficult it must be to intervene through a win-win policy strategy. Other intervening factors have to be considered, such as, for instance, the performance of the countries in terms of atmospheric concentration of pollutants. Indeed, data on air quality (2014)[9] by the European Environment Agency (EEA) (2014) show that countries performing badly in terms of PM_{10} levels, such as Italy, Poland and Bulgaria, tend to be more concerned about air quality.

Conversely, countries such as Spain and Portugal, which sensibly improved their performances in terms of the measured PM_{10} levels, are less concerned by air quality. According to the EEA, Lithuania is the worst Baltic country in terms of PM_{10} levels, which might explain its strong air quality concerns. This is not true in Estonia, where air quality data are better than in Lithuania but the concern is higher.

[9] www.eea.europa.eu/themes/air/interactive/pm10-interpolated-maps. Data available from 2006 to 2010.

Table 6.2 Acceptability drivers converted into indicators

Acceptability driver	Indicators
1. Environmental sensibility and interest	Environmental sensibility
2. Behaviour	Environmental commitment
3. Estimated efficacy	Judgement on efficacy for environmental resource management by political institutions
4. Equity and fairness	Attributed environmental responsibility
5. Socio-economic status in society	Self-placement on the societal scale
6. Level of knowledge	Self-perceived level of information about the environment

Source: Adapted from SEFIRA project (Valeri et al. 2014)

Such differences are a first element that should be considered in order to actually deal with win-win strategies across the European Union.

Continuing in our investigation of the relationship between the two issues, we compared two mutually exclusive groups: (a) the CCCs and (b) the AQCs. The two groups were compared in terms of the six dimensions of social acceptability for environmental policies identified by the SEFIRA[10] project (Valeri et al. 2014). These were specifically converted into six indicators, according to Eurobarometer's variables (Table 6.2).

The first indicator, environmental sensibility, combines different variables[11] limiting social desirability. The second indicator, behaviour, has been transposed in a measure of commitment (e.g. the number of environmentally friendly actions or membership of an association). The third indicator is a proxy of the judgement of environmental efforts in policy-making by different institutions (European Union and national government), while the fourth indicator is about the responsibility for environmental degradation. The last two indicators are respectively defined by respondents' declarations about their estimated position in the societal scale and about the level of knowledge on environmental issues. The outcome of this comparison is presented in Table 6.3.

The two groups share the same trends, even though some differences emerge. In Table 6.3 we highlighted them in bold. CCCs have a higher general environmental sensitivity and environmental commitment; we should, however, acknowledge that the level tends to be low in both groups. This implies that they carry out few environmentally friendly actions (e.g. reducing car use or implementing energy or water consumption controls) and are rarely active members of an environmental association. The two groups also share the same negative judgement on the efficacy

[10] Sefira (Socio-economic implications for individual responses to Air Pollution Policies in EU +27) is an FP7 Cooperation Project (2013–2016) under the scientific coordination of Prof. Yuri Kazepov and Michela Maione, co-authors of this paper (www.sefira-project.eu).

[11] Namely: EU parliament priorities; to be in favour of innovative policies for contrasting climate change; importance of environmental protection.

Table 6.3 Comparison between AQC and CCC on social acceptability of environmental policies

Indicator	Sig.	Modalities	AQC (n = 4327) (%)	CCC (n = 8167) (%)
1. Environmental sensibility	χ^2: 175,141 p: 0.000	Low	**54.44**	**42.83**
		Medium	33.71	38.88
		High	**11.83**	**18.28**
2. Environmental commitment	χ^2: 48,230 p: 0.000	Low	**73.33**	**63.30**
		Medium	**21.54**	**26.38**
		High	5.13	6.32
3. Judgement on efficacy for environmental resource management by political institutions	χ^2: 14,695 p: 0.005	Not doing anything	59.63	63.07
		Not doing enough	18.41	19.91
		Doing sufficient	16.47	15.56
		Doing enough	2.65	2.02
		Doing a lot of efforts	1.23	0.98
4. Attributed environmental responsibility	χ^2: 50,994 p: 0.000	Big polluters	**14.97**	**10.98**
		Both individuals and big polluters	80.07	82.53
		Individuals	4.96	6.49
5. Self-placement on the societal scale	χ^2: 69,213 p: 0.000	Low	14.51	10.34
		Medium low	43.34	41.21
		Medium high	**39.85**	**46.07**
		High	2.31	2.38
6. Self-perceived level of information about the environment	χ^2: 52,215 p: 0.000	Very badly informed	**8.22**	**5.59**
		Fairly badly informed	33.26	30.59
		Fairly well informed	**51.18**	**55.04**
		Very well informed	7.34	8.78

Source: Own calculations on Eurobarometer (2013), Valeri et al. (2014)

of environmental resource management. The low value of χ^2, however, limits the importance of this indicator. The AQCs tend to attribute more responsibility to big polluters, such as large companies and industrial activities in general, rather than to individuals. This might be a kind of delegation of responsibility to the political and regulatory authorities in charge of controlling activities, and it is normally associated with the absence of a sense of guilt about the importance of their everyday life actions (Kollmuss and Agyeman 2002). However, a general correlation is present between environmental sensibility, recorded through the Individual Environmental

Table 6.4 Respondents' average age and the average age at which they ended full time education

	EU	AQCs	CCCs	Correlation
Age	μ 48.4 years old	μ 50 years old	μ 46.63 years old	−0.444 p: 0.000
	Std. Dev. 18.2	Std. Dev. 18.5	Std. Dev. 17.8	
Ending age of full time education	μ 25.8 years old	μ 25 years old	μ 27.2 years old	
	Std. Dev. 22.2	Std. Dev. 22.4	Std. Dev. 24.2	

Source: Own calculations on Eurobarometer (2013)

Sensibility (IES) index,[12] and responsibility attribution (ρ: 0.73 p: 0.000): indeed, the higher the sensibility, the higher the tendency to consider individuals as responsible for environmental problems (Table 6.4).

Age and level of education either play a role: CCCs are on average younger (46.63 years old) compared to the EU average value (48.36 years old) and even more compared to AQCs (50 years old). Age is also linked to education level: the younger generations are more educated compared to older generations, as shown by the negative correlation between age and the age at which full time education was finished (−0.444 p: 0.000). Again, CCCs left full time education 2 years later than AQCs on average. This seems to be reflected in the number of information sources respondents declared they consulted regularly in order to collect environmental information: AQCs' percentage of respondents who consulted three different sources of information tends to decrease linearly with rising age, from 51.26 % for the group aged 15–24 years old to 48.74 % for the group aged 65 and older. At the opposite end, CCCs' percentage tends to increase: from 52.72 % for the groups aged 15–24 years old to 55.27 % for the group aged 65 and older.

Such differences suggest that people with different environmental concerns are characterized by different profiles, not only in terms of environmental sensibility or commitment but also in terms of other social markers such as age and level of education.

Conclusions

Our contribution showed how complex the integration between scientific and policy fields can be. However, in order to face the challenges of our times, especially for human health protection, it has become a necessary direction to take. The urgency of effective strategies to avoid health problems from climate change for future generations requires new efforts at the political level.

Recent scientific evidence suggests the importance of coupling what has been separated for decades: air quality and climate change. As climate change mitigation

[12] This index has been calculated using three indicators: (1) level of information; (2) environmental sensibility; (3) environmental commitment.

has become the top issue on the global environmental agenda, related fields such as air quality might be downgraded, leading to the risk of financial cuts or political bargains. One recent example is the Clean Air Package proposed by the former European Commission in December 2013, which was supposed to comply fully with air quality regulation by 2020 but has been re-oriented. Indeed, air quality and climate change policies have been re-framed by the vice-commissioner Timmermans within a much longer time frame: 2030, a date that was set by the 2030 Green Paper on Climate and Energy policies (European Commission 2013a, b). The delaying of important deadlines for mortality reduction linked to air pollution have been justified by the economic concerns of European business lobbies, while the economic and social damage of pollution-related diseases have once again been considered as a dependent function of economic growth. According to scientific evidence, continuing to decouple air quality and climate change strategies is a big mistake. Until now, the division between the two issues has split resources. However, fostering a *win-win* strategy for air quality and climate change would avoid health costs and would be more effective. As we have argued, when scientific knowledge is translated into policy practice, the outcomes cannot be easily foreseen. Through the lens of the social sciences, we explored the links between the two problems as matters of concern for European citizens, with the aim of further stimulating reflections on a more concrete translation of scientific evidence into practice. Our analysis of Eurobarometer data shows that air quality and climate change concern people with different characteristics including environmental sensibility and cultural capital; a further element is the relationship between environmental concern and material conditions in the countries where the respondents live. Regarding the latter, our preliminary findings suggest that a single European solution is unlikely to work in the same way in 28 member states: in some countries, sensibility of climate change is higher, while in other countries it is perceived as less important (or even ignored) compared to other environmental threats to health such as, for instance, air quality. Regarding the former, if we imagine national governments communicating the necessity to sustain new economic burdens (i.e. excise taxes for fuels), they may concentrate their efforts on specific target groups which may be particularly hostile. Indeed, people are concerned by different environmental problems according to specific social characteristics. We found that age and education play at least as much of a role as pro-environmental behaviour.

As an answer to the question in our contribution's title: yes, it is possible to use air quality concerns as a driver for climate change policies, but the issue should be considered carefully. While a win-win strategy may be correct—as the scientific evidence has shown—the path of this strategy is paved with social variables (perception, age, education, practices), which policy-makers should seriously take into account.

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Chapter 7
The Health Sector in an Adaptive Dialectic Strategy: The Case of the São Paulo's Municipal Policy on Climate Change

Rubens Landin and Leandro Luiz Giatti

Abstract São Paulo, Brazil, is a big city that suffers the effects of extreme climatic events like intense rains and droughts. In fact, these circumstances are outcomes of deficits accumulated for years in the production of an urban space that neglected environmental factors in their management, construction and planning. As a coping strategy the municipality of São Paulo promulgated in 2009 the Municipal Policy on Climate Change (MPCC), whose original main objective was to mitigate the emission of greenhouse gases. This chapter aims to analyze São Paulo's MPCC until 2012 in terms of the Health Sector's convergence and intersectoral actions, considering a necessary dialectic between global and local towards adaptive measures in the urban scale concerning to climatic variability. The content analysis model as a qualitative approach was applied on documentary data and interviews with public managers. It showed that the primary research hypothesis, which considered that the Health Sector would have its attributions restricted to perform the monitoring of air quality, was refutable. Instead, there was a redirection of health actions, in which a dialectical intersectoral positive relationship was established, with actions that could interact breaking through the traditional model of sectoral policies which are generally reductionist. The MPCC in the perspective of interaction with the Health Sector encountered cooperation among sectors of the government promoting and strengthening adaptive capacities under public health concerns. All of these advances could be possible even with the prevalence of an initial orientation for mitigation in this public policy.

Keywords Public policy for climate change • Adaptation • Urban sustainability • Environmental health

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Introduction

The specific literature on urbanization encompasses risks understood as probabilistic powerful impact forces, and within scenarios of the possible exacerbation of consequences due to climate change, there is an imminent challenge to the public policy arrangements as necessary responses to uncertain crisis. Regarding the world risk society, there are several dimensions and meanings that can unveil a process of disintegration of certainties (Beck et al. 1997). Intrinsic economic, social and policy changes associated with the perspectives of climate change operate complex dynamics in a globalization context characterized by the global interdependence of risk. In this sense the emergent risks and possible consequences can be modulated by ecosystems integrity, governmental capacity of response, infrastructure, investments and vulnerability reduction (Barcellos et al. 2009).

Today the world's population is metropolitan, and the predominant cartography of the human settlements exposes accumulated deficits caused by disordered urbanization and unfair appropriation of territory, resulting in deep inequalities and asymmetry. The fast population concentration in mega-cities that happened mainly in developing countries, coupled with the insufficient public policies, embodied serious vulnerable contexts of social exclusion and environmental degradation (Hogan 2009). The capital that moves the transforming society and affects the environmental integrity is the same that empowers the capacity of some less advantaged groups to accept the degradation in their surroundings or agree with their own displacements to bordering sacrifice zones on benefit of a profitable use of urban speculative areas (Acselrad 2002).

Maricato (2003) argues that the urbanization of the city of São Paulo was oriented by hegemonic interests avoiding a more inclusive model of occupation. In this sense São Paulo is an unsustainable metropolis, which ignores environmental aspects in its historic process of sprawl, and today shows a high social exclusion associated with environmental injustices. The intensification of possible risks and environmental damages will probably be compounded by climate change unfolding as a substantial challenge to predictive models (Santos 2009; Romero and Bruna 2010; Hogan 2009).

The legal framework of climatic governance in Brazil started to be structured since 2009 when specific public policies have been created. Within this process the São Paulo municipality created its own policy named São Paulo's Municipal Policy on Climate Change—MPCC, which could be firstly understood as focusing mainly on mitigation in consonance with a global concern (Furriela 2011). Actually, besides the importance of a mitigation guidance, the serious vulnerable context of São Paulo city would also ask for a necessary adaptive orientation. Nonetheless as a primary hypothesis we considered that the São Paulo's MPCC would have an unilateral relationship with the governmental Health Sector which one would have a minor role related to air quality monitoring activities, keeping a traditional sectoral status.

On the other hand the complexity of social environmental transformations and the perspective of severe crisis demand new and possible modernities opposing the traditional sectoral action and fragmented thinking, making necessary new collaborative attitudes opened to indeterminate contexts (Jacobi 2013). In fact the coherence of a social economic and environmental development to reach health outcomes must be a consequence of proposals that go beyond the reductionism with conceptual and methodological advances, targeting to cope with the social and environmental determinants of health. Thus integrative actions and policies must be imperative to achieve better health conditions for the population. Actually public health cannot be considered as a result of isolated actions of the Health Sector, being necessary public policies from different sectors to reach health and well-being (Buss et al. 2012).

In Brazil like other developing countries the very fast and unplanned urbanization caused a process of offering all the necessary demands for capital production in detriment of social investments (Santos 2009). The relevant concept in such a scenario is that the actions of the Health Sector as a fundamental social investment make possible the reduction of social and environmental vulnerability (Buss 2003). The climatic variability which can be the local unfoldings of the global climate change phenomena raises the emergent need for dealing with the multifaceted local vulnerability (IPCC 2013). One possible approach for this context is to improve public health strategies aiming at promoting health, taking into account territorial attributes (Haines et al. 2006). In Brazil primary health care strategies can target, for example, the control of determinants and causes of infectious diseases in neighborhoods with precarious sanitation, or can also carry out education interventions (Escorel et al. 2007) in order to prevent risks of injures due to extreme climatic events, like floods or landslides. The Health Sector in the broader urban scale can also operate to establish and to control the levels of atmospheric pollutants, one singular problem that can be associated with heat increasing mortality rates or risks for heart attack. In this sense, the Health Sector's actions can be considered as adaptive measures with the potential of reducing the risks exacerbated by climatic variability and its possible consequences (Haines et al. 2006).

This chapter aims to analyze São Paulo's MPCC until 2012 in terms of the Health Sector insertion with expectancy of convergence and intersectoral actions, considering a necessary dialectic[1] between global and local towards adaptive measures in the urban scale concerning to climatic variability. In addiction we expect to explore a perspective of intersectoral approaches regarding the implementation of a public policy on climate change. This chapter also contributes to a gap concerning the study of how cities in the 'global South' are responding to the issue of climate change (Betsill and Bulkeley 2007; Bulkeley 2010).

[1] We assume that the dialectic process is an interactive approach. In our assumption there is intent of proving a thesis by means of arguments which are formatted in contradiction. In such reflexion we apply the term dialectic or dialectical for relationships among global and local as well as among different sectors of governmental administration. Hegel and Marx (Prado 1973) showed that the dialectic method can explain the reality through confrontation of oppositions, thus rejecting appearances imposed by the status quo and believing in the ongoing change of what we consider reality.

Methods

São Paulo is the capital city of São Paulo State, Brazil and the central municipality with other 38 composing the Metropolitan Region of São Paulo with the population of almost 20 million inhabitants. São Paulo city is the higher expression of population and economics concentrated in a city in Brazil, keeping 11.2 million inhabitants and 11.9 of the total national GDP (EMPLASA 2010).

This research was carried out through a qualitative approach because of the perspective of a necessary public policy implementation deep analysis (Bardin 2011). The data collection process was based on acquisition of two kinds of data: first—official documents provided by the municipal government of São Paulo, produced in work meetings with public managers from different sectors/secretariats of the municipality (PMSP 2013). The main issue of interest was concerning the implementation of the studied public policy. In this sense 16 min of meeting were analyzed referring to the period between April/2010 and December/2012; second—qualitative interviews applied to three managers representatives of municipal secretariats—Environment, Health and Education. The Education secretariat was considered relevant because its actions must be convergent in order promote health and environmental education aiming at adaptive strategies. The interview script was composed by questions about policy cycle components and aspects related to collective health, absorptive capacity and cognitive blockage for the policy implementation.

The data was analyzed by the method of Content Analysis (Bardin 2011) in which the relevant information was grouped by common characteristics of interest in the study. It allowed the delimitation of the analysis categories.

As a qualitative study involving human beings this research proposed methodology was submitted and assessed, receiving a positive decision from the Committee of Ethics in Research from the School of Public Health/USP (registration n. 48321), with criteria compatible with the Declaration of Helsinki. Informed consent was acquired with signature of the interviewees.

Results and Discussion

The interaction of the Health Sector in São Paulo's MPCC was identified through six analysis categories as showed in the Table 7.1. The first block of four categories represent actions with high potential for local management, in this it being possible to understand them as a set of adaptive measures strongly linked to human health and well-being. Also these four first categories are very appropriate in terms of other public polices mainly concerning public health.

The last two categories represent situations clearly related to challenges for implementation or even denial of the proposals of the new municipal law which establishes the MPCC. Absorptive capacity is the ability to assimilate new ideas and

Table 7.1 Analysis categories

Preventive health	To forecast and to avoid diseases before they occur by means of controlling their risk factors (Mattos 2004)
Health promotion	To act and share competences in order to deal with the macro determinants of health, searching for favorable living conditions, promoting healthy environments, communities, cities (Buss 2003)
Assistential	Actions directed to identified suffering and injuries (Paim 2003)
Air quality monitoring and control	Actions towards air pollutants with relation to local exposition of humans which offer epidemiological risks
Absorptive capacity	The capacity of assimilating ideas from new fields of interest, making possible operative processes in public policy (Cohen and Levinthal 1990)
Cognitive blockage	Filtering information which is apparently opposite to current interests. Characteristic situation of systems with closed culture and high degree of rejection and conformism (Porto 2012)

Source: Elaborated by the authors

knowledge in order to rethink conventional behaviors (Cohen and Levinthal 1990). Cognitive blockage is the category associated to political filters that compose technical closed cultures inside certain institutions. Frequently, this position is rigid offering rejection to opposite information and contradictory interests (Porto 2012).

With this background the implementation of São Paulo's MPCC is congruent with public policies on health, being this circumstance very desirable to a policy dealing with climate change that could be left in the second level. Actually this perspective of a police convergence can make a better scenario for the studied public policy (Giddens 2010).

Considering the necessary intersectoral approach to reach effective measures for public health, the focus in health related issues was very important to check the possible dialectical relation between the global scale orientation of the municipal policy for climate change and the correspondence to local concerns and possible actions. As São Paulo city has suffered many consequences of a rapid and unequal urbanization with significant lack of social investments, environmental degradation and social exclusion, there is a constant need for urgent responses to cope with climate associated threats. Respectively, those precarious conditions can be strongly associated with a high demand for adaptation measures within the consequences of climate variability, because the vulnerability of this urban system to natural disasters is notorious and constant. Otherwise, mitigation oriented measures as the reduction of greenhouse gases—GHG is something interacting within wide temporal and spatial scales, not necessarily associated with the imminent local vulnerable contexts.

In fact São Paulo city primarily adhered to the C40 Cities Climate Leadership Group of large cities launched in 2005 and the MPCC was a consequence of this process. So, this leadership was certainly one of the reasons that allowed cities or local governments to take a relevant role in climate policies worldwide. However the local governments' initiatives can be considered as mainly oriented to mitigation (Rosenzweig et al. 2010). In a bibliographic review about climate change strategies, Bulkeley (2010) found that mitigation remains as the main focus among actions of ten different cities in India, China, Mexico, Brazil, Australia, South Korea, Indonesia and South Africa. Indeed it seems to be surprising that local actions are more correspondent to global matters than to the notorious and more pressing adaptation issues due to the vulnerable contexts of such countries.

Under this analysis, the qualitative content of the categories explored (Table 7.2) can show correspondence with two possible orientations to be assumed by this municipal policy for climate change: mitigation and adaptation. In such background a number of situations can be observed, sometimes as opportunities for interaction within both mitigation and adaptation, and in other cases as controversies and barriers.

In both frames of data—the documentary and the interviews—the public policy and the Health Sector kept their ongoing perspective also with the intention among different areas. A constant reflection about limitations was also evident meanwhile a self-confrontation and a search for joined efforts were presented to move over isolated actions. This made possible gains for a transversal and intrinsic implementation of the MPCC.

Table 7.2 Synthesis of the evidences from document and interviews

Categories	Official documents	Interviews
Preventive health	Identification of interaction among different governmental sectors to attend urgent demands avoiding critical episodes	A municipal plan for biodiversity protection reinforcing preventive actions to suppress the urban sprawl over natural areas
Health promotion	There is a need for environmental education lead by climate change concerns	Although there are opportunities for trade-offs among different administrative sectors, there are barriers for collective actions aiming at health promotion
Assistential	Positive joint actions between the municipal coordination of civil defense and the Health Secretariat	The working group sustainability and health has had a look at the problems related to climate change health impacts
Air quality monitoring and control	Multi and interdisciplinary studies were highlighted as background for measures to mitigate health effects	Opportunities brought by the law allowed to go beyond the air quality monitoring and control
Absorptive capacity	Observed interaction with academic actors (for example University of São Paulo) and other institutions for implementation of joint initiatives	Although there are positive manifestations for new ideas the absorption of the demands is discussed in the domain of other public sectors or secretariats, consuming time
Cognitive blockage	Relative difficulties for integration among distinct areas of municipal administration	Behavioral manifestations were observed in order to reject intersectoral work. It was motivated by the personal nature of the staff or just by blockage and politic or institutional filters

Source: Elaborated by the authors

In this context adaptation can be viewed as a planned action associated with the resilience capacity presented by certain groups, ecosystems or institutions. Adaptation can balance intensity of vulnerability not only by means of reducing risks, but concerning the potential for dealing with the risks and with new scenarios or emergent external changes. In this sense the capacity of adaptation can be promoted throughout structured and planned actions involving policy, economics, institutional, psychological and social dimensions. The more adequate the capacity of response the minor should be the chance of a significant damage to occur. The capacity of response to risks and threats is a dynamic set of physical and social interactions (Marandola 2009).

The local level of vulnerability becomes evident in a demarcated territory intrinsic to each municipality in the structure of the households where the site for exposition is specific and manifest. The disturbances in the local dynamics are objective threats feasible in immediate contexts (Porto 2012). On its turn the global level generates cumulative impacts with a geopolitical coverage that does not follow suit the physical geography and the administrative competence of the municipalities. The environmental problems as their own rules follow distinct and peculiar distributions in terms of time and space and their effects can be displaced and disposed of as causes of ecosystems degradation in other landscapes, interfering with the traditional and pragmatic punctual administration (Campbell-Lendrum and Corvalán 2007).

Besides, the process of constant urban growing implies to correspondent worsening of inequities and risks exacerbating the social environmental problems. In this sense the ongoing social interactions act constantly reshaping the urban territory (Santos 2009) which is very dynamic even in respect of the vulnerability due to climatic variability. Public policies as São Paulo's MPCC are relevant components of the social interactions with the power to induce territorial changes including a perspective of mediating different degrees of vulnerability.

Conclusion

The results of this research showed a positive intersectoral and dialectic relationship among the Health Sector and the MPCC implementation. This evidence made refutable a primary hypothesis that the Health Sector would be in a marginal participation. On this regard an innovation in policy practices can be evident overcoming traditional sectoral policies, which frequently are also impervious in certain spatial scales. The defined initial character of the São Paulo's MPCC, which was the orientation to mitigation concerned with the global scale, could be seen as keeping its relevance even with the arrangements that made some very important connections with the perspective of local and emergent crisis, thus making also possible an adaptive approach.

The adaptive strategy represented by Health Sector's policies enhanced an important scenario of policy convergence, reinforcing the perspective for the São Paulo's MPCC to be in an ongoing policy cycle able to make relevant and positive role in the social construction of the territory. The analyzed implementation of this municipal public policy aiming at climate change can contribute to enhance the knowledge about urban responses to global concerns mainly in the ‘global South’. The findings on the intersectoral arrangements can also contribute in order to offer managing alternatives for similar policies to be implemented mainly in vulnerable contexts.

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Chapter 8
Reducing Food Waste in the Food Service Sector as a Way to Promote Public Health and Environmental Sustainability

Beatriz Oliveira, Ana Pinto de Moura, and Luís Miguel Cunha

Abstract The global food system makes a significant contribution to climate change, affecting greenhouse gas emissions and other major environmental impacts, along the entire food chain. The present study evaluated the determinants and the consequences of food waste at the food service sector, while considering potential solutions. It takes into account the fact that reducing food waste is an important part of the effort to attain environmental goals and to promote public health.

Keywords Food waste • Food service • Health and environmental • Sustainability

Introduction

Food is essential to our survival, yet the Food and Agriculture Organization of the United Nations (FAO) estimates that about 805 million people are undernourished in 2012–14. About 14.6 million undernourished people lived in developed countries (<5 % of their overall population), whereas 790.7 million undernourished people lived in developing countries, corresponding to 13.5 % of their overall population (FAO et al. 2014). On the other hand, food scarcity coexists with excessive consumption. Globally, 35 % of adults aged 20 and older were overweight, with half of a billion of them obese (WHO 2011). At least 2.8 million people die each year as a result of being overweight or obese. The increasing global prevalence of

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overweight and obesity has serious implications in health, increasing the risk of type 2 diabetes, cardiovascular disease, stroke and some cancers (WHO 2011). Moreover, according to a review developed by Garnett (2013), the increasing global prevalence of overweight and obesity could also have important environmental consequences, because more consumption means that more food (particularly livestock) production is needed, and this increases life cycle emissions from additional food production and transportation. Moreover, it increases greenhouse gas emissions through higher fuel needs for the transportation of heavier people and methane emissions from higher amounts of organic waste (Edwards and Roberts 2009; Michaelowa and Dransfeld 2008). According to Tom et al. (2014), based on driving and passenger information in the United States and on historical anthropometric data, they estimated that from 1970 to 2010, over 205 billion additional litres of fuel were consumed to support the extra weight of the American population, equivalent to 1.1 % of total fuel use for transportation systems in the US.

Furthermore, rising population levels combined with shifting dietary patterns in emerging economies will put increasing pressure on global food supply: more food is necessary to feed people. The United Nations predicts that the world population will reach 9.6 billion by 2050 (UN 2012) and this growth will require at least a 70 % increase in food production, excluding crops used for biofuels (FAO 2009) or a more efficient use of natural resources and food production (European Commission 2014). In this context, food waste generation is particularly an ethical issue: wasting food means missing opportunities to feed the growing world population (FAO 2012a), and consuming scarce resources, like land, water and energy used in the production, processing, distribution and consumption of food (Bräutigam et al. 2014). This, in turn, leads to diminished natural ecosystems and the services they provide (Hall et al. 2009; Foresight 2011; Lipinski et al. 2013).

According to FAO, one-third of all edible food produced for human consumption is wasted or otherwise lost from the food chain per year, or about 1.3 billion tonnes (Gustavsson et al. 2011). The food wastage is particularly severe in industrialized countries: following the FAO's food balance sheet for 2007, the food waste in North America and Europe is about 95–115 kg/capita/year, whereas in South/Southeast Asia and Sub-Saharan Africa is 6–11 kg/capita/year (Gustavsson et al. 2011). Considering the whole food supply chain, with the exception of agricultural production, the generation of food waste across the EU-27, based on the EUROSTAT database, in 2006, accounted for 89 million tonnes, corresponding to 181 kg/capita (Monier et al. 2010).

This significant quantity of waste generates substantial amounts of greenhouse gas emissions, promoting climate change. Methane gas is produced when food waste decomposes under anaerobic conditions at food waste landfills, with methane presenting a global warming potential 25 times higher than the one of CO_2 (Buzby and Hyman 2012). Although in the EU there are clear indications of a shift away from landfilling towards preferred waste management approaches, 50 % of biodegradable waste or bio-waste generated in the EU-27, in 2010, was still landfilled (EEA 2013). Food waste generated within the EU-27, during 2006, generated greenhouse gas emissions equivalent to 170 million tonnes of CO_2, considering the full life cycle of food, from the agricultural sector to the final consumer. Due to the increasing quantities of food waste, emissions estimates for 2020 rise to about 240 million tonnes of carbon dioxide equivalent gases (Monier et al. 2010). That baseline value represents approximately 3 % of total EU-27 emissions in 2008 and is close to the total greenhouse gas emissions of Romania or of the Netherlands in 2008.

In addition, food waste also impacts on human health. According to a review developed by Giusti (2009), this could occur directly by exposure to hazardous substances through: inhalation (emissions from incinerators and landfills), consumption of water (in the case of water supplies contaminated with landfill leachate), the food chain (especially consumption of food contaminated with bacteria and viruses from land spreading of sewage and manure, and food enriched with persistent organic chemicals that may be released from incinerators). The contribution of greenhouse gases from food waste disposal activities indirectly affects human health. Rising temperatures (and low ozone levels) due to climate change would affect old people with cardiovascular problems and both old and young people with respiratory problems such as asthma (Giusti 2009). Moreover, food waste has also nutritional implications, particularly for vulnerable populations (Smith and Cunningham-Sabo 2013). In this context van Bokhorst-de van der Schueren et al. (2012) concluded that food waste is largely attributed to the inadequate intake of many hospitalized patients, considering that patients do not consume complete meals. Similarly, Cohen et al. (2013) found an insufficient amount of calories, fibre, and vitamins and minerals consumed by school populations because foods served were discarded from school lunches.

In addition, food waste causes, at individual and national economic levels, significant monetary losses and other resources invested throughout the initial production of food through the disposal of any uneaten food (Buzby et al. 2011). Buzby and Hyman' results indicate that in the United States, during 2008, food waste at consumer level translated into 124 kg of food lost from human consumption, per capita, at an estimated retail price of $390/capita/year. This is roughly 10 % of the average expenditure of the food consumed in 2008 and over 1 % of the average disposable income (Buzby and Hyman 2012). It is estimated that resource efficiency improvements, all along the value chains, could reduce material needs inputs by 17–24 % by 2030 and a better use of resources could represent an overall savings potential of 630 billion euros per year for European industry (European Commission 2014).

To sum up, food waste prevention is a critical and high priority component of any sustainability strategy with a high potential to improve (Parfitt et al. 2010; Hodges et al. 2011). In this context, food waste prevention has been a main topic on the European political agenda during recent years (Filho and Kovaleva 2015) taken as one of the top priorities in the EU's Sixth Environment Action Programme as well as in the proposal of the European Commission for the 7th Environment Action Programme and the Roadmap to a Resource Efficient Europe (EEA 2013). In 2011, the European Commission identified 'food' as a key sector where resource efficiency should be improved and has set to cut down the generation of food waste by one-half by 2020 (European Commission 2011).

Although food waste occurs along a food supply chain in both developed and developing countries (World Economic Forum 2009; Parfitt et al. 2010), different strategies are needed to tackle food waste in these countries (Gustavsson et al. 2011). In developing countries, food waste arose mostly during the early and middle stages of the food chain (production, harvest, processing, storage and transportation stages), due to lack infrastructures within the food chain, and a lack of knowledge or investment in technologies (FAO 2012b; Godfray et al. 2010). By contrast, in medium and high income countries, food is, to a significant extent, wasted at both retail and consumption stages, both at the household and at food service (Monier et al. 2010). Considering food service, a study in Sweden found that loss at the food service sector is equivalent to wasting the amount of food from 1.5 % of land under cultivation in Sweden (Engström and Carlsson-Kanyama 2004). This approach is particularly important when taking into account the increasing consumption of food away from home in the last decades in Western countries. Modern lifestyles and time scarcity have contributed to an increase in food consumption away from home (Moura and Cunha 2005).

The aim of this paper is to evaluate the main reasons that contribute to food waste in food service, mainly in the industrial catering segment, while considering potential measures to reduce these levels, by trying to summarize the established results of existing studies. In our analysis, it is only considered food products intended for human food consumption. The packaging associated with providing food is not included within the scope of this study.

Characterisation of Food Service Activities

The accommodation and food service sector is one of the 21 Sections of NACE (Rev. 2)—section I, and aggregates the following Divisions: 55—Accommodation, and 56—Food and beverage service activities. The first division includes the provision of short-stay accommodation for visitors and other travellers. The second division, central to the present chapter, includes food and beverage serving activities, providing meals or drinks fit for immediate consumption, whether in traditional restaurants, self-service or take-away restaurants, whether as permanent or temporary stands with or without seating (Table 8.1).

According to Waste and Resources Action Programme (WRAP), the food service sector is split in two sectors. In profit sector environments (e.g. restaurants, cafeterias, fast-food restaurants, take-out eating places, bars, taverns), food service is the primary purpose of the business, often viewed as a leisure activity and likely to have the primary aim of maximising profit from the end consumer. Frequently, the cost sector (education, healthcare, and staff catering) operates in premises owned and operated by third parties and at which the primary purpose of the catering function is to provide a service to staff or other users, such as hospital

Table 8.1 Food and beverage service activities

Group	Class		Description
56.1		**Restaurants and mobile food service activities**	
	56.10	Restaurants and mobile food service activities	This class includes the provision of food services to customers, whether they are served while seated or serve themselves from a display of items, whether they eat the prepared meals on the premises, take them out or have them delivered. This includes the preparation and serving of meals for immediate consumption from motorised vehicles or non-motorised carts. This class includes activities of: restaurants, cafeterias, fast-food restaurants, take-out eating places, ice cream truck vendors, mobile food carts, food preparation in market stalls
56.2		**Event catering and other food service activities**	
	56.21	Event catering activities	This class includes the provision of food services based on contractual arrangements with the customer, at the location specified by the customer, for a specific event
	56.29	Other food service activities	This class includes industrial catering, i.e. the provision of food services based on contractual arrangements with the customer, for a specific period of time. Also included is the operation of food concessions at sports and similar facilities. The food is usually prepared in a central unit. This class includes: activities of food service contractors (e.g. for transportation companies), operation of food concessions at sports and similar facilities, operation of canteens or cafeterias (e.g. for factories, offices, hospitals or schools) on a concession basis
56.3		**Beverage serving activities**	
	56.30	Beverage serving activities	This class includes preparation and serving of beverages for immediate consumption on the premises. This class includes activities of: bars, taverns, cocktail lounges, discotheques (with beverage serving predominant), beer parlours, coffee shops, fruit juice bars, mobile beverage vendors

Source: Adapted from Eurostat (2008)

patients or students. Nevertheless, businesses operating in either segment of the food and beverage service sector are likely to maximise turnover and seek financial gain (Parfitt et al. 2013). Furthermore, there are equally private companies and public organizations operating their own canteens, with their own staff (sometimes also with part time hired staff). These canteens are generally not operated for profit (Marthinsen et al. 2012).

In the EU-27, there were 1.5 million enterprises that reported having food and beverage services as their principal activity, in 2010. They employed 7.8 million people, many of them on a part-time basis. Micro enterprises (1–9 employees), were particularly important in this subsector, with a 43.7 % share of value added and a 46.1 % share of the workforce. The food and beverage services subsector generated 132.3 billion euros of value added which was equivalent to 67.6 % of the sectorial value added and accounted for 85.1 % of all enterprises in the EU-27's accommodation and food services sector and 77.0 % of the persons employed (Eurostat 2013a, b).

Additionally, 55.3 % of all the enterprises within the EU-27's food and beverage services sector were classified as belonging to restaurants and mobile food services (Group 56.1). Beverage serving activities (Group 56.3) accounted for the vast majority of the remaining enterprises (40 %), while event catering and other food services (Group 56.2) accounted for less than 5 % of the enterprises from the food and beverage services sector. The relative importance of restaurants and mobile food services was even greater, accounting for 60.4 % of sectorial value added in the EU-27, around 2.6 times as high as the share for the beverage serving activities (23 %), while the share for event catering and other food services was 16 %. The distribution of employment, between the three different subsectors, showed that restaurants and mobile food services accounted for 60 % of the sectorial workforce, while 30 % of the workforce was engaged within beverage serving activities, and some 16 % within event catering and other food services (Table 8.2).

Within EU, the contract catering sector (specifically, "other food service activities") is characterised by a high level of market concentration in the majority of the member states. In 2008, the three leading contract caterers in the EU-27 represented 59 % of the total market share, and the contract catering market was dominated by two company groups—Compass and Sodexho—with a combined market share of about 50 % (European Foundation for the Improvement of Living and Working Conditions 2010). In recent years, the main growth areas for EU contract caterers have been in sectors other than business and industry, although this segment has remained dominant in terms of market value. Market development and sales growth for contract catering have been higher than average in the health and social welfare sector as well as in the education sector (Gira Foodservice 2009).

Table 8.2 Key indicators of food and beverage service activities in the EU-27's accommodation and food services sector for 2010

	No. of enterprises (thousands)	No. of persons employed (thousands)	Value added (million euros)
Accommodation and food service activities	1,786.0	10,139.1	195,331
– Accommodation activities	267.0	23,329.0	63,331
– Food and beverage service activities	1,519.0	7,806.2	132,308
– Restaurants and mobile food service activities	840.3	4,659.5	79,833
– Event catering and other food service activities	69.7	1,050.5	21,618
– Beverage serving activities	609.0	2,096.2	30,758

Source: Adapted from Eurostat (2013a, b)

Food Waste in the Food Service Sector

Definitions and Food Waste Generation Data

The food value-adding chain has several actors from production to consumption and they are strictly interrelating. Apart from the final consumer, every business in the system is both a buyer and a supplier (Schaffner et al. 2003). Food service may be supplied directly from a supplier (e.g. primary food producers, food processers, manufacturers preparing ready-to-serve food items and meals) or through an intermediary/wholesaler (e.g. wholesalers, contract caterers).

Food losses occur throughout the food supply chain. Food loss refers to food originally produced for human consumption, but then directed to non-food use or waste (Beretta et al. 2013). Food losses occurring at later stage of the food supply chain (retail and final consumption like householders or food service) are called food waste, and are related to behavioural issues (Gustavsson et al. 2011).

Food service activities generated, in 2006, 12.2 million tonnes of food waste for the whole EU-27, the equivalent to 14 % of all the food waste produced by food value-adding chain, excluding agriculture sector, an average of about 25 kg/capita, which is quite substantial (Monier et al. 2010) (Table 8.3). The food and beverage service sector was identified as the third largest source of food waste based on food input at each stage of the value chain.

According to Quested and Johnson (2009), food waste can be grouped into three categories, taking into account edible and inedible food:

1. Avoidable food waste (edible food by the majority of people)—food thrown away because it is no longer wanted (e.g. perishable food or that exceeded their date of expiry). Most avoidable food is composed of material that was, at some point prior to disposal, edible, even though a proportion is not edible at the time of disposal due to deterioration (e.g. gone mouldy, decomposition).
2. Possibly avoidable food waste (edible food by some people)—food that some people eat and others do not (e.g. apple peels) or that can be eaten when prepared in one way but not in another (e.g. potato skin). As with avoidable waste, possibly avoidable waste is composed of material that was, at some point prior to disposal, edible.

Table 8.3 Total food waste generated in manufacturing, household, wholesale/retail and food and beverage service/catering sectors in EU-27

Sectors	kt/year	kg/capita	Share (%)
Food waste			
Manufacturing	34,756	70	39
Households	37,702	76	42
Retail/wholesale	4,433	9	5
Food and beverage service	12,263	25	14
Total	89,154	181	100

Source: Adapted from Monier et al. (2010)

3. Unavoidable food waste (inedible food)—waste arising from food preparation that is not, and has not been, edible under normal circumstances (e.g. egg shells, pineapple and banana skin, apple cores, meat bones, tea leaves, coffee grounds).

Different studies concluded that in food service, food wastes are avoidable to a great extent (Cordingley et al. 2011; Beretta et al. 2013; Betz et al. 2015). According to a WRAP's study, the United Kingdom food and beverage service sector (restaurants, pubs, education, healthcare, quick service restaurants, services, leisure, staff catering) produced an estimated 804 kt of food waste in 2012, with a higher proportion of avoidable food waste (587 kt, 73 %) compared to unavoidable food waste (217 kt, 27 %). The cost sector represented 43 % of food waste produced, whereas 79 % of it (309 kt) is avoidable food waste and 21 % is unavoidable food waste (83 kt). That is, 79 % of food wasted in the catering and other food service activities is avoidable and could have been eaten (Parfitt et al. 2013).

Causes and Actions to Reduce Food Waste in Catering Activities

Different factors have an impact in the amount and type of food waste generated in catering and other food service activities. These factors may be related to certain wasteful behaviours of different actors: (1) operators (independent operators/contract caterers) (2) clients (who defined the contract, e.g. schools, universities, hospitals) and (3) costumers (who use the food service, e.g. students, patients, and workers). For instance, although a client has an opportunity to insist on waste prevention terms within any contract, according to the WRAP survey, waste prevention in most cases comes from initiatives from the contracted caterers themselves (Parfitt et al. 2013). Moreover, the client may require the contracted caterer to provide a smaller range of menu options throughout the service period impacting on increased waste generation. Additionally, contractual stipulations often include criteria for caterers to offer a range of healthy options, even though costumers may not always take advantage of these. Nevertheless, the successful waste prevention programme ultimately depends on the staff commitment (all key actors in the catering and nutrition services) with the programme, and so it is essential to include them in every step of the planning and implementation stages of a waste prevention programme. Attention should be given to the fact that the explanation of the outcomes is essential to motivate staff members (Peregrin 2011; Sonnino and McWilliam 2011).

In addition, the variation in food waste (in particular the proportion of 'avoidable' and 'unavoidable') and wastage rate can in part be explained by differences in the food service characteristics across the sector. In fact, the edible and inedible food waste is generated before, during or after food preparation phases: (1) planning, (2) storage and preparation, (3) serving, and (4) eating (Fig. 8.1).

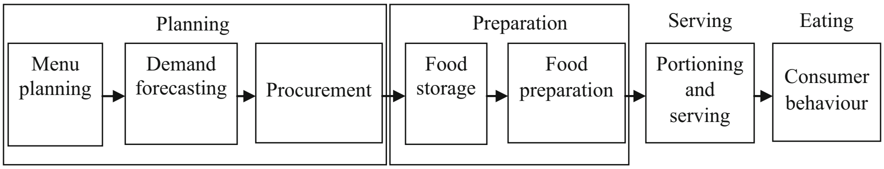

Fig. 8.1 Waste generation in the food service setting [*Source*: Adapted from Engström and Carlsson-Kanyama (2004), Parfitt et al. (2013), Canali et al. (2014)]

Planning

The difficulty to anticipate the consumer demand (i.e., the number of costumers, costumer preferences, menu size) and thus estimating the quantity of food needed leads to over-production (Garrone et al. 2014), because caterers do not want to lose costumers due to under production (Waarts et al. 2011). Considering the case study of hospital food waste, in Wales, UK, Sonnino and McWilliam (2011) concluded that too much food is prepared according to the estimate of the number of patients eating a hot meal. Partly due to the fluctuating patient population and to the lack of staff training, they do not adjust the volumes of food cooked to the information on patients' orders, leading to untouched food being returned from wards for disposal (bulk ordering). By contrast, in a school setting, when students place orders significantly in advance this allows caterers an advantage in forecasting demanding and avoiding over-production (Cordingley et al. 2011).

Moreover, in some situations, the client (e.g. school) may require the caterer to provide a minimum menu rotation and for less familiar menu dishes significant quantities of un-served food may have to be wasted. Additionally, the way in which food is procured has an impact on waste. For caterers it is more convenient and less expensive to buy food products less frequently and to buy them in bulk, because financial incentives favour larger food inventories and reduced transport costs. Besides, for certain food categories, only larger quantities are available to be sold, resulting in oversupply and waste. In addition, sometimes, the portion size demanded by clients, in contract catering, are misadjusted to the intake or nutritional needs of the final consumers, with this also leading to over production.

Preparation

The temperature at which food is supplied influences waste production. Caterers may prefer chilled foods rather than frozen items because they perceived better quality and taste. However, with inaccurate demand anticipation it is expected an over-ordering of foods and larger volumes of waste.

Furthermore, different factors may cause food to spoil: improper storage temperature within catering areas including refrigerated/freeze storage, lack of refrigerator/freezer space leading to food storage in inappropriate manner/local, and food handlers lacking basic knowledge and understanding of microbiological hazards, hygiene and safety rules, presenting potential safety concerns Gomes-Neves et al. 2007, 2011; Martins et al. 2014). This situation points to the need to continuously improve food handlers training and increase awareness regarding the measures imposed by food safety laws in Europe (Ramalho et al. 2015).

Additionally, caterers that traditionally prepare meals using raw ingredients, rather than buying pre-prepared meals or components (e.g. ready-meal sausages, pre-cut vegetables, meat and fish ready-diced or cut to size), engaging themselves to peel potatoes or remove the bones from the meat, directly increase their unavoidable food waste (Engström and Carlsson-Kanyama 2004; Betz et al. 2015). Moreover, the use of raw ingredients leads to longer times to prepare meals and when inaccurate demand exists, larger volumes of waste are to be expected.

Serving

A serving (the amount of a single portion in volume and/or weight) must be of sufficient size to ensure that customers get the nutrition level they need and that they are not left hungry at the end of the meal. However, if portions served are too large, more waste will be produced by the customer. Cohen et al. (2013) found that there is substantial food waste among middle school students in Boston and for most food categories, foods served were a substantial overestimation for food consumed at lunch. Betz et al. (2015) reported serving waste to be the greatest part of total food waste in the catering segment (education and business service).

Portion sizes are most of the times defined by contract, and measured by using standard serving spoons or plates and weight-based recipes. It is based on staff experience or now relying on computer software, where detailed recipe plans, including precise volumes of ingredients are required. In fact, production and other staff generally prepare from recipes which are developed with specific ingredient amounts and a fixed number of servings (e.g. a recipe that produces x servings). Standardized recipes provide consistent and accurate information for food cost control because the same ingredients and quantities of ingredients per serving are used each time the recipe is produced. This can help to reduce the amount of leftover food (prepared food never served) if there has been overproduction, and also will help to prevent shortages of servings on the line.

Eating

Very often costumers leave uneaten food on the plate—plate waste (avoidable and possible avoidable food waste). Mainly, they leave starch components (potatoes, pasta and rice), and fruits and vegetables (Engström and Carlsson-Kanyama 2004; Al-Domi et al. 2011; Betz et al. 2015). These are foods that costumers do not consider as being the main part of the meal, either because they do not ordered them and/or because the social and economic value given to these foods are lower than the one given to meat and fish.

Plate waste is considered an indicator of food service operation efficiency (Gomes and Jorge 2012), and it is also used as an indicator of food consumption adequacy (Cohen et al. 2013). Different reasons explain this wastage behaviour: (1) inadequate portion size, (2) costumer preferences, and (3) costumer attitudes towards waste.

Recent results of research commissioned by WRAP aimed to explore why customers leave food when eating out. Costumers left food mainly because portions are too large, but also because they ordered too much (e.g., by choosing more than one option or by ordering an extra portion) or they served too much when having buffet style or other self-served meals (Giorgi 2013). Simultaneously, increasing portion size is linked to people consuming more food and to underestimation of calorie intake, thus promoting weight gain with serious implications for health (Young and Nestle 2012). As a result, increasing portion size/plate size leads to both increased food intake and food waste (Freedman and Brochado 2010; Kallbekken and Sælen 2013). To overcome this situation, there is a need to optimize set portion sizes of dishes, adapting portion sizes to customer nutritional needs and reducing plate size. Instead, the existence of self-service option allows customers to serve themselves and choose what they want; in the same way, the presence of smaller versions of existing dishes may reduce the waste produced (Betz et al. 2015). These measures should be accompanied providing direct social cue by displaying a sign at the room that encourages costumers to load less food on their plates each time they serve themselves/by staff food service (e.g., using posters), reducing, in turn, the amount left over (Kallbekken and Sælen 2013). Additionally, nutrition education is very important to change such behaviours (Melo et al. 2013).

Besides, wastage of edible and possible edible parts of food may occur because costumer does not like its taste or smell or because of inappropriate methods of preparation (Beretta et al. 2013). Betz et al. (2015) evaluated customers from different German catering companies, finding that the satisfied costumer produced plate waste at a significantly lower frequency, when compared with unsatisfied ones. In the same way, at school setting, different studies have showed that children more satisfied with sensory characteristics of foods were less likely to waste food (Baik and Lee 2009). However, limited budgets or lack of motivation to raise quality may promote food waste in food services which have often difficulty appealing to the tastes of costumers. Besides, costumers might have high expectations towards food (e.g., with a good appearance or looking fresh), leading them to leave food that does not meet their expectations (e.g., poor quality food, food presented at a low temperature or badly cooked) (Giorgi 2013). This suggests that more importance should be attached to costumers' requirements, which need to be analysed before any particular measures are implemented. Considering primary schools, different research results showed that lower satisfaction with the taste, the appearance and the smell of lunch meals was associated with higher plate waste values, both for soup and the main dish (Martins et al. 2013; Yoon and Kim 2012).

Furthermore, in general, people who leave food do not feel a sense of responsibility about the food they leave. Such wasteful behaviour is regarded as natural within in a culture of abundance and convenience (Baudrillard 1998), in the sense that in industrialized countries "people can afford to waste food" (Gustavsson et al. 2011). Besides, the amount of food they get is considered to be out of their control and many people do not want to ask for anything different. That is, consumers are not aware and concerned with food waste (Giorgi 2013; Filho and Kovaleva 2015). When eating out food waste is not something customers think about.

Additionally, social norms (beliefs about what are appropriate or desirable eating behaviours) can explain part of the reason why costumers leave food, because they shape eating behaviours, namely use proper manners at the table and "leave something on the plate" (Giorgi 2013).

Taking into account all these factors, the food redistribution programmes/food donation could be an alternative to reuse food, when food is wasted (Sert et al. 2014). Particularly for catering sector operators, an alternative to the discard of perishable leftovers and untouched food in its packaging, namely whole servings—sandwiches, bread and bakery products and dairy products (with this situation), is to allocated this avoidable waste to food banks. Although food banks have a huge potential in Europe, logistical, political and hygienic factors for both donors and receivers might hinder its development (Beretta et al. 2013). In fact, the degree of recoverability at the food service setting is medium since surplus food is ready for consumption, but has a very short shelf life and a high safety risk. Therefore, caterers or clients must have to package the surplus food, rapidly, lower its temperature using dedicated equipment, and store it in refrigerators (Garrone et al. 2014).

Other initiatives are more relevant for the food service sector within Europe, namely awareness campaigns, information tools and training (Monier et al. 2010). For example, the "Menu Dose Certa" (Right Serving Menu) was a Portuguese initiative created for restaurants by a Porto waste management company with the purpose to get them to serve portions that match what customers can eat. In this context, WRAP developed an awareness campaign targeted to households, including practical tips on how to reduce consumer and household food waste to achieve environmental and economic benefits. Different guides were provided on the food waste prevention at the commercial sector (e.g., National Waste Prevention Programme by Environmental Protection Agency, Ireland) or target to multi-stockholders, including householders (a report developed by the Confederation of the Food and Drink Industry in the EU). Considering training programmes, one may cite the cooking workshops "Anti-Waste Workshops—Cooking Class", that were set for the local Belgium community, highlighting techniques and benefits of food waste reduction at the household (information available at the European Commission site: http://ec.europa.eu/food/safety/food_waste/good_practices/awareness_information_education/index_en.htm). According to research by Whitehair et al. (2013), simple messages drawing attention to the topic of food waste may stimulate reduction in food waste. This finding supports the need for increased education that illustrates the sustainable influence of individual behaviour. These programmes are more sustainable, as they promote the reduction of food waste and of overproduction of food, going from farm to fork. These programmes could also be associated with food banks, with an offer of the raw ingredients that do not go through planning and preparation.

Conclusions

Creating awareness and monitoring the level of food waste at food service settings allows the identification of the main causes for its accumulation, its composition (by food type), and the deployment of strategies for its reduction.

In the catering and food service sector, three main reasons explain food waste, although the weight of each factor is a function of the catering segment: consumers leave uneaten food on the plate, consumers' preferences for given menu items, and overproduction due to inaccurate forecasting of consumers demand.

As a result, in order to reduce food waste, the focus should be on consumers. In this context, it is important to raise consumers' awareness regarding food waste, engaging them to be responsible for the food that they leave on their plates, leading them to choose smaller portions and serving less food. Catering operators should optimize portion sizes to customers' nutritional needs and reduce portion size/plate size, and increase customers' awareness towards sustainability measures through communication. These measures also allow decreasing the amount of food intake, minimizing serious negative health consequences. Alternatively, catering operators could embrace the possible donation of raw ingredients and/or unserved food to local charities, to be distributed to a variety of people who need food. In all situations, addressing the reduction of food waste clearly reduces the environmental impact of the food industry and increases its sustainability.

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Chapter 9
A Review on the Impact of Climate Change on Food Security and Malnutrition in the Sahel Region of Cameroon

Nkwetta Elvis Chabejong

Abstract Climate change has direct and indirect impact on human health. The indirect impact includes Malnutrition caused by food insecurity. The population of the Sahel region of Cameroon continuously experiences an increasing level of malnutrition, partly due to the impact of climate change since harsh climatic conditions leading to extreme drought have a negative influence on agriculture. In particular, the extreme drought conditions lead to a reduction in agricultural production an important parameter of food security. This review chapter assesses the impact of climate change on food security which leads to an increase malnutrition in this region. It will help to suggest measures to raise awareness on climate change, food security and malnutrition.

Keywords Sahel • Climate change • Malnutrition • Food security • Agriculture • Cameroon

Introduction

Cameroon, is found on the West Coast of Sub-Saharan Africa and has borders with Chad, Central African Republic, Republic of Congo, Equatorial Guinea, Nigeria and Gabon. The Extreme North is also known as the Sahel of Cameroon is located in Latitudes 09°19′N and Longitudes 13°21′E. This region is marked with Sahel Savanna vegetation and tropical climate (Epule 2009). The Sahel region has a short rainy season that last 4 months spanning from June to September, with annual rainfall of about 400–1400 mm (Kenga et al. 2005) and 8 months of the dry season (Molua and Lambi 2006). It has an average temperature of 28.8 °C (Kenga et al. 2005). According to Plan (2015) about 3.5 million people live in the Extreme North of Cameroon within an area of 34,263 sq. Km. An increase in the surface temperature has been reported in the IPCC Fifth Assessment Report (Niang

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et al. 2014), that the West and Sahel region of Africa have increased over the last 50 years while New et al. (2006) argue that the number of cold days and nights are decreasing. Sanderson et al. (2011), projected a faster temperature rise than the global average increase during the twenty-first century. With the increase in mean temperature noticed in the Sahel region of Cameroon, this leads to shortening of the time of crop maturity, less grain production and water stress. However, Porter et al. (2014) argue that, the relation between weather and crop yield is region specific meaning that a global temperature increase might not generally affect agriculture in all regions, also the CALESA project (Trincheria et al. 2015) stated that different crops respond to temperature differently, with an example on maize and sorghum. Cameroon has experienced an increase of natural hazard from the nineteenth century (Fig. 9.1) with drought occurring twice in the last three decades.

Agriculture is very important to the Cameroon economy as about 73 % of its active population depend on the agricultural sector for employment (Molua and Lambi 2006). The socioeconomic of the Sahel region is characterized by land, labors, resources, marketing, tenure practices and nomads (Kenga et al. 2005). In this region climate has been seen as the main determinant of food production (Epule 2009) and with its harsh climatic condition the Sahel region is vulnerable to food insecurity (Molua and Lambi 2006). Food security has been defined by the Food and Agricultural Organization (FAO 1996), as a condition where "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" and food insecurity is when people do not have access to enough food due to any

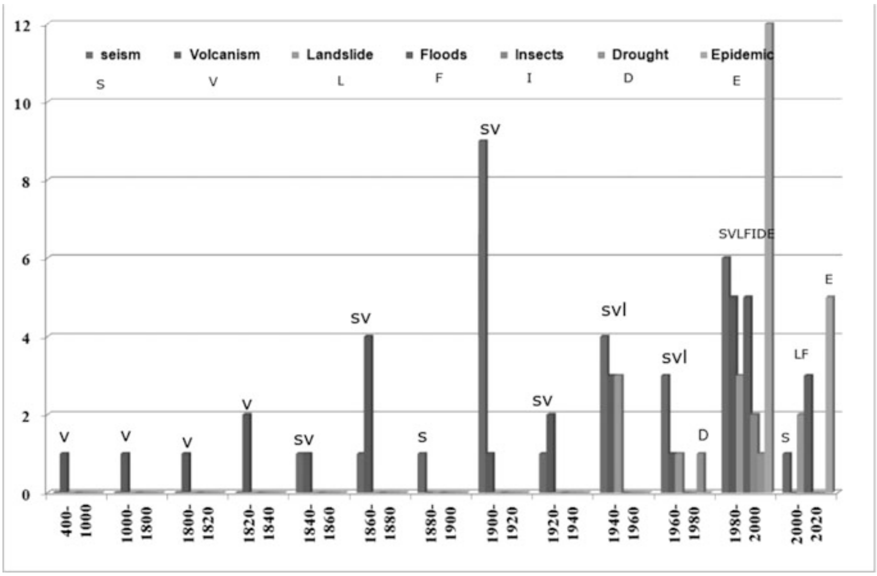

Fig. 9.1 Hazards identified in Cameroon from the early nineteenth century to the twentieth century (Mesmin 2007) (*Source*: icaci.org. The last three decades from 1980 to 2000 have shown a dramatic increase of natural hazard with the occurrence of drought)

factors. Porter et al. (2014) argue that, most people in the world have adequate food, but a high number of undernourished people lived in developing countries with an estimated amount of 26.8 % in Sub-Saharan Africa. While out of the eight million people suffering from hunger in the world, half of this population is found in the Sub-Saharan Africa (Bain et al. 2013). When food production is affected by factors of climate change, there are less resilient crops and the resilient crops might be less nutritive, the lack of food variables leads to higher food prices causing food insecurity due to the fact that the poor will not be able to afford it (Porter et al. 2014). Globally malnutrition is said to contribute indirectly to one third of all child deaths. In 2001 malnutrition was associated with 54 % of death in children in developing countries (Bain et al. 2013). In Cameroon, out of the 10 regions the Sahel region has the highest prevalence of Malnutrition (Vikas and Zakari 2013) Stunting and wasting used in measuring the rate of malnutrition in a population are highly attributable to climate change which have been seen in a survey of five different regions of South Asia and Sub-Saharan Africa (Lloyd et al. 2011). Bain et al. (2013) argue that drought, poor soils and deforestation have been seen as one of the main contributors to poverty, hunger and malnutrition, while Blossner and co-workers (2005) included corruption in developing countries and overpopulation as one of the main contributors of malnutrition.

At the time of writing this integrated review paper, several works has been done (Bain et al. 2013; Campbell and Trechter 1982; Lloyd et al. 2011) however, no integrated review has been written on the impact of climate change on food security contributing to Malnutrition. This review focuses on the impact of climate change on food security in the Sahel region of Cameroon and how it influences the high rate of malnutrition in the region.

Materials and Methods

This study seeks to assess the impact of climate change on food security associated with malnutrition in the Sahel region of Cameroon. The literature was search using the electronic database; Pubmed, Sciencedirect, Springer International Publishing, Springer Science & Business Media, Google scholar, BioMed, Earth and Environmental Science, and websites. The related MESH keywords were; Sahel, Climate Change, malnutrition, food security, agriculture and Cameroon were used. The following combination of the keyword was applied to search for articles; *climate change AND Cameroon, climate change AND food security AND Cameroon, climate change AND Sahel Cameroon, food security AND Sahel Cameroon, Agriculture AND climate change AND Cameroon*. Some authors with topics dealing with water and agriculture in the Sahel region of Cameroon were contacted through ResearchGate. The search articles were only English journals published in related topic with no year limit. This resulted in 688 articles and abstracts, the articles were further filtered from topics, abstracts. The Far North of Cameroon was selected because it lay adjacent to the South West of the Sahel belt of Africa with

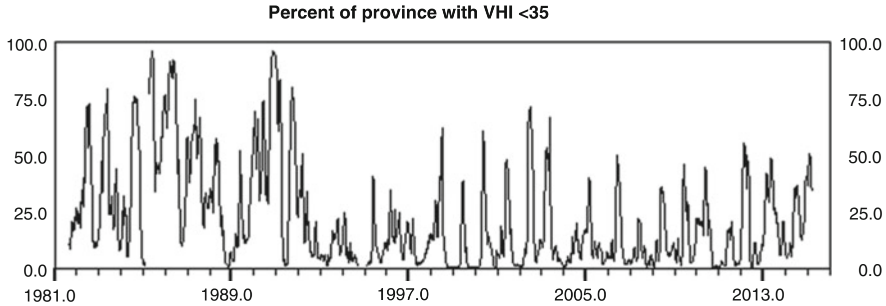

Fig. 9.2 VHI <35 indicates drought from moderate-to-exceptional intensity in the Far North Region (Sahel region) of Cameroon (NOAASTAR, 2014). The NOAASTAR (2014) satellite data analyzed vegetation health index (VHI) of drought intensity for the period of 1981 to 2013in the Extreme North of Cameroon

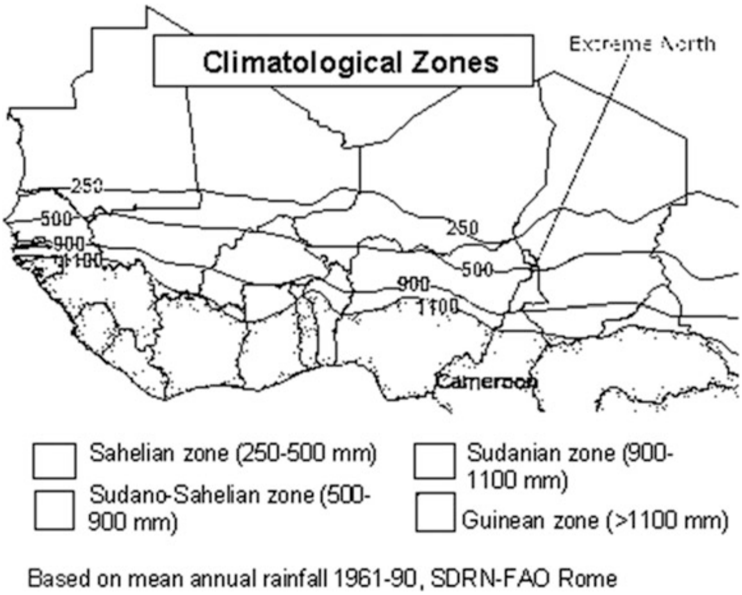

Fig. 9.3 The African Sahel climatological zones, the four zones are differentiated into layers using colors (FAO Corporate document repository, 2005)

harsh climatic conditions causing food insecurity (Fig. 9.2). The climatological zone picture showing the Far North region and the natural hazard Cameroon graph were downloaded online and edited using "PIXLR EDITOR". A current situation of malnutrition about the Sahel region was taken from the UNICEF Cameroon monthly humanitarian report (Vikas and Zakari 2013) (Fig. 9.3).

The four different eco-climatic zones are based on the average annual precipitation and agricultural features, i.e., Sahelian zone, Sudano-Sahelian zone, Sudanian zone and Guinean zone.

Results

Using inclusion and exclusion criteria 14 articles were retained and reviewed, a brief description of 10 of the reviewed papers are presented in Table 9.1. In the Sub-Saharan Africa, agriculture is mostly rainfed and any adverse change of the climate will directly affect crops, livestock and food security. The current food crisis and water scarcity in the Sub-Saharan Africa has been attributed to high population growth and unreliable rainfall (Roudier et al. 2011), leading to an increase rate of food insecurity and malnutrition. Figure 9.4 below shows below how climate change affects agricultural yield and lead to malnutrition, it also sheds light on the main objectives of this study.

Climate change affects the amount of rainfall; it leads to flooding, severe drought, and water stress. High temperature affects the ecosystem. Low agricultural yield means the loss of crops and livestock, shortage of food leading to food insecurity and low income to the household (Heather et al. 2010). The above conditions contributes to child malnutrition. The Sahel region of Cameroon has limited food varieties (Table 9.2) with cereal being the main cultivated food crop due to the weather condition.

Cereal being the most cultivated crops has faced a reduction in production for the last three decades (Fig. 9.5).

The figure indicates that the quantity of cereal produced was less than quantity needed except in the year 1980–1985, the shortage of cereal production in the Sudano-Sahelian region of Cameroon from 1998 to 2005 was attributed by most farmers to deforestation, population growth, capital, technology, and land management (Epule et al. 2011), in this survey farmers failed to mention rainfall, drought and increasing temperature. According to Trincheria et al. (2015), average cereal production will reduce by about 200 kg per hectare with an increase of one degree temperature above the optimal temperature. According to Lloyd et al. (2011) a future decline in cereal production caused by climate change will have an impact on food security and lead to malnutrition, food shortage could be threatened with high food prices, making it difficult for the poor to be able to buy what they don't have (Niang et al. 2014). This was further confirmed by using a model to estimate the increase rate of moderate stunting of 1–29 % by 2050 and a greater impact on severe stunting which will increase by 23 %. The model further suggested that improving only socioeconomic conditions is not enough to reduce malnutrition, but it should be a combination of food access and reducing greenhouse gas emission.

According to FAO (2013) measuring Stunting, wasting, low weight on children of age under five can approximate the nutritional status of a population (Fig. 9.6). This parameter can easily be measured and applied as food security indicators.

Table 9.1 The 10 articles reviewed

Author, Year	Topic	Participants	Region	Methodology	Results
Epule et al. (2013)	The causes, effects and challenges of Sahelian droughts	Review	African Sahel	They reviewed articles on the causes, effects and challenges of Sahelian droughts	The identified the four main causes of Sahelian drought The effects of drought on ecosystem services like forest, food yields The challenges included; internal political instability and public health concerns like HIV/AIDS abd Malaria
Epule et al. (2011)	Rainfall and Deforestation Dilemma for Cereal Production in the Sudano-Sahel of Cameroon	Sites; Touroua, Garoua, Maroua and Kousseri 124-farmers, 52-cattle readers, 10-teachers and 14-rice vendors	Sudano-Sahel of Cameroon	Data collection and analysis on cereal production from 1975 to 2005 The focus group was 200 farmers, 200 questionnaire and authorities of ministry of agriculture	The result was based on Cereal output trends and the population Perceptions of causes of observed trends They attributed the decline of cereal production to; deforestation, population growth and capital technology
Epule Terence Epule (2009)	The Effects of climate change and land use patterns on Water and agricultural Resources in the Sahel of Cameroon Population Vulnerability and Adaptations	General public, ministerial department and cereal office Study site; Kousseri, Maroua-Yagoua and Garoua	Extreme North Cameroon	They collected data by using questionnaires, Interviews with officials, collection of river water samples and literature search	The region experience temperature increase and declining rainfall and land use patterns affecting the agricultural output. A decline in river flow or discharge indirectly caused the quality of river water to decline

Molua and Lambi (2006)	Climate, Hydrology and Water Resources in Cameroon	Department of Economics, University of Buea,	Cameroon	Quantitative assessment	The African Sahel climate is shifting southward, it will affect water availability as a result affect agriculture and the supply of hydro electric power in the North of Cameroon
ORC Macro, Calverton, Maryland, USA, 2006	Cameroon 2004, Nutrition of Young Children and Mothers	Mothers and Children under 5 years of age.	Cameroon	The data used in the report are presented in the report are from the 2004 Cameroon Demographic and Health Survey by NIS	The result showed an over view of the rate of malnutrition in Cameroon. Malnutrition was determined by measuring stunting, wasting, underweight and overweight rate including background characteristics
Kenga et al. (2005)	Sudano Savanna Zone of Cameroon and Implication for Research Priority Setting	7 study site; North; Fignolé, Laindé, Mafakilda, Séboré, Extreme North; Mowo, Gadas, BalazaDomayo	SudanoSavanna Cameroon	They conducted a 3 months Participatory Rural Appraisal, monitored households activities, individual and group interview	There is limited rainfall in this zone, land degradation, and a growing land constraint, the farmers developed two or three cropping system as an adaptation method.
Mathieu et al. (2002)	The Recent Extension of Muskwari Sorghums in Northern Cameroon	Study site; Balaza and Mowo village	Extreme Northern region Cameroon	Two study site were chosen and satellite images used to demonstrate the increase in the areas under transplanted sorghum in the small regions around each site	In Balaza, the areas surveyed in 1995 displayed a 150 % increase in muskwari from 1983 to 1995, In Mowo, the cultivated land showed that the total areas cultivated have increased since 1994, the cultivation of transplanted sorghum is aimed above all at food self-sufficiency

(continued)

Table 9.1 (continued)

Author, Year	Topic	Participants	Region	Methodology	Results
Lloyd et al. (2011)	Climate Change, Crop Yields, and Undernutrition: Development of a Model to Quantify the Impact of Climate Scenarios on Child Undernutrition	Children less than 5 years,	South Asia and Sub-Saharan Africa	They described the development and fitting of a model for estimating the prevalence of stunting, they outline the process of estimating the proportion undernourished, and the simulation process for estimating future undernutrition attributable to global climate change	The result showed that climate change will lead to a relative increase in moderate stunting of 1–29 % in 2050. Climate change will have a greater impact on rates of severe stunting, and will increase by 23 % (central SSA) to 62 % (South Asia)
Thompson et al. (2010)	Climate Change and Food Security in Sub-Saharan Africa	Institute for the Study of International Development, McGill University and Department of Geography, McGill University	Sub-Saharan Africa	The methods included a Systematic review of peer-reviewed literature related to climate change and food security. The review was guided by using a questionnaire	The three key mechanisms of food security descript in the results are; **Availability**: Higher temperature will decrease crop growth and duration, Warming with intensive rainfall will produce drought, lack of good quality soil will reduce crop yield **Access** and **utilization** of food

Trincheria et al. (2015)	Adapting Agriculture to Climate Change by Developing Promising Strategies Using Analogue Locations in Eastern and Southern Africa	Hamburg University of Applied Sciences, International Crops Research Institute for the Semi-Arid Tropics Nairobi, Kenya, International Crops Research Institute for the Semi-Arid Tropics Bulawayo, Zimbabwe	Eastern and Southern Africa	The method was a combination of model-based ex ante analyses couple with literature field-based research on station and in farmers' field	There is variability in rainfall during cropping season, temperature increase by about 0.5 degree in the last decades and crop generally decline with increasing temperature, but crops respond different in different temperature, example Maize and Sorghum

This table presents the articles' author, year, topic, participants, region with comments on methods and the results

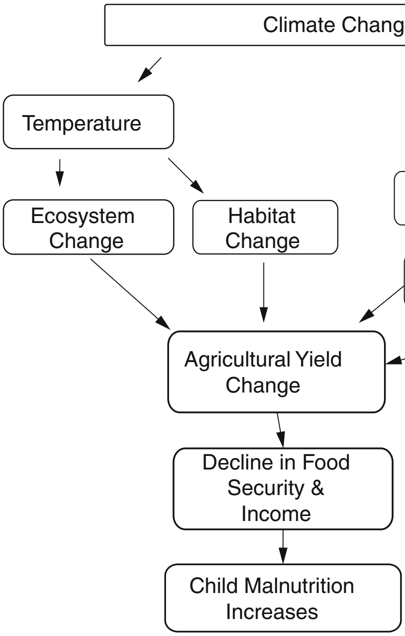

Fig. 9.4 Climate change effect on crop yield and malnutrition (Back and Cameron 2008). The figure shows that climate change is a key driver of food insecurity causing Malnutrition (Gregory et al. 2005)

Table 9.2 Agricultural products of the Cameroon Sahel region (Kenga et al. 2005)

Cash crop	Livestock	Food crop
Cotton	Cattle, sheep, goats, horse, donkey	Millet, sorghum, maize, peanut, cowpea, cereal

This is a geographical representation of stunting and wasting among children less than 5 years in all the 12 regions of Cameroon. The Extreme North (Sahel region) second highest with 37 % stunted children (chronic malnutrition) and first with 9 % wasting children (acute malnutrition). Table 9.3, represent an acute malnutrition rate measured in the four most affected regions in Cameroon.

The rate of acute malnutrition in the Far North is above the emergency threshold while the severe acute malnutrition prevalence is below emergency threshold (Vikas and Zakari 2013). This is similar to the report from Macro (2006) (Fig. 9.6).

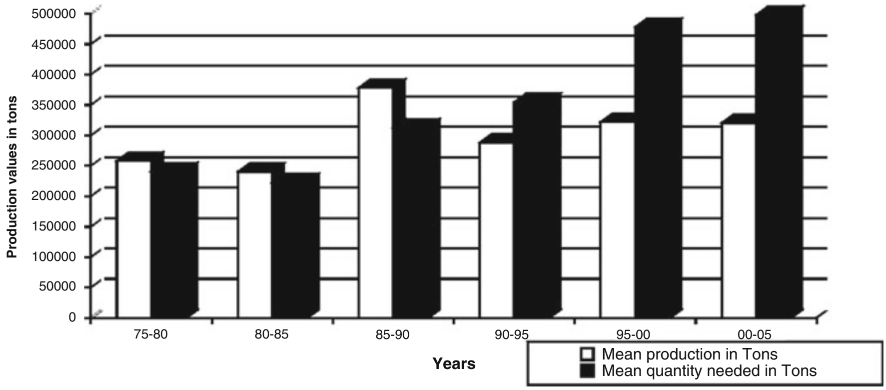

Fig. 9.5 Mean trends of cereal quantity produced and quantity needed in the Extreme North from 1975 to 2005 (Epule 2009; *Source*: Cereal Office and Ministry of Agriculture and Rural Development 2009)

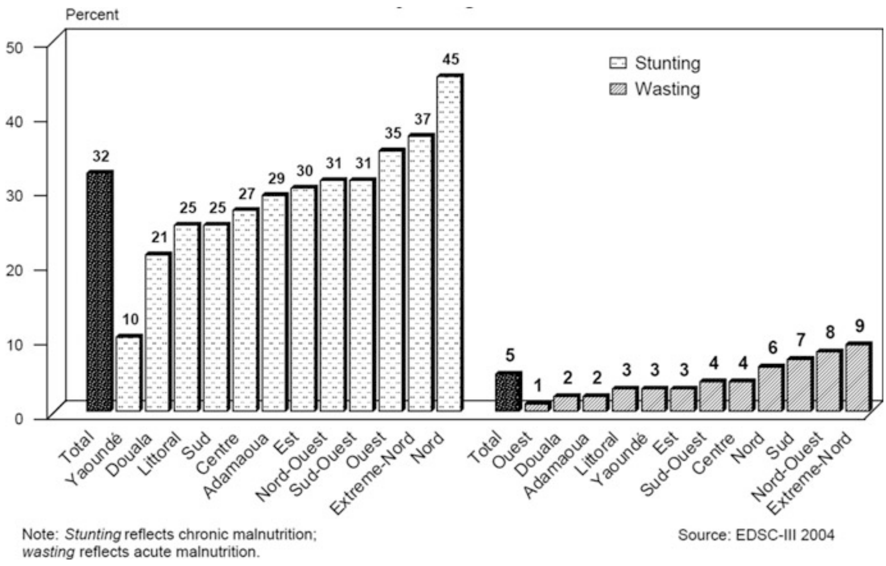

Fig. 9.6 A percentage stunting and wasting in 10 regions of Cameroon (Macro 2006)

Table 9.3 Prevalence of malnutrition in four most affected regions of Cameroon (Vikas and Zakari 2013)

	Children from less than 5 years	Acute malnutrition (AM)					
Region	Number	Global AM		Moderate AM		Severe AM	
		N	%	N	%	N	%
Far North	710	61	8.6 (6.5–11.2)	48	6.8 (4.9–9.2)	13	1.8 (1.1–3.1)
North	651	38	5.8 (4.3–7.8)	39	4.6 (3.3–6.4)	8	1.2 (0.06–2.5)
Adamawa	417	18	4.3 (2.0–8.9)	18	4.3 (2.0–8.9)	0	0
East	492	15	3.0 (1.7–5.5)	12	2.4 (1.2–4.8)	3	0.6 (0.2–1.9)

Discussion and Adaptation

Discussion

Looking at the factors of climate change, one can conclude that climate change is directly linked to food insecurity in the Sahel of Cameroon. The Sahel region has very limited varieties of food crops and Cereal being the most cultivated crops have faced deficit in the last decades. This has been attributed to irregular rainfall, an increase in temperature, frequent drought, deforestation, desertification over population and technology (Kenga et al. 2005; Epule 2009; Epule et al. 2011, 2013; Molua and Lambi 2006). The lack of storage facilities during harvest is also a significant factor contributing to food insecurity in the Sahel region (Heather et al. 2010). The population growth in the extreme north of Cameroon includes the influx of refugees from Nigeria into Cameroon due to the Boko Haram crisis. According to IFAD (2001), there has been a fall on subsidies provided by the governments and NGOs from about 20 % in 1980s to about 12 % today. Considering the 73 % of Cameroon citizens depending on agriculture a reduction of 8 % subsidy will hamper the progress to reduce hunger and malnutrition in the Extreme North. The WHO classification for assessing severity of malnutrition by prevalence rate among children less than 5 years shows that the 2006 report from Macro (2006) and (Vikas and Zakari 2013) were above the emergency threshold in the Far North region of Cameroon. It is important to know that malnutrition can have a lifelong impact on health and development; it can impair growth, resistance to diseases, pregnancy, physical work and less learning ability. Malnutrition causes a population to be more vulnerable to malaria and diarrheal diseases (Niang et al. 2014). This could be the more reason why the Sahel region has frequent outbreaks. Heather et al. (2010) argue that ‘dealing with malnutrition, it is insufficient to provide food of any description, but to consider the nutritional value of the food’. Bain et al. (2013) stated that genetically modified food will increase food production; reduce poverty and malnutrition in developing countries. According to Heather et al. (2010) organic agriculture is often seen as a cost effective method to improved agricultural yield because the inputs are natural and is obtainable from local sources. The organization of the 13 States of the Sahel belt called the Permanent

Interstates Committee for Drought Monitoring (Seydou et al. 2014) can help Cameroon monitor the drought conditions in the Far North. The adaptation methods following needs both financial capital and willingness to change a historical and cultural practices, this is true especially when it comes to buying chemical fertilizer or diverting from the custom of planting season in the Sahel region.

Adaptations

Adaptation is very important for every scientific and policy making when talking about climate change (Trincheria et al. 2015). According to Trincheria et al. (2015) developing countries have the highest impact on climate change when hit by disasters; this implies that their governments need to take climate change as a top priority in making policies. Better policies will improve agricultural yield, availability and access to food, this includes combining the most efficient and cost effective adaptation strategies. The reduction in rainfall with temperature increase during planting seasons has forced the farmers of the Sahel region to use indigenous knowledge to develop some kind of adaptation methods to overcome such adverse climatic condition but it might not be applicable in the future, an example of these techniques are Crop rotation between cotton and sorghum, transplanted sorghum, making the choice of crop depending on the climatic situation of the year and mixed crop-livestock farming practice (Ngambeki et al. 1992; Mathieu et al. 2002). This is the reason why they attributed the cereal food reduction to other factors and not just climate change. It has also been noted that these farmers have low purchasing power and subsidies provided by the government are insufficient or never reach them due to corruption. This makes it very difficult for farmers to adapt to modern strategies. Some adaptation methods that have been put in place in this region include dams for irrigation, to reduce the problem of irregular rainfall (Epule 2009). Munang and Rivington (2009) used a simulation model to show that sowing dates might not be an effective method in mitigating the adverse effect of climate change, but rather genetically modified crops, but one would not cancel the idea of shifting date methods because it might be applicable in different areas, in this case the both methods could be tried in the Sahel region that has irregular rainfall. Chuku and Okoye (2009) outline the four main adaptation strategies that can be applied in the Sahel region of Cameroon to help small farm holders to cope with climate change. (1) Granting credit, subsidies and incentives to farmers from the Government, buying crop insurance to reduce the risk of asset loss due to poor yield, sales from drought, floods or market fluctuations. (2) Implementing policies and programs that will influence the use of land and water resources. (3) Production methods, land use, land topography, irrigation and timing. (4) Increase crop yield, increases tolerance by developing new crop varieties, this will provide crop choices that can best suit the temperature, provide weather and climate information systems by generating forecasts, encourage Agri-biotechnology research by funding it and for Livestock, the used for supplementary feeding by fodder, rotation of pasture and altered grazing or development of new heat resistant varieties of livestock will reduce the threat (Parry 2007). Since Crop irrigation and rainwater harvesting have seen sustainability in other parts of Africa (AFRHINET) this will be feasible if implemented in the Sahel region (Heather et al. 2010). According to Epule et al. (2011) the entire farming system can be transformed from extensive unproductive farms to intensive mechanized and organic fertilizer farms, however, some school of thoughts has argued that fertilizer production is the highest emission of greenhouse gas (GHG) (Vermeulen et al. 2012) therefore caution should be taken when using fertilizer as a strategy to improve crop yield in the Sahel. The adaptation measures on malnutrition could include providing early warning systems, vulnerability mapping using GIS to locate the site at risk, diet diversification; coordination with food and agriculture sectors and improved the public health functions to address underlying diseases (Niang et al. 2014). Heather et al. (2010) suggested that the government, the private investors and NGO's could create jobs in other sectors other than agriculture to enable the farmers or their children to earn money for a better family livelihood.

Conclusion

This integrated review will help raise awareness on climate change, its effect on food security leading to malnutrition and adaptation strategies. This study has proven that there exist drought, deforestation, unreliable rainfall and increasing temperature affecting crop yield, there is a high rate of stunting and wasting (malnutrition) in the Sahel region of Cameroon, but due to the limitation of this study one would be very cautious in drawing a conclusion that food insecurity is the sole cause of malnutrition because additional factors like portable water, education and health care also play a big role. This broad base work can be applied in all other African countries (Nigeria, Chad, Niger, Sudan, Mali and Senegal) affected by the Sahel belt climate even though it was focused on Cameroon.

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Part II
Climate Change and Infectious Diseases

Chapter 10
The Social and Political Dimensions of the Ebola Response: Global Inequality, Climate Change, and Infectious Disease

Harris Ali, Barlu Dumbuya, Michaela Hynie, Pablo Idahosa, Roger Keil, and Patricia Perkins

Abstract The 2014 Ebola crisis has highlighted public-health vulnerabilities in Liberia, Sierra Leone, and Guinea—countries ravaged by extreme poverty, deforestation and mining-related disruption of livelihoods and ecosystems, and bloody civil wars in the cases of Liberia and Sierra Leone. Ebola's emergence and impact are grounded in the legacy of colonialism and its creation of enduring inequalities within African nations and globally, via neoliberalism and the Washington Consensus. Recent experiences with new and emerging diseases such as SARS and various strains of HN influenzas have demonstrated the effectiveness of a coordinated local and global public health and education-oriented response to contain epidemics. To what extent is international assistance to fight Ebola strengthening local public health and medical capacity in a sustainable way, so that other emerging disease threats, which are accelerating with climate change, may be met successfully? This chapter considers the wide-ranging socio-political, medical, legal and environmental factors that have contributed to the rapid spread of Ebola, with particular emphasis on the politics of the global and public health response and the role of gender, social inequality, colonialism and racism as they relate to the mobilization and establishment of the public health infrastructure required to combat Ebola and other emerging diseases in times of climate change.

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Introduction: Learning from Ebola

The Ebola crisis of 2014–2015 holds a number of lessons regarding global preparedness to meet the challenges posed by emerging diseases in times of climate change. These lessons relate to the causes and origins of the Ebola spread, the initial responses to the epidemic at the local level, international responses and their long-term effects, and global disparities in health access.

This chapter brings together a range of facts and commentary about the Ebola epidemic, focusing on the role of climate change in exacerbating socio-economic vulnerabilities, and extending the discussion and analysis to future/emerging diseases and their relation to global climate change.

By combining discourse analysis and sources of public information about the Ebola crisis such as newspapers and online sources with statistics and academic analyses of local health systems, global institutions, climate change-induced weather patterns, social institutions, public opinion, economic trends, investment and urbanization, we present an interdisciplinary contextual analysis of emergent pressures on local health systems in times of climate change, with global implications. While direct causality among factors is nearly impossible to "prove" in complex circumstances such as this, systems researchers rely on such triangulation and multiple evidence-based methodologies to track trends and make sense of emergent linked phenomena (Klenk and Meehan 2015; Poteete et al. 2010; Roe 1998; Moran-Ellis et al. 2006). The literature on hazards and disasters distinguishes between the former as being a precondition (in the form of a hazardous agent or circumstance) to a disaster. A hazard is therefore a disaster waiting to happen. Hazardous conditions set the stage for a disaster to occur. In the case of Ebola, the hazardous agent is the virus itself. The virus itself does not in itself "cause" the outbreak, just as a hazard in itself does not "cause" the disaster. Rather, the social, political, cultural, economic and biophysical conditions and factors we write about in this chapter all contributed to enabling the disease to spread. Here the enablement of disease spread also, notably, extends to the outbreak response, including how these numerous factors hindered the outbreak response.

The following section discusses the Ebola epidemic's roots in globalization, international trade pressures, financial flows, Bretton Woods institutions, incapacity and created weakness in African health-care systems, and the prospects for addressing these inequities as climate change worsens. Section 3 "Ebola's Roots in Extended Urbanization", gives more detail on how mining, transportation networks, urbanization, and the scale of environmental-economic transformations both in Africa and worldwide lead to the conditions in which new diseases emerge and spread. In section 4 "Health Infrastructure, Climate Change, and Ebola's Spread", photos and statistics demonstrate the relationship between climate change, poverty, poor nutrition, eroding infrastructure, and Ebola transmission rates. Section 5 "Stigmatization and the Local and Global Response to Ebola", discusses the role of stigmatization in the political and global aid response to Ebola. Section 6 "Community Engagement and the Ebola Response", examines the long-term impact of global health assistance on sustainable community-based health services. The Conclusion builds on this background to consider Ebola's lessons in relation to future and emergent health risks in times of climate change.

Ebola, Globalization, and Neoliberal Retrenchment

Ebola's emergence is grounded in the legacy of colonialism and its contribution to enduring inequalities within African nations and globally. The contemporary expression of this history is seen in the "Washington Consensus," the international aid industry and the underfunding and decentralization of service delivery, through privatization, reduced public expenditures, and lack of access to health care for the most vulnerable. Developmentalism still informs and has implications for the effectiveness of current public health responses. The racist discourse of the diseased, incapable African, requiring outsiders to swoop in to save the day, can only be superseded through sincere and authentic participatory approaches—real collaboration between global institutions such as the World Health Organization (WHO) and local public health and government officials.

The whole world bears the responsibility for the Ebola crisis. As noted by the People's Health Movement, "The epidemic, in all probability, will run its course and die down after leaving a trail of death and destruction (not) because we as a global community would have done very much right, but because of the nature of the virus itself. The moot question is, will we have learnt anything? Or will it be back to business as usual?" (PHM 2014: 7). Market demand from consumers in the Global North fuels the resource exploitation that produces the conditions in which the Ebola epidemic emerged, and other diseases are sure to follow. Ebola has its origin in "the unchecked exploitation of natural resources by international timber and mining companies," as The Observer (2014) noted in early October 2014 based on a WHO report on the disease.

As long as Ebola erupted sporadically in small villages along the global resource economies' path, as it did beginning in the 1970s, the outbreaks flared up and went away as quickly as the global corporations leave their tailings ponds behind. The situation is different now. The virus found its way along the human food chain towards the exploding centres of a rapidly urbanizing Africa. It reached large cities with their huge inequities, overcrowding, and underdeveloped sanitation and public health systems, and only extreme measures fuelled by moral panic have thus far (and perhaps temporarily) prevented its global spread in the same way SARS expanded across the globe in 2003. The unspoken divisions in how these measures play out reveal deep injustices at the global level.

For example, in the early days of the Ebola crisis, some criticized the unavailability of vaccines to help the sick, despite the fact that several vaccines had been in development for many years in the Global North (Stanford 2014). It was also pointed out that a large pool of exposed but disease-resistant people, such as those now living in Ebola-ravaged areas of West Africa, would facilitate the development of a serum-based vaccine. Even if a vaccine is developed and tested, will it ever be widely available and accessible to all those who need it, in Africa and globally? Will this become yet another source of profits for Big Pharma? As has often been noted, there are "tensions inherent in the socioeconomic construct that is today's pharmaceutical industry [which on one hand seeks to protect] the health of the public, but on the other it seeks to maximize profit" (Cohen et al. 2006: 2). There may, then, be an understandable concern that seeking a cure or antidote for Ebola might become either an opportunity for the pharmaceutical industry to use Africa as a laboratory (see Chippaux 2004), or as another source of profits for the pharmaceutical industry, rather than promoting the enhancement of well-being. Or, as David Healy has said more dramatically, "an incentive to chase blockbuster profits—doing so regardless of patient welfare" (Healy 2012: 55).

The WHO, hit hard by UN retrenchment related to the 2008 global financial downturn, cut its budget and downscaled its activities rather than insisting on adequate support and new funding approaches, which left the WHO woefully unprepared to help Guinea, Liberia and Sierra Leone mount a speedy and effective Ebola response in early 2014 (PHM 2014; Lee 2009; Harman 2009; Kay and Williams 2009). This put organizations like Medecins san Frontières (MSF), missionaries, and Cuban doctors in the position of heroic first responders in very difficult circumstances.

Points out Ibrahim Abdullah, who teaches at the University of Sierra Leone (the oldest university in West Africa) in Freetown, the epicenter of the epidemic, "This is the neo-liberal scourge: if you privatize health care in the context of mass poverty, you get the Ebola epidemic. If, however, you put people at the centre of development by modernizing health and education, you can prevent Ebola. Ebola is about governance and modernity" (personal communication 2014). This crisis is neoliberal precisely because each of the three hardest-hit countries (Liberia, Sierra Leone and Guinea), in addition to suffering civil wars and large-scale human displacement over the past decade, were also encouraged to privatize health care and introduce-fee-for-service systems that crumbled amidst poverty—a recipe for the Ebola disaster (PHM 2014). This impoverishment has also opened up the same countries for land-grabs, mining exploitation, rapacious Foreign Direct Investment, agro-forestry, habitat destruction, and human displacement which destroys social resilience, endangers public health, and makes quarantine and disease-control systems nearly impossible to manage.

The only way to combat these trends is for African states to be encouraged and supported in the harder part of development: building health care and education systems that are public and sustainable. The Ebola crisis reveals, thus, both shorter term and longer term issues of development, which represent the deeper crisis affecting not only the three main Ebola-affected countries but global distribution in general.

Ebola's Roots in Extended Urbanization

The West Africa of the 2014 Ebola epidemic is one of the fastest urbanizing regions on the planet (Diallo and Dilorenzo 2014; Salaam-Blyther 2014). Perhaps the most dynamic social process in Africa is its rapid urbanization (including peri- and suburbanization). The ravaging of the countryside by resource companies and the expansion of the urban fabric into regional hinterlands demonstrate the interface between humans and infectious disease.

This is, of course, not just an African story. A planetary process of urbanization is underway across vast networks of infrastructure lines, resource supply chains and human travel (Brenner 2014). As much of this urbanization leads to massive peripheral settlement in existing and new urban centres, often in contiguity with previously mostly undisturbed natural landscapes, we can speak of "suburban constellations" at the heart of the process (Keil 2013; Bloch 2015; Mabin 2013; Leahy 2011). A new landscape of risk emerges (Bloch et al. 2013). In mining towns, sometimes physically remote and isolated but connected through global metabolisms and labour markets, we can speak of a "feral" form of suburbanization that confronts human and non-human nature in direct encounter (Shields 2012). By 2030, it is expected that urbanized land on the planet will cover 1.2 million square kilometres which is twice as much as in 2000. This massive urbanization is unequally distributed across the globe, with China and Africa absorbing the lion's share of global urbanization during the next generation. We can expect significant consequences for climate change, biodiversity, etc. (Seto et al. 2012; Oxfam 2008). In this context, Ebola, once thought of as being an isolated problem in remote rural areas, has become an urban disease affecting cities and their peripheries, where its spread tends to be rapid and seemingly random due to massive human interaction and often dense and unhygienic living conditions.

In the past, disease outbreaks were associated with squalid and unhygienic urban conditions and the immobility of affected communities (Keil 2014). The new bundled problematique of urbanization, density, and migration has often been the source of huge moral panic (Wald 2008: 114–156). Emerging forms of urbanization lack the infrastructure necessary to support communities in a health emergency. Places like Kroo Bay in Freetown, described by a journalist as "a labyrinth of shacks and muddy pathways perched at the edge of a large rubbish dump stretching out into the Atlantic Ocean", caused concern amongst health care professionals. One was quoted as saying that "These places are always prone to outbreaks" (Trenchard 2014: n.p.). But now the attention is on the (transnational) network of extended urbanization as "the virus is travelling effortlessly across borders by plane, car and foot, shifting from forests to cities and springing up in clusters far from any previously known infections. Border closures, flight bans and mass quarantines have been ineffective" (Diallo and Dilorenzo 2014: n.p.; see also Salaam-Blyther 2014; Keil 2011).

Standard textbooks on globalization and health tend to overlook the urban dimension and lean towards seeing urban political pathologies in the framework of the nation state system (Cockerham and Cockerham 2010; Price-Smith 2009). With the SARS crisis of 2003, the world was made aware of the importance of cities in the governance of global health crises (Ali and Keil 2008). But this also meant moving from public health governance in and by cities to global public health governance in urban society—a different challenge altogether. The Ebola crisis points further in this direction: public health institutions and procedures in cities are absolutely critical (and they often failed in the cases of SARS as well as Ebola). The time has come for a systemic and networked view of governance (and not just health governance) across the global urban expanse, the entire field of extended urbanization.

Global institutions, in their imperfection, have begun to act. Urban public health systems could be a prime target of international aid to stave off the Ebola threat while creating the conditions for future epidemic prevention. The WHO made a courageous step in 2008 to strengthen the roles of cities in improving public health and in the fight against Emerging Infectious Diseases (WHO 2009). While Ebola proved to be resistant to many conventional containment measures, the strengthening of urban public health institutions in the overall architecture of global health governance and responses is certainly a path that must be pursued in future outbreaks of this and other infectious diseases as cities grow faster and in different patterns than in the past.

Health Infrastructure, Climate Change, and Ebola's Spread

The impoverished public health sector and desperate state of critical infrastructure in Guinea, Liberia, Mali and Sierra Leone—barely functioning hospitals, inaccessible and inadequate care with few medical staff, intermittent electricity, underdeveloped transportation networks and non-existent communication networks—are markers of the extent to which the Ebola outbreak was able to spread and impact the region (WHO 2012; Oladele et al. 2012). Lack of surveillance, monitoring, and—laboratory facilities delayed early Ebola diagnoses until March 2014. The region's history, beset by political and social unrest and internal strife, adds to the complexity. Both Liberia and Sierra Leone experienced over a decade long civil conflict that decimated their already weak public health infrastructure. Health care expenditures in these countries are heavily dependent on foreign aid, tied to commitments that often prohibit investments in public infrastructure (UNDP 2011) (Table 10.1). Furthermore, countries with a health care workforce below WHO's recommended critical threshold of 23 professionals (physicians, nurses and midwives) per 10,000 people have a lower resilience for diseases and epidemics (Afri-Dev.Info 2014; WHO 2014a) (Table 10.1).

Table 10.1 Health statistics for Ebola-affected countries

	Guinea	Liberia	Sierra Leone	Mali	Nigeria
Health expenditure as a % of GDP (2012)	6.3	19.5	18.8	5.8	5.3
Life expectancy (years)	58	62	46	57	58
Population (thousands)	11,451	4190	5598	14,854	168,834
Doctors	940	51	136	1291	58,363
Nurses an midwives	4408	978	1017	6715	224,943
Doctors, nurses and midwives per 10,000 people	1	3	2	3	20
Doctors working abroad	99	122	236	160	4611
Nurses working abroad	94	1240	2057	227	13,398

Source: Afri-Dev.Info (2014), Dumont and Zurn (2007)

It is no surprise that the Ebola response was weak and characterized by what MSF (2014) cites as huge gaps "in medical care, training of health staff, infection control, contact tracing, epidemiological surveillance, alert and referral systems, community mobilization and education"—important components of a comprehensive Ebola preparedness and response plan as outlined by the WHO. Mistrust, miscommunication, and rumours fuelled community resistance and avoidance that interfered with public health measures in the region (Fofana 2014).

Unlike Nigeria and Mali, Sierra Leone, Liberia and Guinea's outbreak started in rural areas with porous geopolitical borders, plus woefully inadequate and inaccessible public health care, forcing people to seek alternative affordable and accessible traditional medicine (WHO 2015). Nigeria and Mali had successful outcomes for several reasons. First, as the epidemic was in its fourth month, they had enough time to draw up Ebola preparedness and response plans. Second, both countries repurposed existing infrastructure for Ebola: Nigeria used its polio facility as an Ebola Response Centre and Mali equipped an existing laboratory for Ebola testing (WHO 2014b, 2014c, 2015). Third, the index case arrived in urban cities, where medical care was available (Nigeria's by air to Lagos City and Mali's via road to Bamako), allowing for quick diagnosis and activation of monitoring and contact tracing.

The region's colonial history depicts an exploitative and extractive relationship with the Global North since the 1800s, plus a history of disease importation to the region, and is the backdrop that sheds light on the level of mistrust of national and international agencies that partly shaped public response to the Ebola outbreak. For example, in August 1918, the Spanish influenza arrived on the shores of Sierra Leone aboard a British naval vessel (Rashid 2011; Olaniyan 2004). Rural areas—the disease epicenter—are underserved. Post independence, national governments perpetuate this exploitative legacy. In Sierra Leone, rural agriculture and minerals account for a high percentage of national GDP, yet rural areas have not had proportional investment in basic infrastructure like health, water and sanitation and transportation networks (BTI 2012).

It is increasingly evident that climate change is adversely affecting human health. The health burden of climate change also includes the emergence and

Fig. 10.1 Sierra Leone's King Jimmy bridge collapsed after torrential rains in August, 2013, killing six people

increased incidence of infectious and water borne diseases. The current Ebola outbreak was a chance encounter between a 2-year old child and a fruit bat, the reservoir for the virus (Baize et al. 2014; Saéz et al. 2015; WHO 2015). Some studies cite climate variability as the cause for fruit bats to migrate long distances and reside near cities and towns (Frumkin et al. 2008; Pinzon et al. 2004). An Action Aid (2006) study on the increasing flood frequency in six African cities reports that "climate change is altering rainfall patterns and tending to increase storm frequency and intensity". In Sierra Leone, recent extreme weather observed includes heavy rains that cause flash floods, mass land movement, injuries and fatalities, and infrastructure damage (Figs. 10.1, 10.2 and 10.3). Heavy rains precipitated the 2012 cholera epidemic that started in Guinea (7350 cases and 133 fatalities) and eventually spread to Sierra Leone (23,124 cases and 299 fatalities) (WHO 2012).

Resource exploitation and extreme weather displaces farmers who practice mostly subsistence farming in rural communities. They have to venture deeper into forests in search of land and new livelihoods, bringing them in closer contact with infected animals (WHO 2015), while human activities cause bats and other animals to venture closer to human habitats.

Women accounted for roughly 60–75 % of deaths in the 2014 Ebola epidemic (Wolfe 2014). Ebola's gendered impacts—including greater fatality rates for pregnant women, higher risks for caregivers who are often women, and dangers from sexual violence due to Ebola-related economic collapse (Thomas 2014)—have implications for social resilience, survival of caregivers and mothers, economic

Fig. 10.2 Sierra Leone's collapsed King Jimmy bridge along Wallace Johnson Street in Freetown, August 2013

Fig. 10.3 In Sierra Leone, June to August is called "the hungry season," when heavy rains make it hard to harvest and obtain food

decline and subsequent recovery in disease-affected areas, and the strength of public health systems (Perkins 2014).

When economic and ecological pressures, exacerbated by climate change, bring people and animals into closer contact while uprooting communities, depleting health care systems, undermining social resilience, and degrading infrastructure, this becomes a "perfect storm" for the emergence and spread of infectious disease.

Stigmatization and the Local and Global Response to Ebola

Disease ecology reminds us that the transmission dynamics of infectious disease spread involves a complex interplay between natural ecosystems, human economic activity and cultural belief systems (Mayer 2000). An oft-neglected consideration of the disease ecology is the role that stigmatization may play in disease transmission dynamics. Stigma is a common aspect of all cultural systems and quite often used in the service of social control (Goffman 1963). As such, despite the reality of the lethality of Ebola, the challenges that stigmatization poses for the effectiveness of outbreak response should not be trivialized. Patients may conceal the fact that they are infected, for various reasons related to stigmatization. For instance, one Liberian physician observed that "Some patients don't tell the truth. They come to you with a different story, like 'abdominal pain'. It's because of the stigma of Ebola. They think they won't be treated and they'll be sent away" (York 2014c). Stigmatization in the Ebola outbreak situation is not limited to patients. Health care workers, for example, were evicted from their homes by landlords out of fear (York 2014b). Furthermore, mobs in rural villages attacked journalists and health care workers (including those engaged in educational efforts but especially those responsible for removing the deceased). Similar to the situation with HIV/AIDS (Lewis 2006), orphans whose parents had succumbed to Ebola also became stigmatized during the earlier stages of the outbreaks. Given that UNICEF found that as of 6 February 2015, there existed 16,000 orphans in the Ebola-affected West African countries (UN NewsCentre 2015), the potential for a tragic problem has loomed. However, a UNICEF official remarked on a positive note that:

> There were fears that stigma around Ebola would isolate the orphaned children, which would mean there would be thousands of abandoned children, but that has, luckily, not materialized. (UN NewsCentre 2015: n.p.).

UNICEF programs provided cash support, material assistance, psycho-social support, and implemented programs to refer families for food assistance. This collectively helped to mitigate the effects of stigmatization and led to 80 % of the orphaned children being reunified with their extended families (ibid.).

Combatting stigma in populations where half the population is illiterate poses challenging problems. Programs that have successfully addressed such challenges may however be found. In Monrovia, billboards and posters visible on every major street helped to raise awareness, while thousands of "social mobilizers", consisting of health workers, teachers, religious leaders and youth activists, were recruited in Ebola-affected areas to spread the message about the disease (York 2014b). UNICEF produced videos and catchy songs with the same intent (ibid.).

Public health responders from outside West Africa were themselves hampered by stigmatization. This is an especially important issue in light of the observation by the WHO Director-General that the Ebola outbreak response urgently required outside assistance (Weintraub 2014). Western hospitals were reluctant to allow medical staff to go to West Africa, or take in Ebola-infected patients, due to worries of being labelled as the "Ebola hospital" in their community, or because of concerns that taking such actions would cause anxiety amongst in-house hospital staff (York 2014a). At another level, stigmatization may be understood as coming from the conflation of race with disease. This association may be bolstered by the term "Ebola" itself. According to one linguist, "Ebola" connotes to American listeners the very idea of Africa because of its sound similarities to 'ebonics' or 'ebony' in the American vernacular (Troutman 2014).

These types of stigmatization have deep structural origins that can be traced to the legacies of imperialism and colonialism in which "tropicality" is associated with disease (Bankoff 2001). In this type of colonialist discourse, "other" parts of the world are depicted as dangerous, particularly those with "warm climates" from where "new and emerging diseases" are seen to emanate in the twenty-first century (ibid). The effects of such neocolonial influences are seen, for example, in the way in which medical research in the Global North has benefited from blood, parasites, and viruses collected from the people of the Global South. The patented vaccines developed from such materials benefit those in the Global North (and especially the private pharmaceutical companies). As noted by Fearnley (2015), such biomedical gains did little to help build public health capacity and infrastructure within West Africa. Dealing with such enduring forms of stigmatization is vexing because of the structural dimensions involved in the geopolitics of dependency and Global North-South relations. One way forward, however, may be seen in the recent efforts of the African Union to establish an Ebola Solidarity Fund and an African centre for disease control by mid-2015 (Anders 2015). This initiative may have the potential to serve as an impetus to organize and institutionalize efforts against the types of stigmatization that ensue from structural dependency and power differentials embedded in neocolonialism.

While Ebola may be lethal for those contracting the disease, many, especially the medical practitioners involved in fighting Ebola (see Gbakima et al. 2014), as well as a number of mainstream journalists, have pointed to the media sensationalism surrounding the disease. As such it has been noted that there is a "tendency (in) the international media to attract viewers (which) has led some careless journalists to focus almost exclusively on the fear-invoking mode of death from the disease" such as the garish images of victims "coughing up blood" (Wallace 2014). Such foci are often fed by stereotypes about Africa, which are also linked to the oft-depicted image of Africa as a site of primitivism and catastrophe, the sources of which lie in colonial discourses of backwardness, exoticism and savagery. Thus, while it may be that having a fear of Ebola is a somewhat understandable response and not in itself a colonial attitude, the colonial legacy nevertheless exerts a tacit and often unrecognized influence on the fear. Specifically, it may "fan the flames of fear" or to put it in more technical terms, the colonial legacy may contribute to the phenomenon known as the "social amplification of risk", whereby peoples' perceptions of risk are unreasonably intensified (Kasperson et al. 1988).

Community Engagement and the Ebola Response

One criticism of the international Ebola response has been the failure of some international agencies to partner effectively with local government agencies, NGOs, and community organizations to respond appropriately and effectively to the epidemic, and to build capacity for the future (Gundan 2014; Kaba Jones and Norman 2014). The need to engage communities in successful health initiatives is well-established (Israel et al. 1998) and yet this seems to have been lost in the urgency of the international response. International initiatives responding to the Ebola epidemic focused on immediate treatment responses, the development and delivery of vaccines, security and containment, and large initiatives like building hospitals. For example, Canada's contribution to the Ebola campaign was the provision of protective gear, setting up mobile labs, and the delivery of an experimental vaccine (Public Health Agency of Canada 2014). At best, these responses have been slow, expensive, difficult to coordinate, and unsustainable (Gundan 2014). At their worst, the responses met resistance by local populations, and were slow to adapt to the local contexts, thus rendering such responses ineffective and inefficient, and in the end, leaving the communities vulnerable to the next health crises.

The importance of acknowledging and respecting concerns and practices of local communities and their socio-political context has been identified as a major issue in implementing health policies and practices (Nichter 2008). In reviewing the trajectory of the response to the Ebola outbreak, Petherick (2015) noted the general lack of trust between medical teams and local communities. This lack of trust contributed to community responses ranging from hiding Ebola cases from health workers, to attacking health workers and health facilities, driven by the belief that medical staff were spreading the infection, rather than trying to contain it. Mitman (2014) argues that the colonial history between Africa and Europe is one underlying source of this mistrust, a history that began with slave traders and missionaries and continues with the current European exploitation of resources and labour and Western military involvement in a range of conflicts. In the early to mid 1900s, American medical researchers followed this path of exploitation, extracting blood, tissue and, ultimately, knowledge, on expeditions to Africa, with some amount of coercion and without benefit or explanation to local populations (Karamouzian and Hategekimana 2015). This history of violence, invasion and exploitation has not been forgotten and could only have been reinforced by the presence of Western military personnel supporting biohazard-suited health workers (Bayntun et al. 2014).

Community based health initiatives are rapid and culturally appropriate responses from agencies trusted by the communities, and as such are more likely to be successful (Teutsch and Fielding 2013). Effective and innovative grassroots community led responses began immediately in Ebola-affected areas across West Africa and have been successful (Kaba Jones and Norman 2014). Moreover, strengthening these local community organizations can also be part of a strategy to build primary health care in general (Anders 2014). However, obtaining international support for grassroots initiatives is challenging. Most international funding is directed to EU or US organizations, which may have local initiatives and a history of working successfully in the area, but little funding is generally directed to local grassroots organizations or to the development of sustainable health infrastructure (Gundan 2014).

The Ebola epidemic rose rapidly in countries experiencing severe poverty, with a recent history of political unrest and conflict, and with very poor health care systems and infrastructure. Prevention of future epidemics requires development of strong social, political and health infrastructure (Kaba Jones and Norman 2014). The challenge is that international responses often do little to produce sustainable development. In an interview with journalist Flavie Halais, development expert Ian Smillie noted that Canada's interventions in Sierra Leone would have no lasting impact on the health care system (Halais 2014), and thus make no contribution towards the prevention of future epidemics.

Representatives of the UK Department for International Development (DfID) now claim that they should have focused on prevention and social mobilization earlier, and funneled more funding to local grassroots organizations to do so effectively (Jóźwiak 2015). In the same article, however, the author noted that DfID's funding policies made it difficult to fund local agencies, and that they report no plans to shift funding policies, reflecting the disconnect between evidence based practices in population health, and the politics of international aid funding.

Conclusion: Climate Change, Social Resilience, and Emerging Diseases

Ebola is a well-studied disease, not an unknown one like SARS was when it first appeared in 2003, with a fatality rate of 18 %. Ebola's genomes have been sequenced and patented, and supportive health care can reduce its fatality rate to about 20 %, according to health researcher Laurie Garrett (CBC 2015). But as former WHO staffer Akong Charles Ndika notes, the desperate state of most African health-care systems enables the threat posed by Ebola outbreaks to be maintained, and these inequities "will continue in [the] future to manufacture new and re-emerging epidemics like Ebola . . . with frightening impact on a global scale" (Ndika 2014: n.p.).

Moral panic is not helpful. Health-care workers need the training and equipment to protect themselves, and basic health education for the general public is crucial to counter stigma, fear, ignorance, and superstition. Participatory education and logistics are the main challenges, not just to build hospitals and public health interventions, but also to support food security, infrastructure and governance systems, especially at local levels across the Global South. This is a huge and pressing endeavour which only the WHO can coordinate, working closely with local institutions. So the WHO must be supported—not just in words but with significant financial and material resources—in order to meet the immediate challenges of new disease outbreaks and also to build the longer-term capacity of local public health agencies so that local units can function effectively and sustainably, since future outbreaks are inevitable in today's globalized world. This applies not only to the need to increase the supply of material resources needed for the emergency response, but also the training of local staff so that they can thwart the threat themselves. Broad public participation in governance of the entire health care system is also necessary, both locally and globally, so that education and democracy go hand in hand with the development of strong health care systems. Urban public health systems should become a prime focus of WHO and international support.

Analysis of the social and economic roots of the Ebola epidemic demonstrates that the 2014 crisis was grounded in global income inequality and the same impoverishment that had opened up countries for land grabbing, rapacious foreign direct investment and agro-forestry, the displacement of more and more people, the destruction of natural habitats and the erosion of the capacity for social resilience. These conditions will continue to produce outbreaks of emergent diseases in times of climate change, and unless they are addressed, these outbreaks will continue to facilitate ongoing global health threats.

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Chapter 11
Climate Variation and Challenges of Human Health in Nigeria: Malaria in Perspective

Vincent Nduka Ojeh and Sheyi A. Aworinde

Abstract The patterns of general circulation of the atmosphere which determines the characteristics of global and regional climate variations will be different from what it is currently. Current global warming may lead to significant change in global and regional climate related health challenges on humans. The main purpose of this work is to investigate the potential impact of climatic variations in relation to human health with Malaria in perspective. The climatic parameter that was used include the average temperature, rainfall amounts and health indexes of the study area. We investigated the factors responsible for increases or decreases in human's health in relation to climate variations. Six years climate data and in and out patient malaria records from hospitals in Kosofe, Lagos were used and analyzed with linear regression analyses using the SPSS. The climate variables used in the bivariate correlation analyses include annual and seasonal totals and monthly rainfall in Nigeria. Preliminary result shows that there is a strong relationship between climate variation in rainfall and malaria disease in Nigeria with seasonal cycles.

Keywords Climatic variation • Weather • Human health • Malaria disease

Introduction

The impact of the global climate change debacle is felt everywhere by both human and ecosystem. Climate variability and change threaten the wellbeing of humans (Tunde et al. 2013). Climate variability can be referred to as difference from statistical average of climate aggregated over certain time periods from months to years. Variability of the Climate could be the result of natural (e.g. impact of variations in solar radiation, Solar and lunar tides, interaction between Oceans and atmosphere and that of atmosphere and biosphere) or anthropogenic (e.g. burning of fossil fuels by humans, changes in land use for development

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purposes (deforestation) and agricultural activities, etc) forcing. According to IPCC (2007) Fourth Assessment Report (AR4), change in the state of the climate that can be identified (e g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period typically decades or longer is called climate change.

In recent years, there has been a consensus among climate scientist that anthropogenic activities constituted the major cause of climate change. Human-induced alterations of the natural world have contributed to the high increase in the rate of gaseous emissions into the atmosphere, thereby causing global warming. Past studies (Buba 2004; Porbeni 2004; DeWeerdt 2007; Odjugo 2007) over decades have revealed that anthropogenic activities like urbanization, population explosion, deforestation, industrialization and the release of greenhouse gases contribute highly to the depletion of the ozone layer and its associated global warming, climate variability and change.

Climate change is adversely impacting the health and lives of billions of people around the world (WHO 2003, 2011). Since 1970s and until the year 2004, over 140,000 excess annual deaths were caused by global warming, with an estimated US$2–4 billion/year direct damage costs to health by 2030 (WHO 2013). There are several ways in which climate change can affect health; some of which are direct effects of hazards—such as heat waves, storms and floods, while others have a more complex pathway that results in the increase of infectious diseases' transmission, disrupting the ecosystem, and causing migration and displacement, as well as conflict that is caused over depleted resources, such as fertile land, water and fisheries (WHO 2003; Pachauri and Reisinger 2007). Health inequity and inequality, manifested through poverty, low education levels, food security, and other factors, play a major role in determining the extent of those health impacts (Akerman 2009), as climate change exacerbates these circumstances posing an increased health risk to vulnerable populations (UNITAR 2013).

From what past studies have already shown about the past health impact of climate change, it is expected that it will adversely impact the lives and health of billions of people over the next decades (WHO 2011; Costello et al. 2009). Indeed, climate variability and change affects the most basic health requirements: clear air, safe water, sufficient food and adequate shelter (UNITAR 2013). It also poses new challenges to the control of infectious diseases, and gradually increases the pressure on the natural, economic and social systems that sustain health (WHO 2009). Health impacts of climate change may differ across populations, and are dependent on several factors such as existing vulnerability and adaptive capacity to changing meteorological conditions of these populations and the associated human and social consequences, as well as a myriad of other determinants that include capacities, available resources, and existing behaviours and attitudes of these populations (UNITAR 2013).

A variation in the climate has direct effect on the epidemiology of many vector borne diseases (Tsai and Liu 2008; Efe and Ojoh 2013), and one of such diseases is malaria (Weli and Efe 2015). Malaria is a major public health burden in the tropics, and has the potential to significantly increase in response to climate change (Sachs and Malaney 2002). Over the past century the world has warmed by 0.6 °C, with a range of ecological consequences WHO (2004). The World Health Organization (WHO) estimates that about 150,000 deaths annually (especially in African countries) are attributable to climate change. About 93 % of the people living in Africa are at the risk of malaria disease (WHO 1985). According to WHO (2004), malaria kills over one million people each year, while 300–500 million people are suffering from chronic malaria around the world. This is one of the most common and serious diseases of our time. The death toll is predicted to double in the next 20 years if no new control measures are developed (Chapman et al. 2005). The disease represents one of the major causes of morbidity and mortality in Nigeria when it is at the peak of its epidemic stature (Salako 1986; Opara et al. 2011). It is also a major cause of maternal death, abortion, stillbirth, premature delivery and pneumonia (FMoH 1989; Opara et al. 2011). Malaria caused 198 million cases in 2014 and killed more than 500,000 people (Murphy 2015). The impact of malaria is widespread and efforts to stop its spread, targets the mosquitoes that carry it (Murphy 2015).

Climate variations and its relations to vector borne diseases was carried out by Githeko and Ndegwa (2001) and it was reported that climate variation has a direct influence on vector borne disease epidemics. A complex interaction exists between man, the parasite, the vector and the environment and this interaction determine malaria‘s endemicity. Climate variation therefore has major impacts on vector and the parasite development. Climate variation is one of the major driving force behind malaria transmission and climate data are often used to account for spatial, seasonal and inter-annual variations in malaria. The transmission of many infectious diseases varies noticeable by seasons, for example, the majority of influenza outbreak in the northern hemisphere occur in mid to late winter (WHO 2000).

Malaria is a significant health and development problem and its contribution to morbidity and mortality among the people of Africa has been a subject of academic interest. An estimated 500 million people suffer from malaria each year and 70 million Sub-Sahara African children of pre-school age (1–5 years) are estimated to be at risk of dying from the disease (WHO 2004). A World Health Organization publication reports that malaria kills over two million people every year, over 80 % of this is in Africa. In addition to child mortality, malaria also causes severe anaemia, miscarriages and deaths in pregnant women; it is also responsible for almost a third of preventable low birth weight in young children (WHO 2006).

Malaria incidence is closely linked with temperature as it affects transmission in several ways among which we can account for two reasons: either the minimum temperature is low that it prevents parasite and vector development or the temperature is too high resulting in increased mortality of the vector. A minimum temperature of 16 °C, restricts parasite development and prevents the development of the vector in an aquatic stages. At 17 °C, parasite develop but not rapidly enough to cause an epidemic (Lindsay and Martens 1998), the annual average of temperature in Nigeria is between 28 and 35 °C. This temperature amount allows rapid development of the malaria epidemic and malaria vector.

Temperature plays a fundamentals role in the rate of multiplication of the parasite in mosquitoes and directly influences the mosquitoes' development. In warmer temperature mosquitoes develop more rapidly, this accelerate the mosquitoes' life cycle and replicating rapidly the growth of the parasite (WHO 2001). The optimum temperature for the malaria parasite extrinsic incubation period is between 20 and 27 °C, while the maximum temperature for both vector and parasite is 40 °C. The average temperature condition of Nigeria is suitable for the development of both the vector and the parasite, this is why malaria is one of the major diseases facing in Nigeria.

Methods and Research Instruments

Study Area

Nigeria lies between latitude 4° and 14° N of the equator and longitudes 3° and 15° E of the Greenwich meridian. The total land area of Nigeria is approximately 923,768 km^2 (Iwena 2000). The farthest distance from east to west is approximately 1300 km and from north to south is approximately 1100 km encompassing a vast geographical area of contrasting landform, climatic conditions and vegetation belts. The country is bordered in the north by Niger republic, in the East by the republic of Cameroon, in the west by the republic of Benin and the south by the Gulf of Guinea in the Atlantic Ocean. Nigeria is a federal republic state consisting of 36 states and Federal capital territory (FCT).

Nigeria is an amalgam of ancient kingdom, caliphates and empires and city states with a long history of organized cities. Nigeria is the most populous nation in Africa, Nigeria account for one-six of Africa population, about 25 % of Nigeria are urban dwellers with over 400 ethnic groups and this gives Nigeria a cultural diversity with population of over 150 million (NPC 2006).

Lagos State

Lagos state is the smallest state in Nigeria, with an area of 356,861 hectares of which 75,755 hectares are wetlands, yet it has the highest population, which is over five per cent of the national estimate. As at 2006, the population of Lagos State was 17.5 million, (based on the parallel count conducted by the state during the National Census) with a growth rate of 3.2 %, the state today has a population of over 21 million. This was corroborated by the recent immunization exercise carried out across the State, where 4.3 million children were immunized. Children within the Immunization bracket are estimated at 20 % of the entire population.

The UN estimates that at its present growth rate, Lagos state will be third largest mega city the world by 2025 after Tokyo in Japan and Bombay in India. Of this population, Metropolitan Lagos, an area covering 37 % of the land area of Lagos State is home to over 85 % of the State population. The rate of population growth is about 600,000 per annum with a population density of about 4193 persons per sq. km. In the built-up areas of Metropolitan Lagos, the average density is over 20,000 persons per square km. Current demographic trend analysis revealed that the State population growth rate of 8 % has resulted in its capturing of 36.8 % of Nigeria's urban population (World Bank 1996) estimate at 49.8 million people of the national populations. The implication is that whereas the country population growth is 4/5 % and global 2 %, Lagos population is growing ten times faster than New York and Los Angeles with grave implication for urban sustainability.

Kosofe Local Government area is the case study for this work and it is located at the northern part of Lagos state, Nigeria. It encompasses an area of about 178.855 km^2, with population of 665,393 (NPC 2006).

Data Collection and Analysis

The data used for this study are Temperature and Rainfall amount obtained from the Nigeria Meteorological Agency (NIMET). Other data collected from the study area consists of health care information on malaria incidents in Kosofe Local Government area of Lagos state Nigeria, public and private health service unit and some health facilities between years 2007 and 2012. According to various categories across various wards and recorded years of the incidence of malaria cases.

Questionnaire instrument was also employed in this study to be able to authenticate the data collected from the local government and health service official. The household head were the major target for the questionnaire administration to get the information on the frequency of occurrences of the malaria diseases. A total of 200 household heads were sampled to get information on the incidence and occurrence of malaria. The household heads were selected randomly within the Kosofe Local Government area.

Data Analysis

Data was analyzed using version 20 of IBM's SPSS software. The regression model was used the test the contribution of temperature, rainfall to malaria incidence.

Regression formula:

$$\text{Regression Equation}(y) = a + bx$$

$$\text{Slope}(b) = \left(N\sum XY - \left(\sum X\right)\left(\sum Y\right)\right) / \left(N\sum X^2 - \left(\sum X\right)^2\right)$$

$$\text{Intercept}(a) = \left(\sum Y - b\left(\sum X\right)\right)/N$$

where

x and y are the variables.
b = The slope of the regression line
a = The intercept point of the regression line and the y axis.
N = Number of values or elements
X = First Score
Y = Second Score
$\sum XY$ = Sum of the product of first and Second Scores
$\sum X$ = Sum of First Scores
$\sum Y$ = Sum of Second Scores
$\sum X^2$ = Sum of square First Scores

The data from the questionnaire was analyzed for the environmental conditions prevalent on site, the percentage of responses were used and presented using tables of percentile and charts.

Result and Discussion

Rainfall, Temperature Variability and Malaria Incidence

Figure 11.1 revealed that the highest amount of rainfall for the 6 year period occurred in 2010. There was a reduction in 2011 after which the rainfall rallied high in 2012. The highest yearly mean temperature peaks were in 2008 and 2010 but gradual drop in 2011and 2012.

From Table 11.1 and Fig. 11.2, Malaria incidence within 6 years was observed and analyzed, from 2007 to 2012, we recorded over 182,987 incidences of malaria infections within the local government area with the highest rate of incidence in 2010 when the highest amount of yearly mean temperature and rainfall were recorded. This amount was distributed between Adult, Children and pregnant women as presented. The highest group of people infected with the malaria are adults followed by the children and lastly by the pregnant women. The amount of malaria infections reduced in 2011 down to 2012. This could be due to fact that Federal Government of Nigeria and the Health Sector embarked in giving out mosquito treated net to the citizenry and created more awareness on eradicating of mosquito infections as well as monitoring the types of drugs used for the treatment of malaria infections. The average annual temperature of the study area is between 30 and 32 °C while the average temperature expected supposed to be 29 °C annually.

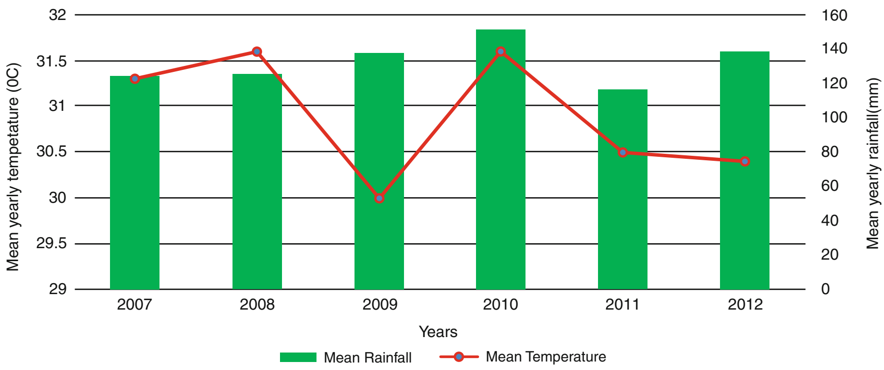

Fig. 11.1 Mean rainfall and temperature variability in Lagos, Nigeria (2007–2012)

Table 11.1 Incidence of malaria in Kosofe, Lagos

Categories	2007	2008	2009	2010	2011	2012
Adult	23,741	27,665	29,130	31,810	27,648	25,361
Children	1099	1669	2011	2907	2239	1460
Pregnant women	873	1213	985	884	1238	1054

Source: Kosofe Local Government Public Health Department (2013)

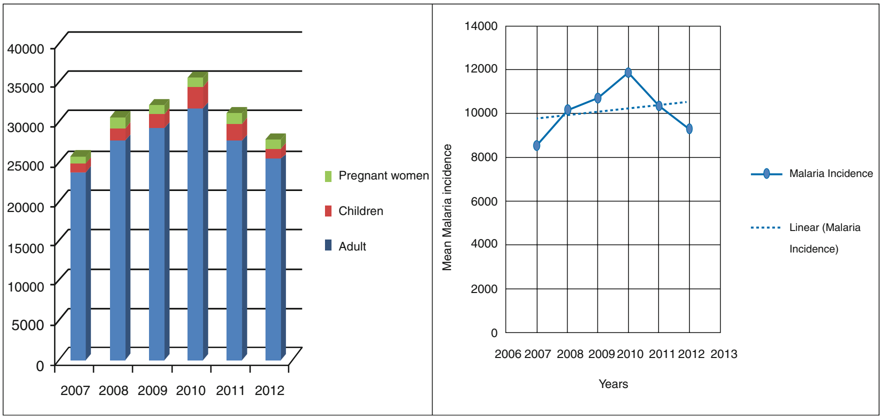

Fig. 11.2 Incidence of malaria between 2007 and 2012 among adults, children and pregnant women in Lagos

Figure 11.3, revealed a correlation value of −0.53253, Y = 33.754x + 15448 and R^2 of 0.0756 between rainfall and malaria indicating a positive relationship between rainfall and malaria disease. The result is 33.75 implies that a unit change in Y it will lead to 33.75 change in X, i.e. a unit change in rainfall, will increase X, (Malaria) by 33.75. The rate of change is $R^2 = 0.0756$ which is expressed as $0.0756 \times 100 = 7.5$ % Therefore, the rate of change in the linear equation capture

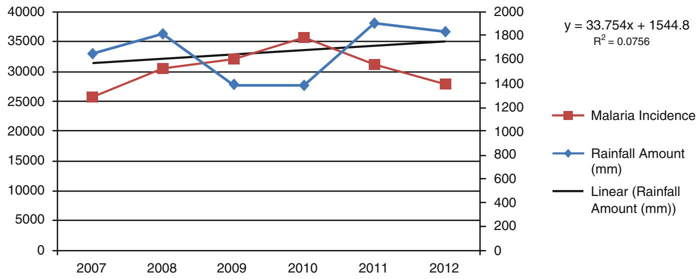

Fig. 11.3 Showing statistical equation of malaria and rainfall in Kosofe local government

is 7.5 %. Correlation also show that the result is positive. i.e., the climatic variable, rainfall fluctuations has direct relationship and impact on malaria in the study area (see Table 11.2) The result corroborates Ayoade (2008) looking at the relationship between climatic element and one climatic control.

Table 11.2 (see Annex) revealed a correlation value, (r) of .548. The strength of the relationship is $.5482 \times 100 = 30$ %. This implies that changes in malaria infection is accounted for by 30 % increase in rainfall variability during the study period.

Figure 11.4, Correlation for malaria with temperature = 0.107788, $Y = -0.0061x + 30.701$ and $R^2 + 0.0003$. There is direct negative relationship between the two variables of temperature and malaria infection incidences. The result is $-0.0061x$, implying that a unit change in Y, (temperature) leads to $-0.0061x$ change in X (Malaria infection). The rate of change is $R^2 + 0.0003$ which is express as $0.0003 \times 100 = 0.03$ % the rate of change in the linear equation capture is 0.03 %. Correlation also show that the result is negative, i.e. temperature has no significant direct impact on the malaria infection in Nigeria (see Annex for Table 11.3).

Table 11.3 (see Annex) revealed a correlation value, (r) of .109. The strength of the relationship is $.109 \times 100 = 1$ %. This implies that changes in malaria infection is accounted for by 1 % increase in temperature variability during the study period.

Household Survey

From the household survey done within the local government. Out of 100 household interviewed, 91 % of them has suffered from malaria infection in the last 6 months one way or the other, either the household head, wife or the children has suffered from the malaria incident. However, none of the household has lost any member of their household to malaria in the last 6 months. It was gathered from the household that they visit both private and public health center and hospitals to treat malarias infections. But about 47 % of the household insist that the hospital treatment is not 100 % effective therefore they also used some local herbs to cure the disease. Of the

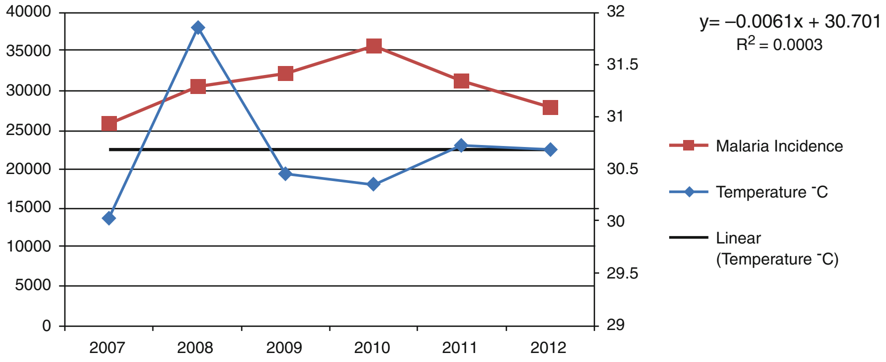

Fig. 11.4 Showing statistical equation of malaria and temperature in Kosofe local government

household interviewed 83 %, of the household uses treated mosquito net and it was given to them in the year 2011, and they have been using it till date. This is why the malaria infection reduced in the year 2011. More also, the same amount of household have mosquito net at their windows and door in their houses. 44.90 % of the respondents believed that the level of malaria had increased, 31.63 % believed it had reduced while 23.47 % felt that it is stagnant. It can therefore be deduced that the level of malaria cannot be ascertained.

Table 11.4 shows that the major cause of malaria according to respondents are mosquito bites (84.5 %), Malnutrition (8 %), Stress (7 %) and other causes (.5 %).

Table 11.5 revealed that the incidence of malaria are higher during the raining season (76 %) and lower during the dry season (24 %).

From Table 11.6, it can be deduced that 27 % of the respondents prefer the use of insecticides in combating mosquitoes, 10 % believed in environmental sanitation, 8.5 % chose mosquito nets, and 46.5 % prefer ITNs while 8 % chose others which include the use of mosquito coils, avoidance of stagnant water etc. This indicates that insecticides Treated Nets (ITNs) are widely used while the use of ordinary mosquito nets is low.

From the survey, 65 %, of the household contribute to the cleaning of their environmental during the monthly environmental sanitation exercise. While 23 %, household involves in the weekly environmental sanitation exercise, 46 %, has no waste bin, while 95 % household make use of municipal waste collector, and 5 % make use of cat pusher to dispose their waste. 48 % indicates that there is urban farming in their neighborhood. This could lead to breeding of the mosquito's eggs.

Table 11.4 Causes of malaria

Causes of malaria	Frequency	Percentage
Stress	14	7
Mosquito bites	169	84.5
Malnutrition	16	8
Others	1	0.5
Total	**200**	**100**

Source: Field observation (2013)

Table 11.5 Season in which malaria incidence is high

Season of higher infection	Frequency	Percentage
Rainy season	152	76
Dry season	48	24
Total	**200**	**100**

Source: Field observation (2013)

Table 11.6 Mosquito's combatants

Mosquitoes combatants	Frequency	Percentage
Insecticides	54	27
Mosquito nets	17	8.5
Insecticides Treated Nets (ITNs)	93	46.5
Environmental sanitation	20	10
Others	16	8
Total	**200**	**100**

Source: Field observation (2013)

Policy Issues: Abuja Summit and Declaration and Its Effect on Malaria in Nigeria

The Roll Back Malaria (RBM) partnership held a summit in Abuja, Nigeria in April 2000. One of the targets was to have 60 % of population at risk sleeping under insecticide-treated net, (ITNs) (a special type of treated mosquito net) by 2005. This will require 32 million mosquito nets and a similar number of insecticides re-treatments each year. To promote the use of ITNs, RBM agreed on the following:

- Organize public education campaigns in malaria endemic areas;
- Lobby for reduction or waiver of taxes or tariffs on mosquito nets, netting materials and insecticides;
- Simulate local ITN industries and encourage competition among them by ensuring private sector investment in manufacturing and importation of mosquito nets;
- Further government action in the form of targeted subsidies, or subsidy schemes to bring ITN prices down to level affordable to the poorest families;
- Focus and capitalize on the potential of newly developed long lasting insecticides treated mosquito nets (LLINs).

Unfortunately, ITNs can be expensive for families at risk of malaria, who are among the poorest in the world. The best hope lies with newly developed long lasting insecticide-treated nets (LLINs) which may retain their insecticides properties for 4–5 years, the life span of the nets, thus making retreatment unnecessary.

Summary of Findings

The summary of findings is discussed below:

- The variation or fluctuation in climate parameter of rainfall has a positive effect and therefore correlation on the incidence of malaria in Kosofe LGA while temperature has a negative correlation;
- The incidence of malaria despite all innovation is still high in study area and it is higher during the raining season and that the major cause is through mosquito's bites, and ways people have been preventing these mosquitoes bites is through the use of insecticides, environmental sanitation, mosquito coil etc;
- The knowledge of insecticides treated mosquito nets is very high, and this can be attributed to effective campaign through the television and radio about the effectiveness of the insecticides treated mosquito nets and its distribution by the local government, the usage level of ITNs however is very low and this may be due partly to the general lack of access, cost, possible inconveniences caused by its use and the fear of possible health implication;
- The ITNs are very economical especially the LLINs because it can last for 2–5 years before replacement and this actually correlate with research findings. However the durability of the nets depends on its nature this is because some are needed to be treated on a monthly basis (ITNs) while some can actually last for 3 years i.e. the LLINs.

Conclusion/Recommendations

Malaria is still a major endemic health problem in Nigeria. Climate variability exacerbates the incidence of malaria as the reported incidence varies from 76 % during the rainy season to 24 % during the dry season as a result of its correlation with rainfall and temperature. Malaria is a preventable and curable disease whose causal agents, mosquitoes of the genius anopheles are the vector for the four plasmodia parasites (Greenwood et al. 2002). Therefore a lot of effort should be put in place in order to improve the situation. This could include making the nets available to those at the highest risk who cannot afford the nets and not only that but also ensure that the people use the nets. The effectiveness of ITNs intervention in reducing the burden of malaria has been amply demonstrated in a variety of epidemiological settings. Now, the advent of LLINs and treatment technologies has opened up prospects for improving ITNs intervention by addressing the issue of treatment and re-treatment. It is critical to seize this opportunity and rapidly expand access to these new technologies for all populations at risk of malaria, integrating the distribution of free and highly subsidized LLINs into existing health services, especially immunization and antenatal care services, complemented by distribution through child health days/weeks and immunization campaigns should help in the rapid achievement, and sustaining of full ITNs coverage. To increase current ITNs coverage, the untreated or conventionally treated nets currently in use should be treated using long-lasting treatments kits, once they are available. Effective communication and monitoring and evaluation strategies must be in place, alongside systems for delivery, so that the impact of the intervention can be enhanced and assessed.

Based on the findings of the study, the following are recommended to ensure that some of the elements that will ensure that the incidence of malaria is reduced and the use of ITNs are accepted and used on a sustainable:

1. Environmental engineering: This Includes removal of stagnant water, proper drainage system, proper disposal of waste, cutting of grasses on the fields;
2. Avoidance of vectors: this involves cultivating the habit that encourages the separation of humans from the malaria vectors (i.e. the mosquitoes) through the use of repellant, indoor spraying with residual insecticides, and insecticides treated mosquito nets in order to reduce the incidence of malaria;
3. Cost and Quality of the nets: the cost of the nets should not be too high so that they are affordable to all especially the target population which are the most vulnerable i.e. children between the ages of 3–5 years and pregnant women. In order to achieve this, it may require the subsidization of the cost of the nets. However, the cost of the nets should not be set so low that people would prefer to buy new nets rather than maintaining the old ones. In order words so that people will not take it for granted and also in order not to produce nets with little or no quality;
4. Sensitization about the effectiveness and adverse effects of the nets if not properly used: This may involve organizing seminars, campaign programs, and counseling programs for the people at the various health centers on the effectiveness of the nets and how to use it in order to get the desired results without any health implications.

Acknowledgements The authors acknowledged the viable suggestions offered by the two independent reviewers and the editor which helped to improve the quality of the work. Thank you.

Annex

Table 11.2 Pearson correlation between malaria and rainfall

Correlations			
		Mean rainfall	Mean malaria incidence
Mean rainfall	Pearson Correlation	1	.548
	Sig. (2-tailed)		.020
	Sum of Squares and Cross-products	818.540	40,097.060
	Covariance	163.708	8019.412
	N	6	6
Mean malaria incidence	Pearson Correlation	.548	1
	Sig. (2-tailed)	.260	
	Sum of Squares and Cross-products	40,097.060	6,540,296.455
	Covariance	8019.412	1,308,059.291
	N	6	6

Table 11.3 Pearson correlations between temperature and malaria

		Mean malaria incidence	Mean temperature
Mean malaria incidence	Pearson Correlation	1	.109
	Sig. (2-tailed)		.837
	Sum of Squares and Cross-products	6,540,296.455	429.230
	Covariance	1,308,059.291	85.846
	N	6	6
Mean temperature	Pearson Correlation	.109	1
	Sig. (2-tailed)	.837	
	Sum of Squares and Cross-products	429.230	2.360
	Covariance	85.846	.472
	N	6	6

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Chapter 12
Climate Change and Mosquito-Borne Diseases

Teresa Nazareth, Gonçalo Seixas, and Carla A. Sousa

Abstract Ecology, development, behaviour, and survival of mosquitoes as well as the transmission dynamic of pathogens, strongly depend on climatic factors. Models have been developed to predict forthcoming mosquito-borne diseases scenarios based on estimations of future climate patterns. However, the complex interplay of climate variables with the mosquito-host-pathogen systems rend the overall effect of the climate on the local prevalence of mosquito-borne diseases difficult to determine. Therefore, the assumption that warmer global temperatures will produce increase mosquito proliferation and geographic range may not be entirely true. Furthermore, general climatic observations may not reflect the local microclimates experienced by mosquitoes, mainly by the synantrophic species which live in mild human-modified habitats. Human socio-economic context, community's culture or behavioural habits are also sidestepped factors prone to influence MBD transmission.

This chapter pretends to illustrate the complex scenario where mosquito-borne diseases develop and the myriad of consequences that climate may induce in the incidence of these illness. Different types of models used to predict forthcoming mosquito-borne diseases scenarios are presented as well as the limitations that might preclude their use as tools for the design of surveillance or control strategies.

As an example, it is also presented the history of dengue prevention and re-emergence. The evolution of this well documented disease reveals that besides climate, the increase of human population density, the growth urbanized areas, the upsurge of international mobility, the discontinuity of sustainable source-reduction activities and the emergence of insecticide resistance in mosquitoes are also determinants for dengue prevalence increase.

Keywords Climate change • Mosquito-borne diseases • Disease transmission dynamics • Predictive models • Non-climate factors • Dengue

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Introduction

Mosquitoes have a development cycle which starts when an adult female lay eggs in water. These eggs hatch into larvae, that metamorphosis into pupae, before generating new adult flying mosquitoes. Most species are hematophagous, biting vertebrates to acquire nutrients (Lane and Crosskey 1993) that are essential for eggs maturation. It is due to this biological feature that mosquitoes can transmit, to the vertebrates that are bitten, different types of pathogens. Some of these pathogens are responsible for important human diseases, such as virus (dengue, Chikungunya and yellow fevers), protozoa (malaria) or helminths (filariasis).

All mosquito-borne diseases (MBD) depend on the existence of three partners and a perfect interplay between them: a susceptible human population, a sufficiently prevailing pathogen and a vector (mosquito) population.

It seems unquestionable that the transmission of MBD strongly depends on climate factors and consequently climate change can drive important alterations in MDB burden and distribution. This trend is strengthened by the recent increase of several MBD worldwide frequently related to the current alterations in climate. In order to prevent and respond to this public health challenge, models have been developed to predict forthcoming MBD scenarios based on estimations of future climate patterns.

Understanding (1) how mosquito populations are or will be affected by climate, and; (2) how pathogen development inside the mosquito-vector is affected by the surrounding environment, are two paramount issues to predict the response of MBD to climate change. However, being a complex system, MBD are affected by several environmental alterations from the molecular to the human population level, where climate change is only one example of variation input.

In this chapter we will try to give an overview not only of the relevant conclusions from predictive climate-based modelling studies but also the sidestepped social, economic and cultural factors that underline MBD transmission dynamics. Due to the myriad of pathogens transmitted by mosquitoes, these subjects will be explored in the context of dengue disease. Thus, this chapter is organized in three main topics: one concise review of the most common types of predictive models used to forecast the effect of climate change on MBD; a second topic which address the main limitations of these predictive models and a third section which intends to illustrate, using the dengue context, the main conclusions of this chapter.

Climate-Based Predictive Models

Two approaches can be adopted to achieve predictions: (1) through **mechanistic/physiologically-based models** (Buckley et al. 2010) and (2) through **correlative-based models** (Kearney et al. 2010). The former are explicitly based on the key mechanisms by which environmental factors determine population viability. In these models all the parameters have biological definitions and can be measured independently. Correlative models, on the other hand, rely on the spatial association between the species distribution and a set of potentially important environmental factors to deduce the drivers of distribution.

R0-Based Models

Predictive models for the emergency or resurgence of MBD are often based on estimates of the basic reproduction rates, also denoted R0 models (see Exp 12.1). The most elaborated ones evaluate three different parameters: (1) **infectivity**, namely, the mosquito vector competence, (2) the **receptivity**, determined according to the vectorial capacity of the population of mosquitoes present; and; (3) the **vulnerability** of the territory, estimated by the number of pathogens carriers capable of transmitting the infection to the population of mosquitoes introduced per unit time in the territory under study (Alten et al. 2007). Thus,

$$\mathrm{R0} = \mathrm{Infectivity} * \mathrm{receptivity} * \mathrm{vulnerability} \tag{Exp 12.1}$$

where,

R0—Refers to the risk of local transmission of a MBD;

Infectivity—Assessed as mosquito vector competence;

Receptivity—Refers to mosquito vectorial capacity;

Vulnerability—Estimated as the number of pathogen carriers infectious to the mosquito population.

To become a pathogen vector, the mosquito must present both **vector competence** as well as **vectorial capacity** to transmit the disease agent. Although easily confounded, these two epidemiological parameters address to quite different aspects of MBD transmission. The first assesses the mosquito susceptibility to became infective, measuring the mean number of mosquitoes (in a population) that, after an infective blood meal, are able to transmit the pathogen to unaffected hosts. The second parameter assesses the mosquito transmission ability, estimating how many potential infective mosquito bites (in humans) a population of mosquitoes can generate from a single case of disease, per unit of time (usually a day), if all the vector females biting the case became infected (Garrett-Jones 1964). Due to the physiological complexity of parameters underling mosquito-species vector competence and vectorial capacity, some predictive models address only of these parameters with detriment of the other.

Models Addressing Pathogens' Developing Cycle Inside the Mosquito Vector

Insects have an immune system that can prevent the pathogen from developing inside them. Vector competence, estimates the proportion of mosquitoes of one population that are able to replicate and transmit a pathogen to an uninfected host. The development phase of a pathogen inside their vector is called **extrinsic cycle**. The interval of days that elapse since the pathogen is acquired by the vector until the vector is able to transmit it to other susceptible vertebrate hosts is called **extrinsic incubation period** (EIP). Mosquitoes like other insects are heterothermic animals and thus their body temperature depends on the environmental temperature. In the same way, a pathogens' development inside an arthropod can also be affected by climatic conditions.

One can find temperature-based models developed for several pathogens (e.g. malaria parasites and filariasis) that are aimed at: (1) modelling the duration of the extrinsic incubation period (e.g. Detinova 1962) or, (2) the assessment of the number of days, per year, that the mosquito population may harbour or allow the development of a pathogen inside their specimens (e.g. Slocombe et al. 1989).

However, these physiological models usually address vector competence as an on/off system, since they answer to the questions: whether or not temperature allows the development of the pathogen, and if yes, what is the duration of the extrinsic incubation period under different temperature conditions. Most of then, in fact, do not assess how vector competence is modulated by climate variables.

Models Addressing Mosquito's Vectorial Capacity

The presence of 100 % competent vector species, infected with target-pathogen, under favourable climate conditions for pathogen development inside the insect, does not mean that disease transmission will take place. Thus, some physiological risk models try to address this issue looking, not to how climate will affect vector competence, but how it will affect transmission of the disease, i.e. the vectorial capacity of the mosquito (C). In places where disease does not exist, the vectorial capacity will also show how receptive to transmission those places may be, that is, what rate of inoculation (i.e. number of potential infective mosquito bites) may be expected to result from the introduction of an imported disease case (Garrett-Jones and Shidrawi 1969).

To assess the vectorial capacity of a local population of mosquitoes (C), we have to determine, in time and space, estimates of biological variables such as the density of the species, their longevity, their trophic behavior as well as the pathogen's EIP duration. In general, the vectorial capacity of a local mosquito population is calculated based on Exp 12.2, in which, m stands for vector densities related to humans and a for vector biting habit; p refers to the daily survival probability or proportion of vectors surviving *per* day; and, n is the incubation period of the parasite inside the vector (EIP).

$$C = \frac{ma^2p^n}{-\ln p} \qquad \text{(Exp 12.2)}$$

Habitat Suitability Models

Due to the complexity of parameters estimation, often **receptivity** risk assessment is restricted to the development of habitat suitability models. Although being relatively less complex models, they can be very informative regarding diseases dependent on the vectors density, such as malaria in temperate regions or dengue in epidemic areas. These correlative-based models try to relate the presence and/or absence of a certain species with a set of environmental independent variables considered influential in the species distribution.

The selection of environmental variables with the greatest predictive potential must be made based on existing knowledge about the factors that influence the distribution of the target-species. Considered one of the major steps in habitat suitability modelling (Araújo and Guisan 2006) this selection usually includes variables associated with temperature, precipitation, the presence of water, type of land use, among others.

These correlative models may also be established using variables estimates collected by remote sensing as meteorological and landscape proxies. In this case, beside the adequate assortment of environmental parameters, the success of these models also depends on the selection of appropriate spatial and temporal scales. Some of these studies are not efficient for environmental analysis at high resolution scales because they do not detect climate heterogeneity and environmental fragmentation of certain biotopes. Thus, predictions about areas not physically sampled, usually require the analysis of environmental parameters acquired in the appropriate scales over large geographic regions (Rogers et al. 2002) but the advantage of satellite data as environmental surrogates has been shown by several authors (e.g. Rogers et al. 2002; Green and Hay 2002; Machault et al. 2011). Several studies have addressed not only species geographic distribution (Capinha et al. 2014) but have related temporal and spatial vegetation indices variability (e.g. NDVI) with the dynamics of vector populations (Rogers et al. 1996; Hay et al. 1997; Sainz-Elipe et al. 2010; Lourenço et al. 2011); or have identified potential larval habitats of mosquitoes using medium-high (e.g. Land Sat or Mikonos) resolution satellite data (e.g. Pope et al. 1994; Hay et al. 1998; Mushinzimana et al. 2006).

Finally, models with better predictive assessment present, not only a correct selection of environmental variables and appropriated spatial and temporal scales, but are built on well-defined entomological information. Entomological data should be gathered based on: (1) collection methods specific each vector species; (2) well defined and standardized collection protocols, and; (3) specimen's captures prolonged in time and/or space. The choice of the method for mosquito's collections and their periodicity assumes prior knowledge of the species under study.

Habitat suitability models can also be used to infer how climate-driven changes are likely to affect species distributions, namely, the loss of current appropriate habitats, the appearance of newly suitable areas and changes in habitats size either due to fragmentation or coalescence (Pereira et al. 2010). These changes in habitat suitability will have potential impact not only on the target-species, but also on biotic-community interactions, ecosystem function (Lavergne et al. 2010), and thus in disease transmission.

Limitations of Climate-Based Predictive Models

It is unquestionable that the transmission of MBD strongly depends on climatic factors. However, the assumption that climate change is the major driver of the current increase in mosquito-borne transmission, or that estimations of future climate patterns can predict forthcoming mosquito-borne disease scenarios is not consensual among experts (Reiter 2001; Jansen and Beebe 2010).

Several authors have been pointing out the relevance of some factors in MBD transmission dynamics (Reiter 2008; Rezza 2014; Tabachnick 2010) that might impose limitations on the predictive value of models, thus, precluding their use as tools for the design of surveillance or control strategies and general public health decision making. These factors are summarized in subsequent paragraphs.

Besides temperature, mosquito proliferation is altered by several climate factors some of them with opposite effects. Rainfall and humidity are determinant variables, and even wind velocity and photoperiod can be influential. Global warming may lead to an increase of temperature but in some regions this rise will be accompanied by the decreased of relative humidity. So, if, by one hand, the rise of temperature might accelerate the development cycle of the mosquito contributing for the increase of the species densities and of disease transmission, on the other hand, the decrease of humidity may restrict mosquito longevity, diminishing transmission, and simultaneously upsurge females biting frequency, increasing transmission. Therefore, the prediction of the climate effect on mosquito proliferation is not a straight forward issue, frequently requiring the unravelling of a complex orchestration of climatic and entomologic factors. Since not only the overall climate alteration is difficult to predict, but also its final input on mosquito proliferation is hardly foreseen (Cook and Zumla 2009), and given that predictive models can integrate a limited number of variables, and barely consider their cumulative interdependent interaction, the validity of their conclusions could be compromised.

The second issue has already been mentioned previously. Most mosquito-vectors of human diseases explore human-related habitats in microclimate conditions not detailed in many climate-based predictive models. For instance, the 'heat island effect' in the urban environment or milder human-modified habitats can impact the mosquito climatic suitability regardless the global climate change effect (Rezza et al. 2007). Thus, the predictive power of macroclimate alone as a general forecaster of the species distribution or abundancy have been frequently questioned (Reiter 2001; Jansen and Beebe 2010). Moreover, the association between climate and MBD transmission will almost certainly vary between localities according to the socio-economic and cultural context of the host population (Nazareth et al. 2014). Sociological characteristics will determine water storage practices (and consequently the availability of water collections for larval development), the adoption of protective/preventive measures, the human density inside households, the connectivity of the locality with endemic/infested areas, and the access to healthcare of the local population. Therefore, in order to attain a precise prediction of local MBD prevalence, models should not only be able to consider climate data at a micro-level, but also to contemplate other non-climate variables.

Finally, the use of climate-based predictive models to estimate MBD burden and dispersion usually assume that mosquito bionomics and behaviour will not be altered in time. In fact models' assumptions accept that environment will affect vector ecology in a shorter timescale than vector evolution. If one assumes that this paradigm might not be correct, and that natural selection might modulate/alter mosquito responses (and thus, disease dynamics) to climate changes, conclusions drawn from predictive models may be compromised. This subject have already been addressed by some authors (Sternberg and Thomas 2014) but studies related to vectors evolutionary dynamics as a result of climate change are difficult to conduct and interpret (Egizia et al. 2015).

Dengue, an Emerging Mosquito-Borne Disease

Dengue is currently considered by WHO the major human arboviral infection worldwide (Murray and Wilder-Smith 2013).

Over the past 50 years, the global number of dengue cases has increased 30-fold, and it is currently emerging in temperate areas all over the world. In 2010 and 2013, sporadic autochthonous cases were reported in mainland Europe (Gould et al. 2010; Gjenero-Margan et al. 2011). Moreover, in 2012, the first dengue outbreak occurred in the European Madeira Island with more than 2100 dengue reported cases (Sousa et al. 2012; Rodrigues et al. 2015). Since 2001, several areas of the USA reported autochthonous dengue outbreaks (Adalja et al. 2012). In northern-east, Australia virus importation and transmission has been increasingly observed in the last 20 years, causing sporadic outbreaks (Warrilow et al. 2012). Africa is not an exception, being now-a-days also considered as a high-risk area for dengue transmission despite the alleged diagnosis' underestimation (Rodrigues et al. 2013; Parreira and Sousa 2015).

These increasing dengue burden and global distribution have been (at least partially) attributed to the recent global warming, assuming that it have generated (and are still generating) climate suitability for dengue transmission in a broader global area. Several studies have attempted to explain current dengue distribution and predict its potential forthcoming range shifts under present and future climate scenarios.

Suitable conditions for the establishment of dengue main vector, *Aedes aegypti*, are unquestionably related to climate. Water-scarcity and thermal extremes are well known constraints to its establishment. Long-term exposures to temperatures below 0 °C or above 34 °C are commonly fatal to larvae (Chirstophers 1960). In what concerns the global distribution of dengue main vector, *Ae. aegypti*, despite the multiple factors that can shape it, it is assumed that climate is largely responsible for the delineation of its maximum range limit, and thus climate change may indeed promote relevant modifications on the species' global distribution (Capinha et al. 2014).

However, *Ae. aegypti*, presents a marked synanthropic behavior, being able to freely enter in human houses, feeding, and resting inside or around them (Jansen and Beebe 2010). Females of these species usually fly less than 25 m to lay their eggs and their most frequent breeding sites are artificial water-containers of domestic use, such as, drums, buckets, or tyres. Thus, *Ae. aegypti* specimens can complete their entire life cycle in the domestic environment (Harrington et al. 2005). Due to this close association with human environments, *Ae. aegypti* can particularly overcome unsuitable climatic conditions by exploiting human-made thermal shelters. Therefore, models strictly based on the physiological response of *Ae. aegypti* to climate (Hopp and Foley 2001), predict narrower range of suitable habitats than those built on an occurrence-based approach that take into account the potential role of facilitating human-factors (Capinha et al. 2014).

Furthermore, variations on *Ae. aegypti*'s distribution may also be caused by changes on vector control programs (Omeara et al. 1995; Vasconcelos et al. 1999). Current geographical spread of *Ae. aegypti*, does not reflect the maximum range it has already achieved before 1950 (Lounibos 2002). Europe, North America and part of Australia presented important dengue epidemics until the late nineteenth century, revealing that these territories already had climatic suitability for dengue transmission before the global warming registered in the past 50 years (Reiter 2001). Subsequent dengue declination and recent re-emergence in these territories, has been seen as irrespective to the current climate change. The advent of powerful insecticides, such as DDT, and the housing conditions improvement sustained the former. The latter was triggered by the rapid emergence and spread of insecticide resistance, followed by difficulties in implementing alternative sustainable vector-control activities.

The close association of *Ae. aegypti* to humans also turns dengue transmission, and overall disease prevalence, much more prone to be influenced by human socio-economic context, community's culture or behavioural habits, than other MBD. Moreover, climate itself can also drive behavioural changes in humans altering the transmission dynamics differently from what would be theoretically expected. Several studies suggest a positive association between drought-climate and dengue transmission despite the known requisite of water availability for egg hatching and larval development (Chretien et al. 2007; Beebe et al. 2009; Pontes et al. 2000).

This apparent paradoxical result is explained by a human behavioural adaptation to collect water in provisory and inadequate domestic water stores during dry seasons. Thus, several authors have point out factors, other than those climate-driven, for the current pattern of dengue escalation. Among those factors, increased population density, a growing urbanization, a rise of international mobility (touristic and trade), an ineffective mosquito control strategy and an improved reporting capacity (Gubler 2004; Brathwaite Dick et al. 2012) are some of the most stated.

Conclusions

There is a complex interplay of several factors determining the overall effect of the climate on local MBD. Predictions regarding MBD based on the effect of climate change are not simple. Climate-based predictive models are critical to provide conclusive evidence on how climate can alter this complex system. However, a deeper understanding of the mosquito-pathogen-host system and how it relates with the interconnected environmental variables is still lacking to ensure a reliable prediction of climate-driven effects on future MBD' prevalence or dispersion. Moreover there are unavoidable non-climate factors which also importantly influence resulting prevalence of MBDs. When translating models' conclusions to local decision-making, these non-climate factors need also to be considered in order to provide effective guidelines for surveillance and preparedness in MBDs risk areas. Nonetheless, climate-based predictive models are still one of the best tools available to pin-point the potential hotspots for some MBD's emergence. They provide scientific evidences that support the implementation and/or maintenance of MBD surveillance programs. It is clear that its limitations are recognized and thus, predictive models which aim to assess risk of MBD's emergence are becoming more complexes, trying to tackle several disease determinants, beside climate itself.

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2012, and as WHO consultant during Mozambique's Dengue outbreak (2014). Teaching commitments include coordination of one Curricular Unit since 2011. She is/was the co/main supervisor of 2 PhD students, 5 MSc students and 1 graduation student. At IHMT, she is member of the Scientific Council, Ethical Board and IHMT's Council. C. A. Sousa is author/co-author of 42 peer reviewed research papers and two book chapters.

Chapter 13
Climate Impacts on Dengue Risk in Brazil: Current and Future Risks

Paula Carvalho Pereda and Denisard Cneio de Oliveira Alves

Abstract Dengue fever is a climate-sensitive disease that affects thousands of Brazilians every year and generates substantial losses in private and public markets. This chapter aims to identify the roles of climate, both seasonal and historical, on the risk of dengue epidemics in Brazil while controlling for socioeconomical and political influences on the disease as well as the immune status and spatial contagion of populations. By testing and understanding the climate effects on dengue using a risk function for Brazilian data, this chapter intends to link two relevant agendas: the identification of ways to manage the climate related risks of today and improve the understanding of future risks in the country.

The findings indicate that if climate change occurs as expected, there will be a potential added risk for central-southern areas in Brazil and a risk reduction for northern areas of the country. Short-term deviations from normal rainfall conditions in summer also increase the risk of dengue. Other relevant findings suggest the ineffectiveness of current local expenditures for epidemiological surveillance and the need for integrated actions to control the disease, which include the best use of climate forecast to predict dengue cases.

Keywords Dengue fever • Climate-sensitive diseases • Economics of climate • Climate change • Future dengue risks

Introduction

Dengue fever is the main target infectious disease in Latin America, and it represents 83 % of the Brazilian cases of diseases with mandatory notification in previous years. There were approximately 4.2 million dengue fever notifications in Brazil between 2001 and 2010 (SINAN 2011).[1] In 2010, a spate of dengue fever epidemics occurred, and approximately one million cases of the disease were

[1] SINAN is a national system for notification and investigation of notifiable disease cases that has been in existence since 2001.

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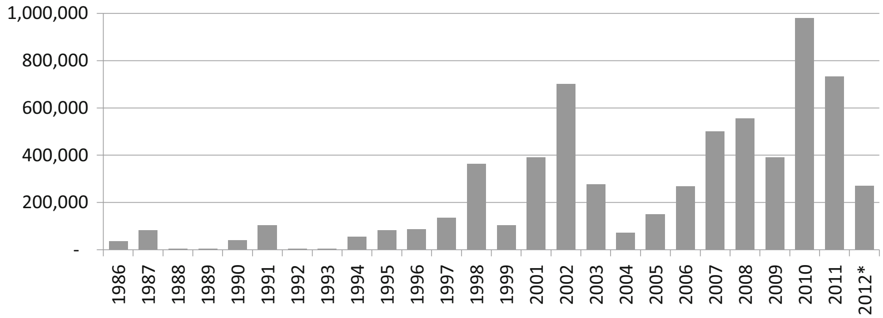


Fig. 13.1 Dengue notifications by year in Brazil, 1986–2012. Source: SINAN (2011). Prepared by the author

reported in the country. The aggravation of dengue incidence in Brazil has caused private and public losses of approximately $880 million dollars in 2010, which represents $383 per hospital patient[2] (Shepard et al. 2011) (Fig. 13.1).

The spatial distribution of dengue cases suggests state dependence of the aggregate data. The Southeast and Midwest exhibited the highest incidence of dengue in 2010, which accounted for 458,515 cases and 209,855 cases, respectively. A high incidence was identified throughout the country, with the exception of the South, where the current climate conditions are less favorable for mosquitoes (Fig. 13.2).

Since the 1990s, the Brazilian dengue control has been established by zoonosis control and the collective action of society as a whole (Braga and Valle 2007). However, the programs have not achieved the goals to eradicate dengue, and vaccines for dengue fever remain unavailable.[3]

Dengue is transmitted to humans mainly by female *Aedes aegypti* mosquitoes, which are highly sensitive to environmental conditions. Seasonal changes in air temperature, humidity and hydrological cycles lead to changes in the reproductive cycle and survival of these vectors. Mosquitoes have no regulatory system; thus, their body temperature is the same as the air temperature. Higher temperatures reduce the time for virus replication and dissemination in the mosquito; furthermore, if it becomes infectious faster because temperatures are warmer, which thereby increases the risk of human infection. Water accumulation is also important for the reproduction and spread of mosquitoes because they breed in water. In Brazil, water can accumulate in houses because of rainfall accumulation or storage for self-consumption, especially during droughts (Shope 1991; Kelly-Hope and Thomson 2008; Brazil 2008).

The international literature regarding the relationship between climate and infectious disease focuses on the study of malaria because of its importance in the African continent. In general, the literature indicates evidence of an existent but

[2] This refers to direct and indirect costs, not including mosquito control campaigns.

[3] The four current serotypes of dengue (DEN-1, DEN-2, DEN-3, and DEN-4) are spread in many Latin American countries, which makes the development of a vaccine for dengue more difficult.

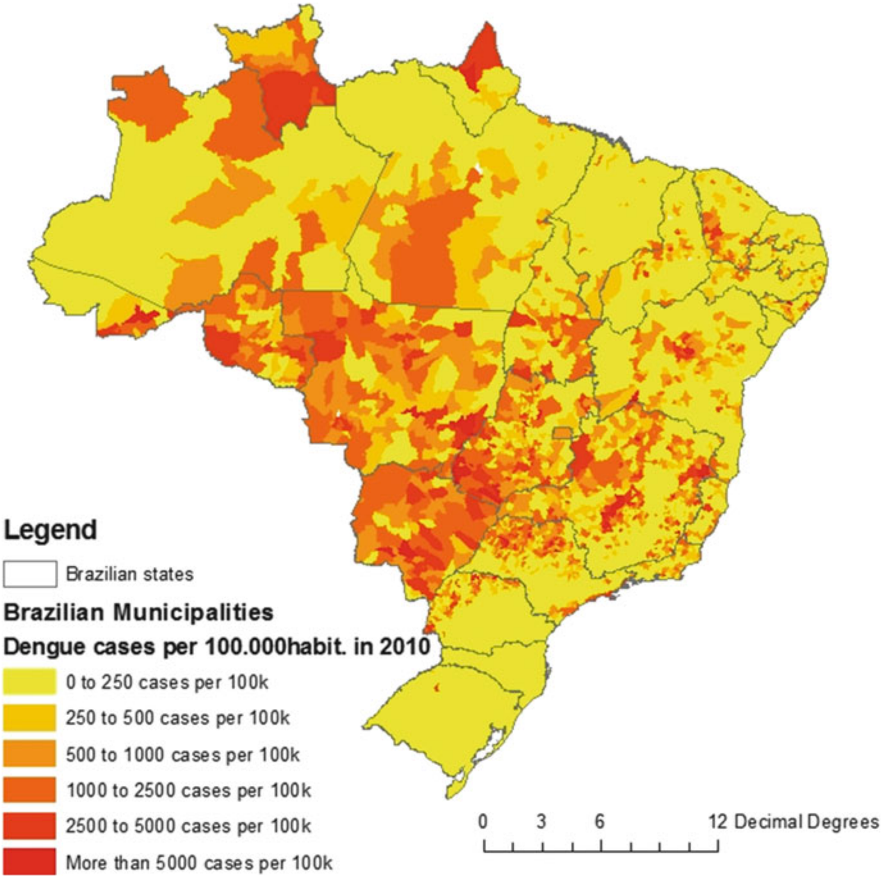


Fig. 13.2 Spatial distribution of dengue per 100,000 inhabitants, Brazilian municipalities, 2010

complex effect of temperatures on malaria (Tanser et al. 2003; Hales and Woodward 2003; Reiter et al. 2004; Thomson et al. 2006).

In regard to dengue fever, ecological studies typically investigate the effect of mosquito evolution on the disease incidence. These studies often disregard factors not closely related to the reproduction and development of mosquitoes, such as regional and socioeconomic factors, which are important for disease vulnerability (Wu et al. 2009).

Naish et al. (2014) and Morin et al. (2013) reviewed international studies that associate climatic conditions and dengue transmission. The authors highlight that the evidence indicates dengue transmission is sensitive to climate, and it is important to develop and integrate different modeling approaches to identify dengue risks. Both reviews also emphasize that human factors, including behavior, immune status, and socioeconomic influences, also contribute to the complexity of these relations, and few studies consider these factors in the modeling strategy.

Brazil is an interesting setting to study the impacts of climate and public policy on the pattern of dengue because of its regional and climatic diversity, which facilitates identification of climate effects on the disease. Few studies have explored the relationship between climate and dengue in Brazil, and most studies examined specific municipalities: Rio de Janeiro (Gomes et al. 2012); Campo Grande, Maringá and Ribeirão Preto in the Center-South regions (Roseghini et al. 2011); and Boa vista, capital city of the northern state of Roraima (Rosa-Freitas et al. 2006). Lowe et al. (2010) also developed a model to predict short-term climate effects on dengue cases in Brazil.

The studies that analyzed Brazilian data have focused on the short-term effect of climate on dengue cases and identified a statistically significant effect of temperature and rainfall on dengue risk (Gomes et al. 2012; Roseghini et al. 2011; Lowe et al. 2010). These studies predominately comprised linear lagged relationships (weekly and monthly), and only a few studies included social determinants to explain the disease incidence. In regard to climate change risks, Brazil (2008) is the only study that addresses the threats of climate change on health issues, especially infectious disease; however, the study does not predict the potential effects.

As a result of the increasing concern with dengue and its relationship with climate in Brazil, this chapter aims to: (1) identify the role of climate on the risk of dengue epidemics in Brazil (seasonal and long-term effects), (2) control for socioeconomic and political influences on the disease, (3) forecast the future risks of the disease, and (4) control the model for the immune status and spatial contagion (neighborhood transmission) of the population.

We hypothesize that if climate changes are confirmed, the dengue fever risk will increase in climate vulnerable areas, in which climatic conditions better suit the reproduction and survival of mosquitoes. Furthermore, the risk will decrease in areas in which the temperatures are currently high and are expected to further increase.

Different count data models with distinct strategies for climate variables are analyzed in a risk function of the disease controlling for socioeconomic, political and environmental determinants. To the best of our knowledge, no previous study has incorporated all determinants of dengue fever together with climatic conditions in the short and long-term for all municipalities in Brazil. This approach enables an improved identification of the intended effects.

The following section develops the empirical strategy and modeling approach to test the proposed problems as well as the database description, which is followed by a section that presents the model outputs. The final section summarizes the main findings and addresses the limitations and future research topics.

Methods

Production Function for Dengue Eradication

This subsection describes how the ideas originally developed by health economists can be used to investigate dengue inside the literature of health production functions (Grossman 1972). The motivations for individuals to pursue better health are that a good health status positively affects their welfare (whereas sick time has negative effects) and increases the amount of hours available for work or non-work activities. In this chapter, we focus on the health status related to dengue incidence, namely, a "dengue health status". To support this idea, it is assumed that individuals consider dengue eradication as a normal good, which creates welfare for the family. The environmental influences, in particular, are considered exogenous to dengue incidence (or dengue health status of populations), which indicates that dengue is influenced by environmental conditions; however, the environment is not influenced by dengue cases (there is no reverse causality).[4]

In solving this optimization, the incidence of dengue depends on local environmental conditions and actions to control the disease, such as the local infrastructure and other socioeconomic characteristics. After accounting for all determinants of dengue, the final model represents a reduced form that can be described as a risk function for dengue for region i in time t:

$$d_i = g\left(d_i^{t-1}, d_i^{j}, M_i, E_i, C_i, F_i, S_i, P_i, V_i, pd_i\right), \forall\, i, j = 1, \ldots, N \;\; and\, i \neq j \quad (13.1)$$

Thus, the determinants of dengue incidence (d) can be explained by a production function (g) of the variable groups: environmental, socio-demographic and medical/political factors and local history of the disease. These determinants are also discussed in the epidemiological literature (Barcellos et al. 2009).

The environmental factors are strongly dominated by the importance of climate (C) on the incidence of dengue, as outlined in the introductory section, mild temperatures, sufficient humidity, and reasonable precipitation for the deposition of eggs (droughts also encourage individuals to store water for self-consumption, which contributions to water accumulation). Furthermore, vegetation (V) may be relevant to guarantee water accumulation.

The most important socio-demographic factors to investigate regarding the incidence of dengue are as follows: urbanization or population density (pd); income (P), coverage of water, sewage and garbage collection systems (S); and other information on susceptible areas (F).[5] The incidence of dengue is also influenced

[4] Moreover, other factors that could influence both the disease incidence and the decision to live in milder climates will be controlled for in the analysis.

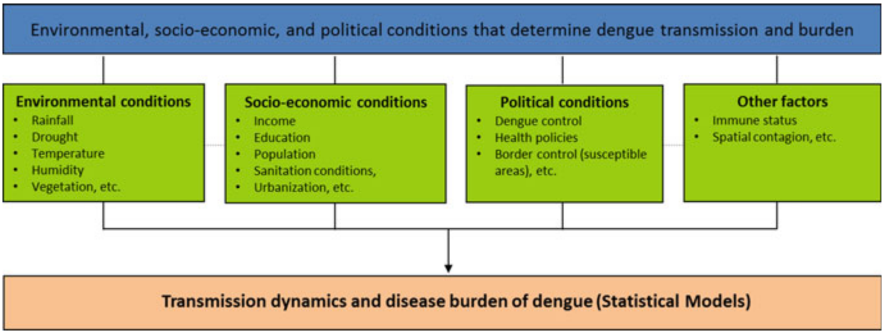
[5] Urbanization and population density may accelerate dengue transmission. A lack of water and sewer system and garbage collection services force some families to maintain reservoirs of

by the educational level of the population (E). Literature relating health and education suggests that more educated individuals are more efficient producers of health (Grossman and Kaestner 1997).[6] This efficiency may occur because more educated individuals may have more knowledge regarding how to reduce the risks of dengue, e.g., by not storing water outside the house.

To assess the local history of the disease, a dynamic component is defined (d^{t-1}). The dynamic component measures the influence of the previous notifications of dengue, which may help explain important situations not observed, such as the immune status of the population and prevalent serotypes. Furthermore, it allows the time dependency of the disease to be determined.

The spatiality of the transmission must be accounted as a proxy for spatial contagion from dengue transmission in the neighborhood (j municipalities), d^j (Wen et al. 2006). Both measures may generate endogeneity in the model, which will be further discussed. The influence of public health investment in inputs for the eradication of dengue fever and other vector-borne diseases (M) is also an important determinant to test in the model as previously discussed.

The following schematic diagram summarizes the interactions among the variables that explain the transmission dynamics and disease burden of dengue.



drinking water, which may act as breeding places of mosquito larvae. Coastal regions may play a role because of the natural increased humidity in these areas; furthermore, border regions are more sensitive to dengue because of dengue transmission from other countries.

[6] Potential causal relationships between education and health, reported in the literature, are excluded from this analysis because they do not make sense in the context of the study of dengue. The discussion regarding the causality of schooling is based on the time preference hypothesis (Fuchs 1982). More future-oriented individuals tend to have a higher degree of time preference for the future, attend school for longer periods of time and contribute larger investments in health. Thus, the effect of schooling on health may be biased if one fails to control for time preference.

Statistical Model: Count Data Model with Instrumental Variables

As a result of the nonnegative and discrete data generating process of the dependent variable of interest, the number of dengue notifications per municipality (d_i), the following count data distributions are considered: Poisson, Negative Binomial, and Hurdle (Cameron and Trivedi 2010). Because of the non-linearity of the functional form, these models must be analyzed by their marginal effects.[7]

The three main sources of endogeneity from the model originate from the following: (a) the time-lagged dengue incidence, which is included to test the relevance of local history on dengue incidence. This problem will be corrected using higher lags of the variable as instrumental variables; (b) the spatial-lagged dengue variable, which is included to test the suspicion of spatial contagion of dengue. This problem will be corrected using exogenous spatial lag variables as instruments; and (c) local government expenditures for dengue control. The endogeneity problem originates from the reverse causality of public investments in actions for dengue control. As the expenditures for epidemiological surveillance in Brazil are typically performed by observing epidemics in the beginning of the year, local government expenditures for epidemiological surveillance in the previous years are used as instruments.

Thus, the count data model with endogeneity correction can consistently estimate the effects of the determinants on dengue risk. Formally, the estimated dengue risk equation is:

$$E(d/\boldsymbol{x_i}) = exp\left(d_i^{t-1}, d_i^{\,j}, \boldsymbol{M}_i, \boldsymbol{E}_i, q(\boldsymbol{C}_i), \boldsymbol{F_i}, \boldsymbol{S_i}, \boldsymbol{P_i}, \boldsymbol{V_i}, \boldsymbol{res_i}\right);$$
$$i = 1, \ldots, n; \;\; t = 2010 \qquad (13.2)$$

where $\boldsymbol{res_i} = (res_{1i}, res_{2i}, res_{3i})$, which indicates the error components estimated from each reduced form equation of the endogenous variables against the exogenous equation plus its instruments; $\boldsymbol{x_i}$ is the vector of exogenous covariates of the model. A polynomial specification of climate is assumed, *q(.)*, to test nonlinearities and complex relationships, as previously reported.

Data Sources

The sample consists of an annual cross-section of municipalities[8] for the year 2010. The data regarding dengue notifications (dengue fever and dengue hemorrhagic

[7] Wooldridge (2002) derives the model's conditions and marginal effects from pages 645 to 660.

[8] Municipalities are the smallest administrative unit in Brazil. They represent the local political unit in the country and are similar to a county, with the exception that there is a single mayor and municipal council.

fever) refer to confirmed lab cases or suspected cases.[9] In 2010, an outbreak of several regional dengue epidemics occurred; in the same year, the most recent Brazilian Demographic Census was also conducted, which generated socioeconomical and sanitation information for all 5565 municipalities in the country (Brazilian Bureau of Geography and Statistics, IBGE 2010).

The historical climate data for Brazil were obtained from the National Meteorology Institute (INMET), under the Ministry of Agriculture (MAPA). The institute collects information at weather stations regarding the average, minimum and maximum temperatures, total precipitation (in millimeters and rainy days) and relative humidity. To transform the data from the weather stations into municipal data, the kriging method of interpolation was used (Haas 1990).

Thus, for all climatic variables by municipality, the average for 2010 and the 30-year historical average over the seasons are created by gathering the information over the months of each season. Thus, climate information represents the average temperature, precipitation and relative humidity of the season, as well as the minimum and maximum temperatures of the whole season.

For climate predictions, the CPTEC/INPE (the department for weather forecasting and climate studies of the National Institute for Space Research) data are used. The CPTEC/INPE uses regional models, which downscale the global models (HadRM3P Model; Eta/CPTEC Model; and RegCM3 Model). Correlation anomalies among the models are calculated to identify consistent signals for the predictions. The output of the models comprises an average of the combined results from three forecasting models, which is referred to as a "multi-model ensemble technique".

Most social and demographic variables are available from the 2010 Brazilian Demographic Census by municipality. The variables included and tested in the dengue risk model are subdivided into categories and described in Table 13.1. A limited number of variables are collected from different data sources. In this case, the source is identified in parentheses immediately after the variable explanation.

Regarding the spatial variable, which potentially measures the neighborhood contagion, two different weighting matrices are tested to identify the spatial dependence structure of dengue: the queen contiguity of first order; and the distance matrix of 250 km. OpenGeoda software[10] is used to generate the matrices for a neighborhood: All weights of $\boldsymbol{W} = [w_{ij}]$ are calculated as the inverse distance

[9] In 2010, dengue notifications comprised lab confirmed cases or suspected cases (individual who lives or has traveled within the previous 14 days to the area in which transmission of dengue is occurring, presents fever between 2 and 7 days, and presents two or more of the following symptoms: nausea, vomiting, rash, myalgia, arthralgia, headache, retro-orbital pain, petechiae or positive tourniquet test, and leucopenia). In 2014, the Ministry of Health changed the notification, and it is possible to identify the results of the exams, as well as the serotype.

[10] The development of GeoDa and related materials has been supported by the U.S. National Science Foundation/the Center for Spatially Integrated Social Science (CSISS) (Anselin et al. 2005).

Table 13.1 Variables and sources by municipality

Determinant group	Variables and sources
Educational variables	Illiteracy rate, percentage of individuals from different educational levels, measured by years of schooling (IBGE 2010)
Regional variables	Area of municipality, dummy variables for border and coastal municipalities (IBGE 2010)
Demographic variables	Population density, population per square kilometer, percentage of urban households, total population (IBGE 2010)
Income/social variables	Median income for rural and urban households, Gini index, ownership of durable goods (radio, TV[a]), percentage of households with at least one bathroom, wall construction material (IBGE 2010)
Urban infrastructure	Garbage collection, sewer system, water system (IBGE 2010)
Environmental variables	Average climate conditions, $E(C_{1980-2009})$: Pattern of rainfall, air temperature and relative humidity by season from 1980 to 2009 (long-term average), and Deviation from climate conditions, $C_{2010} - E(C_{1980-2009})$: Deviations from the pattern of rainfall, air temperatures and relative humidity by season in 2010 (INMET 2013)
Health inputs	Local authorities' total expenses for individual health, family health and epidemiological surveillance per individual (Brazil 2013)[b], percentage of households in the municipality that receive assistance from the Family Health Program (FHP) in 2010, number of visits per family assisted (FHP), number of private and public hospitals in the municipality (Datasus 2013)[c]
Other environmental variables	Normalized Differenced Vegetation Index—NDVI (Pinzon et al. 2005; Tucker et al. 2005)[d], dummies for Brazilian biomes (IBGE 2013)

Notes:
[a]Proxy to measure the potential effect of advertisements and government actions against dengue in the period
[b]The municipal epidemiological surveillance expenditures comprise notification of reportable diseases; epidemiological investigation; capture of vectors; identification and collection of the rate of infestation; actions of chemical and biological control of vectors and elimination of breeding sites (Finbra, Data System of the National Treasury in Brazil, from 2005 to 2010)
[c]Datasus is the Data Center of the Ministry of Health in Brazil
[d]NDVI: indicates probability of having vegetation by remote sensing measurements (presence or absence of live green vegetation). It varies from −1 to 1
Sources: Brazil (2013), IBGE (2010), INMET (2013), Pinzon et al. (2005), Tucker et al. (2005), IBGE (2013), Datasus (2013)

from neighbors and standardized to ensure each row sums to unity (1): $w^*_{\boldsymbol{ij}} = \frac{1}{d_{ij}}; w_{ij} = \frac{w^*_{ij}}{\sum_{\boldsymbol{j}} w^*_{ij}}$. The two matrices presented similar results for the spatial lag coefficients; thus, the queen contiguity matrix is used for further calculations because of its simplicity.

Table 13.2 Average climate conditions by biomes and season, long-term average from 1980 to 2009

Climate by biome	Amazônia	Caatinga	Cerrado	Mata Atlântica	Pampa	Pantanal	Average (Brazil)
Average monthly rainfall from 1980 to 2009, in millimeters (mm)							
Summer	216.3	97.1	213.2	175.4	146.3	213.2	171.5
Fall	243.9	141.1	140.5	111.9	101.3	136.0	132.4
Winter	89.1	54.7	26.1	68.1	92.2	45.6	60.1
Spring	95.2	28.2	99.2	114.9	135.0	118.8	95.7
Average monthly temperature from 1980 to 2009, in °C							
Summer	26.3	26.3	24.9	23.7	23.0	25.6	24.6
Fall	26.0	25.5	24.1	21.6	19.4	24.2	23.0
Winter	25.8	24.3	22.5	18.0	14.0	21.8	20.5
Spring	27.0	26.4	25.1	21.5	18.4	25.0	23.4
Average monthly relative humidity from 1980 to 2009, in %							
Summer	84.0	69.9	78.5	76.5	74.7	82.6	76.3
Fall	85.1	76.5	77.3	77.6	77.5	81.9	77.9
Winter	75.9	69.8	64.8	73.8	75.9	72.9	71.6
Spring	75.2	62.6	66.5	72.0	74.0	74.4	69.6

Data Description

Climate in Brazil

Table 13.2 summarizes the distribution of rainfall, humidity, and temperatures for biomes in Brazil (see the Map of biomes in Appendix) using the model data.

The table provides evidence of the tropical features of the Amazon region (in the North region), with high temperatures year-round, and more temperate areas in the Pampa and Mata Atlântica biomes, which represent most of the southern and southeastern regions of Brazil.

Precipitation in Brazil has a strong seasonal component that is more intense during the summer and fall. The rainiest biomes are Amazonia, Cerrado and Mata Atlântica, respectively. The Pampa, in Southern Brazil, has lower temperatures with the occasional occurrence of frosts during the winter, which decreases the probability of mosquito survival in the region. In the case of Caatinga, low rainfall during most of the year causes poor conditions for mosquitoes to breed.

Dengue Determinants

Table 13.3 presents the descriptive statistics of the dengue determinants discussed in section "Production Function for Dengue Eradication". The information represents an overview of the municipal data from the most recent census and other sources.

Table 13.3 Descriptive statistics, all variables of the sample

Variable	Obs	Mean	SD[a]	Min[b]	Max[c]
Educational variables (illiteracy rate by gender)					
Illiteracy rate	5565	14.74	8.94	0.90	41.6
Illiteracy rate—men	5565	15.59	10.41	0.80	48.2
Illiteracy rate—women	5565	13.88	7.66	0.80	40.4
Income variables					
Gini coefficient (labor income)	5565	0.46	0.07	0.23	0.78
Median income (in Brazilian reais)	5565	958.51	398.38	134.00	3000.0
Possession of durable goods					
Radio	5565	77.84	13.19	13.28	100.0
TV	5565	90.81	8.23	19.91	100.0
Waste disposal					
Collected or burned	5564	70.26	21.84	0.00	100.0
Precarious (discarded)	5564	4.83	6.33	0.00	58.6
None	5565	1.63	3.67	0.00	43.2
Sewage system					
Integrated network	5565	29.45	31.52	0.00	99.9
Septic tanks	5565	12.83	16.42	0.00	97.3
Integrated network or tanks	5565	42.30	31.28	0.00	100.0
Rudimentary cesspits	5565	43.76	29.03	0.00	99.1
Drainage ditch	5565	3.06	4.50	0.00	50.7
Discharged into rivers, lakes, sea	5565	2.51	6.55	0.00	79.1
None	5565	6.15	9.93	0.00	67.2
Water supply					
Water access	5565	89.54	15.08	5.16	100.0
Sanitation system	5557	65.74	20.90	0.09	100.0
Other supplies (e.g., artesian well)	5552	19.08	15.65	0.11	93.9
No piped water	5106	11.40	15.40	0.01	94.8
Climate variables by season in 2010					
Avg. temperature (C) summer	5555	25.24	1.66	19.47	28.5
Avg. temperature (C) fall	5555	23.35	3.23	14.38	29.5
Avg. temperature (C) winter	5555	20.73	4.40	10.69	30.5
Avg. temperature (C) spring	5555	23.54	3.53	14.49	31.2
Relative humidity (%) summer	5555	75.76	4.50	60.92	90.4
Relative humidity (%) fall	5555	76.50	3.42	66.71	85.1
Relative humidity (%) winter	5555	68.92	9.18	48.22	83.8
Relative humidity (%) spring	5555	67.56	6.12	49.54	79.9
Rainfall (mm) summer	5555	159.90	68.76	24.99	396.6
Rainfall (mm) fall	5555	122.88	46.15	49.29	346.0
Rainfall (mm) winter	5555	51.87	48.45	2.28	258.7
Rainfall (mm) spring	5555	92.27	41.02	15.02	175.0
Climate deviations in 2010 from long term average by season (short term—st)					
Avg. temperature (C) summer	5555	0.67	0.41	−1.23	4.0

(continued)

Table 13.3 (continued)

Variable	Obs	Mean	SD[a]	Min[b]	Max[c]
Avg. temperature (C) fall	5555	0.32	0.82	−3.29	2.4
Avg. temperature (C) winter	5555	0.24	0.70	−2.83	3.1
Avg. temperature (C) spring	5555	0.15	0.59	−2.10	2.1
Relative humidity (%) summer	5555	−0.53	2.74	−9.08	5.3
Relative humidity (%) fall	5555	−1.42	2.36	−9.94	5.1
Relative humidity (%) winter	5555	−2.71	4.11	−18.69	9.4
Relative humidity (%) spring	5555	−2.08	2.72	−16.14	6.0
Rainfall (mm) summer	5555	−11.62	33.29	−115.3	136.5
Rainfall (mm) fall	5555	−9.49	47.08	−133.1	189.7
Rainfall (mm) winter	5555	−8.19	22.22	−103.4	101.0
Rainfall (mm) spring	5555	−3.48	22.53	−75.25	63.9
Population structure and age distribution					
Percentage of urban households	5555	0.64	0.22	0.04	1.0
% of individuals from 0 to 9 years old	5565	15.74	3.48	4.73	36.9
% of individuals from 10 to 19 years old	5565	18.92	2.65	5.86	27.4
% of individuals from 20 to 29 years old	5565	16.62	2.02	7.24	38.0
% of individuals from 30 to 49 years old	5565	27.00	2.84	15.79	38.9
% of individuals from 50 to 69 years old	5565	16.17	3.65	4.64	31.8
% of individuals 70 or more years old	5565	5.55	1.73	0.68	14.5
Dengue notifications by year					
Dengue cases—2003	5564	50.13	357.41	0.00	12,408.0
Dengue cases—2004	5564	12.99	110.02	0.00	3753.0
Dengue cases—2005	5564	27.13	244.83	0.00	11,815.0
Dengue cases—2006	5564	47.87	446.07	0.00	15,617.0
Dengue cases—2007	5564	89.90	818.18	0.00	44,550.0
Dengue cases—2008	5561	99.97	1642.27	0.00	110,093.0
Dengue cases—2009	5561	70.28	622.13	0.00	25,553.0
Dengue cases—2010	5561	176.42	1399.50	0.00	52,773.0
Dengue cases—2011	5561	131.59	1529.34	0.00	80,536.0
Health information/expenditures					
Number of private hospitals	5563	0.01	0.07	0.00	1.5
Number of public hospitals	5563	0.91	2.29	0.00	103.0
% of families covered by the FHP/total	5562	0.18	0.27	0.00	1.0
Number of visits per family (FHP)	5562	8.15	113.95	0.00	6321.0
Health spending per inhabit. (2010)	5557	368.83	198.56	0.00	1928.2
Epidemiological spending per inhabit. (2010)	5557	4.72	8.36	0.00	180.0
Location variables					
Dummy for border municipalities	5564	0.11	0.31	0.00	1.0

(continued)

Table 13.3 (continued)

Variable	Obs	Mean	SD[a]	Min[b]	Max[c]
Population density (habit. per km^2)	5565	108.20	572.44	0.13	13,024.6
NDVI (2006)	5561	0.58	0.10	0.06	0.8

[a]Standard deviation (SD)
[b]Minimum
[c]Maximum

Urban households represent most of the population for nearly all municipalities. Approximately 11 % of the municipalities are located along the border of the country, and 7 % of the municipalities are on the coast. On average, the municipalities have 14 % of the illiterate population, and approximately 59 % of these municipalities have higher illiteracy rates than the Brazilian average of 10 %. The average illiteracy rate is higher for men than women.

Regarding income levels, the median income per household of the municipality varies from R$134 (or $76 dollars) to R$3000 ($1704). The median income for the urban population is approximately $114[11] higher than the median income of the rural population. The Gini coefficient measures the inequality among the values of the frequency distribution of labor income using 2010 data. The Brazilian average is 0.46 and varies from 0.23 (most equal municipality) to 0.78 (most unequal municipality).

According to the census, on average, the majority of the municipalities have households that own radios and televisions, and few families have computers (and Internet access). The ownership of durable goods is typically an indicator of income. However, in the context of dengue, the ownership of radios and televisions may also measure how informed individuals are by the media. During dengue epidemics, the federal government typically uses the media not only to alert individuals regarding the disease but also to educate communities regarding precautions to reduce mosquito breeding places.

The average of the municipalities that have some waste disposal is 70 % (collected or burned). Garbage disposed in no specific location accounts for 5–6 % of the municipalities. Access to a public sewage system is, on average, very poor among the municipalities and appears to be unequally distributed. Rudimentary cesspits are more common than integrated networks. A significant proportion of municipalities have high rates of raw sewage discharge into rivers, lakes, sea or ditches. The water supply is more equally distributed in the country. However, 11.4 % of the municipalities, on average, still do not have access to piped water.

The most important finding regarding climate variables is that 2010 was a year of higher than normal air temperatures (compared with the long-term averages) in all seasons. In terms of humidity, the year was generally less humid in most municipalities. The rainfall comparison between 2010 and the long-term average indicated

[11] Converted to dollars by the 2010 average exchange rate. Source: Sisbacen PTAX800.

less rainfall in many areas (Minas Gerais, Espírito Santo, Bahia, and the northern part of the Northeast region).

The descriptive analysis of the health data indicates that on average, there are more public hospitals than private hospitals in Brazilian municipalities. Regarding the families assisted by the FHP, there are municipalities fully assisted and municipalities not assisted by the program. On average, 18 % of the municipalities nationwide participate in the program. The average number of household visits by PSF agents is eight per year. The epidemiological surveillance spending remains low at R$4.70 ($2.83) per inhabitant in 2010. According to the Epidemiological Guide of the Ministry of Health (Brazil 2005), these expenditures are related to both detection and control of the diseases with mandatory notification.[12] The total municipal expenditure could not be disaggregated by disease; however, dengue fever represented 83.3 % of all diseases with mandatory notifications in Brazil between 2007 and 2010, which provides strong evidence that most expenditures are related to dengue.

Epidemiological Surveillance in Brazil

During the 1990s, dengue control was established by zoonosis control. The Ministry of Health invested approximately $776 million at the time in staff, vehicles and surveillance equipment. However, the action was not successful in achieving the targeted reduction of dengue (Braga and Valle 2007). These results prompted the Ministry of Health to implement the National Dengue Control Program in 2002 (Brazil 2002), whose proposal for dengue control primarily relies on the collective action of society as a whole. The program also included the mobilization of health agents from the Family Health Program for dengue control.

Among the duties of the municipal program, the role of public education and chemical and biological control of mosquitoes can be highlighted. The Ministry of Health invested $300 million in 2002, 85 % of which was allocated for surveillance and vector control. The following year, the actions absorbed approximately $274 million (Braga and Valle 2007). The program has not achieved the goals of eradicating dengue.

The current system of monitoring dengue in Brazil is based on the observation of dengue cases in January and February, with occasional interventions, such as spraying insecticides to kill mosquitoes and their larvae when an increase in the number of cases is identified. This monitoring system is more corrective than preventive and does not use a forecasting mechanism that can anticipate the occurrence of epidemics.

[12] The health problems included in this category are as follows: whooping cough, dengue, chronic Chagas disease, schistosomiasis, yellow fever, typhoid and spotted fever, hantaviruses, viral hepatitis, visceral and cutaneous leishmaniasis, leptospirosis, malaria, measles and rubella, among others (botulism, diphtheria). The category also includes bites by poisonous animals.

Results

Testing the Climate Relevance and Other Determinants

Equation (13.2) is estimated using Stata 12 SE and bootstrapped standard errors after 1000 replications. Climate variables are included in polynomial form (third order) to control for potential nonlinearities. Because of the non-linearity of the count data model, the effects must be analyzed by their marginal effects: $\frac{\partial E(d|\boldsymbol{x})}{\partial x_j} = E\left(d\middle|\boldsymbol{x}\right)\frac{\partial d}{\partial x_j}$ for all x_j variables that belong to the set of covariates (Wooldridge 2002, pp. 648). Note that the marginal effect depends on the values of covariates ($\boldsymbol{x}$). Thus, Table 13.4 exhibits the marginal effects for selected variables in each model estimated, which was calculated from the sample average ($\boldsymbol{x} = \overline{\boldsymbol{x}}$).[13]

The joint test of the long-term climate variables indicates they are relevant to explain dengue risk in 2010 at 1 % significance. The same tests for the climate variability variables suggest the relevance of short-term climate conditions for disease risk. Because of the non-linearity of the relationship with dengue incidence, the climate variables are evaluated in a separate section.

The Poisson and negative binomial models indicate convergent results; however, the latter model has a lower information criterion (AIC) value, whereas the former model appears to fit the data better (squared correlation between predicted and observed values). The joint test for the instrumental variables indicates they are relevant to explain the endogenous variables, and the statistical significance of the residual variables indicates these variables may have captured the endogeneity of the variables (Table 13.4, notes).

There is evidence of spatial contagion from neighboring municipalities because the coefficient for the spatially lagged variable is positive and statistically significant for all models. Another important result is the non-significant time lag variable effect. This evidence suggests that the epidemics did not have significant time dependence and appeared to be more affected by other variables than previous epidemics.

The municipal urbanization has a significant and positive relationship with dengue risk (the vegetation index coefficient indicates a statistically significant effect that corroborates this relationship). There is also evidence that ownership of radios and TVs may reduce the dengue problem. The ownership of durable goods is, in general, an indicator of income. However, the model is controlled for income (median income), inequality index (Gini coefficient) and education (illiteracy rate). Thus, in the context of dengue, the ownership of televisions may also measure how informed individuals are by the media. During dengue epidemics, the federal government typically uses the media not only to alert individuals regarding the disease but also to educate communities regarding precautions to reduce mosquito

[13] Full results are available upon request.

Table 13.4 Marginal effects $\left(\frac{\partial E(d|x)}{\partial x_j}\right)$ from models: (1) Poisson, (2) Negative Binomial, and (3) Hurdle, at sample average ($\bar{x}$), 2010

Variables	(1) Poisson	(2) Negative binom.	(3) Hurdle
Selected covariates			
Spatial lag for dengue	0.00944**	0.0181***	0.0326***
Time lag for dengue	0.000873	−0.000202	0.00298
% of households: ownership of radio	−0.619***	−0.151**	−0.176
% of households: ownership of TV	0.0817	−0.443***	−1.198***
% of urban households	43.73***	31.28***	65.87***
Vegetation index (NDVI)	−33.01*	−25.01**	−79.75**
Surveillance expenditures	1.107***	0.527***	1.672***
Res1: Lagged Dengue Eq.[a]	0.00315*	0.0105***	0.0269***
Res2: Spatial Lagged Dengue Eq.[b]	−0.00954*	−0.0101***	−0.0180**
Res3: Health Expenses Eq.[c]	−0.894***	−0.355***	−1.131***
Group of covariates			
Biomes[d]	Included	Included	Included
Sanitation conditions[e]	Included	Included	Included
Health inputs[f]	Included	Included	Included
Socioeconomic variables[g]	Included	Included	Included
Joint test: Average climate	48.09***	553.52***	338.88***
Joint test: Short-term climate	32.23***	76.54***	48.29***
Akaike information criterion (AIC)	193.47	8.40	10.36
Squared correlation ($\hat{y}$ and y)	0.65	0.21	0.35
Total observations	5544	5544	3915

Statistical significance: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

[a]Residuals from the reduced form for dynamic component (2009). List of instruments: All exogenous + lagged dengue cases (2003–2008). F-test for the excluded exogenous variables: 37.15***

[b]Residuals from the reduced form for neighbor dengue notifications in 2010. List of instruments: All exogenous + spatial lagged from exogenous variables. F-test for the excluded exogenous variables: 412.92***

[c]Residuals from the reduced form for expenditures for epidemiological surveillance per individual in 2010. List of instruments: All exogenous + lagged real expenditures p.p. (2005–2009). F-test for the excluded exogenous variables: 89.16***

[d]Binary variables for the following regions: Amazon, Caatinga, Cerrado, Mata atlântica, Pampa, and Pantanal

[e]The following variables were included in the final model: coverage of water system, coverage of sewage (system and septic tanks), and precarious condition of waste disposal

[f]The following variables were included in the final model: number of private and public hospitals, % of families in the Family Health Program, and average health agent visits

[g]The following variables were included in the final model: illiteracy rate, Gini coefficient, median income, age distribution (% of individuals from 0 to 9, 10 to 19, 20 to 29, 30 to 49, and 50 to 69), and percentage of urban households

breeding places. One hypothesis is that federal government educational programs in the media may be effective in reducing dengue incidence.

The local municipal expenditures for epidemiological surveillance indicate a positive and significant effect on dengue, even after correcting the reverse causality bias. Dengue fever is the main disease with mandatory notification in Brazil; thus, it is expected that this expenditure has a strong correlation with the expenditures related to dengue surveillance and control. Therefore, these findings may suggest the ineffectiveness of such expenditures, mainly because of the delay in which the expenditures are incurred.

Average Climate Results

Figures 13.3, 13.4 and 13.5 indicate the marginal effects of the Poisson Model (13.1) evaluated at different bins of the independent variables for climate (temperature, relative humidity, and rainfall, respectively) and the 95 % Confidence Intervals (CIs). The variables were evaluated for sample averages from 1980 to 2009 for the summer season ($\overline{x}_{1980\ to\ 2009}$) because this season is the most relevant for dengue in Brazil (Brazil 2005).

The most statistically relevant climate variables are temperature and relative humidity. In municipalities in which the average summer temperature is lower than the Brazilian average temperature (21–25 °C), long-term increases in temperature may cause an additional risk of the disease. When the average temperatures during summer are higher than 25.5 °C, increases in the average temperature may reduce the risk of dengue because mosquitoes may find it difficult to survive because of the higher temperatures. The relative humidity findings indicate that as relative humidity increases, the risk of dengue increases. The non-significance of the rainfall estimations suggests that: (1) a humid environment (caused by rainfall conditions) appears to be more important than the average long-term rainfall conditions, and (2) rainfall may be less important because of the role of water storage. Part of the rainfall effect may be captured by the former variable. It is logical to expect that short-term rainfall conditions may be more important to explain water accumulation than long-term rainfall patterns.

To predict the risk of dengue that results from expected climate changes, the climate information used is the B2 scenario of the CPTEC/INPE forecasts for two future time periods: 2040–2069 and 2070–2099.[14] The B2 scenario is chosen because it is considered a low emission economy; thus, it is more optimistic in

[14] The predictions of three models run by INPE are created for two of the IPCC scenarios: A2 (describes a very heterogeneous world, high population growth, slow economic development and technological change); and B2 (describes a world with intermediate population and economic growth and local solutions to economic, social, and environmental sustainability) from 2040 to 2069 and 2070 to 2099.

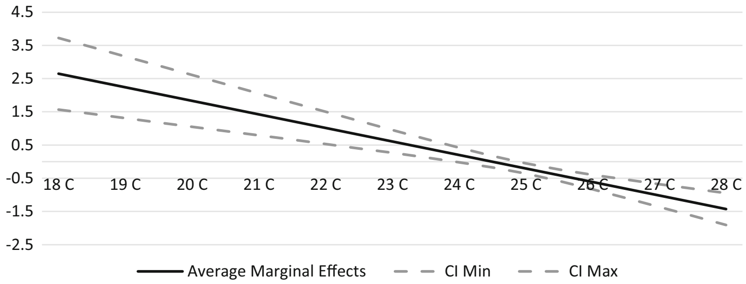


Fig. 13.3 Average marginal effects of temperature, in °C, on % dengue risk (summer average temperature from 1980 to 2009), 95 % Confidence Interval (CI)

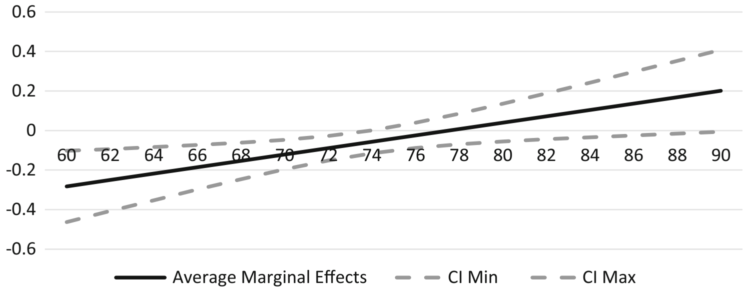


Fig. 13.4 Average marginal effects of relative humidity, in percentage, on % dengue risk (summer average temperature from 1980 to 2009), 95 % Confidence Interval (CI)

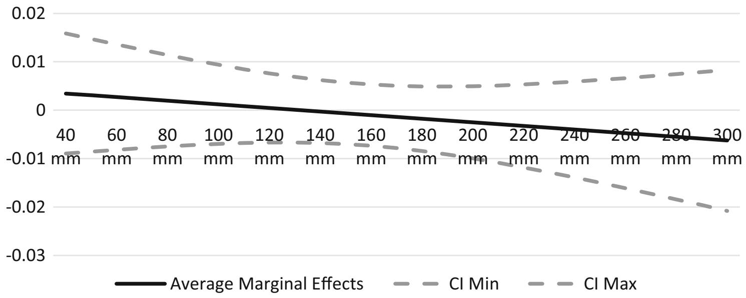


Fig. 13.5 Average marginal effects for average rainfall, in mm, on % dengue risk (summer average temperature from 1980 to 2009), 95 % Confidence Interval (CI)

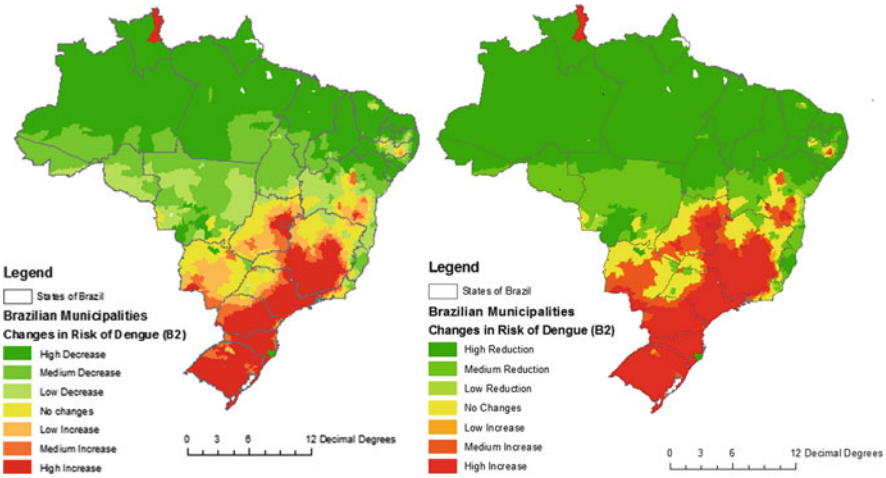


Fig. 13.6 Potential changes in dengue risk because of expected temperature changes, 2040–2069 (*left*) and 2070–2099 (*right*), Brazilian municipalities, Scenario B2. Notes: High reduction: lower than −80 %; Medium reduction: −80 to −40 %; Low reduction: −40 to −2 %; No change: −2 to 2 %; Low increase: 2–40 %; Medium increase: 40–80 %; High increase: higher than 80 %

terms of climate change. Therefore, the findings can be considered a lower bound of the potential effects on dengue risk.

The partial increase or decrease in incidence of dengue as a result of climate changes is shown in Fig. 13.6.[15] If the expected climate changes occur, the most affected areas will be the southern and southeastern areas in Brazil because these areas may acquire better climate conditions for mosquito development. Minas Gerais, São Paulo, Mato Grosso do Sul, Rio de Janeiro, Bahia and Goiás are the states with the highest rates of dengue and may have additional risks of dengue cases if climate changes occur. In regard to the areas in which the risk will decrease, Mato Grosso, Tocantins, Rodônia, Amapá, and Roraima are the states in which dengue had a high incidence in 2010, and climate changes may reduce the probability of mosquito development. The 2040–2069 forecasts indicate only a smooth transition toward 2070–2099 predictions.

These findings are in agreement with the projections of the changes in spatial distribution of infectious diseases in countries. The Intergovernmental Panel on Climate Change (IPCC) emphasized that some studies identified positive evidence regarding changes in the range and transmission potential of malaria in the warmest areas in Africa (Nsubuga et al. 2006). Brazil (2008) is the only study that indicates the threats of climate change on health issues, especially on infectious disease; however, it does not predict the potential effects.

[15] The effect was calculated using the marginal effects formulation with the simple data from a linear climate change in temperature, which represents the variable that guarantees the most reliable long-term forecast. It is noteworthy that this exercise is based on a partial equilibrium model; thus, the effects must be interpreted by considering all other variables fixed.

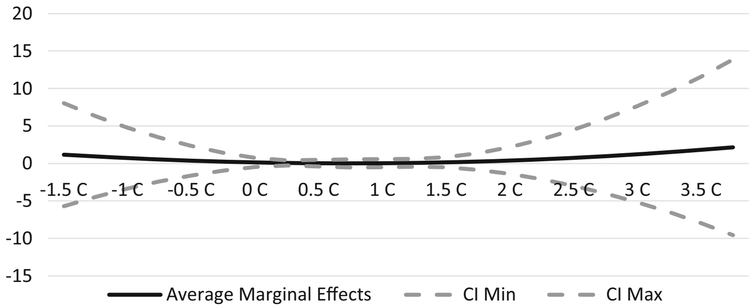


Fig. 13.7 Average marginal effects for 2010 temperature deviations (summer, in °C deviation from long-term average per month), 95 % Confidence Interval (CI)

Short-Term Climate Results

The most important short-term impact is rainfall deviation from the long-term average. Figures 13.7, 13.8 and 13.9 show the marginal effects of the Poisson Model (13.1) evaluated at the 2010 deviation from the long-term average ($\boldsymbol{x}_{\mathbf{2010}} - \overline{\boldsymbol{x}}_{\mathbf{1980}\,\boldsymbol{to}\,\mathbf{2009}}$) of the independent variables for climate (temperature, relative humidity, and rainfall, respectively) and their 95 % CIs. Observed rainfall close to typical conditions reduces the risk of dengue compared with greater deviations. Furthermore, smaller decreases in relative humidity in the short-term may slightly increase the acute dengue risk.

The coefficients estimated for the short-term climate effects can be used to anticipate the risk of dengue that results from specific short-term climate conditions. Socioeconomic conditions are fixed in the short term, and one of the most important determinants for dengue that can change acutely is the climate variability measure for rainfall, i.e., the deviation from the long-term trend. For the short-term analysis, the INPE/INMET estimates the seasonal predictions for rainfall in the summer of 2011.[16]

Figures 13.10 and 13.11 compare the INPE/INMET seasonal forecasts with the observed rainfall considering the same criteria. Figure 13.10 indicates the climate probability forecast issued in November 2010 by the INPE/INMET regarding the 2011 summer precipitation conditions. The numbers represent the probability of rainfall below normal conditions, inside normal conditions and above normal

[16] The model uses seasonal hindcasts of three DEMETER (EU-funded project Development of a European Multimodel Ensemble system for seasonal to interannual prediction) coupled models (ECMWF—European Centre for Medium-Range and Weather Forecasts, Met Office and Météo-France), which comprise real-time multi-model seasonal forecast systems. Coelho (2005) developed a statistical model that uses sea surface temperatures as rainfall predictors in South America. The seasonal climate forecast is typically expressed by probabilities over the next three months in a given region (below the normal range, in the normal range, or above the normal range). These ranges are based on tertiles of the historical distribution. Coelho et al. (2003) discuss the skill scores of the model.

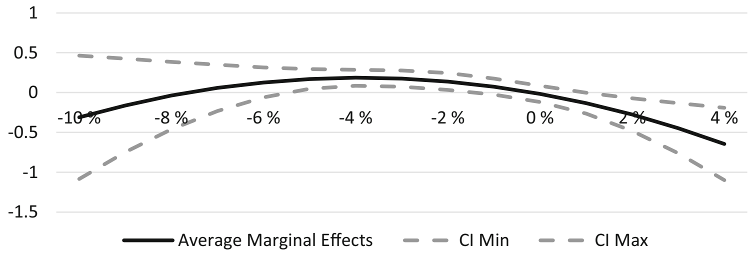


Fig. 13.8 Average marginal effects for 2010 relative humidity deviation (summer, in % deviation from long-term average per month), 95 % Confidence Interval (CI)

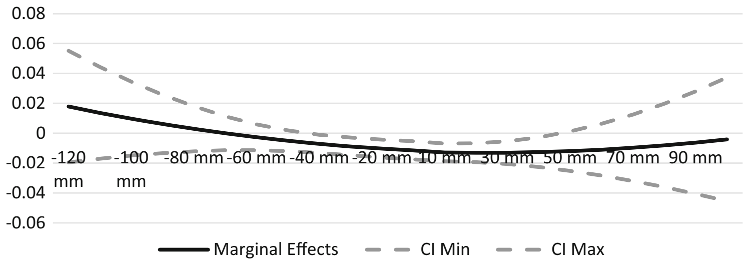


Fig. 13.9 Average marginal effects for 2010 rainfall deviation (summer, in mm deviation from long-term average per month), 95 % Confidence Interval (CI)

rainfall in the region. Figure 13.11 indicates the observed precipitation of summer 2011, classified by below and above normal rainfall conditions (normal conditions comprise the interval between the first and second tertiles).[17] The INPE/INMET predictions for summer 2011 are best adjusted to the following regions: the northern region of the country, where rainfall above normal had a probability of 45 %, and observed rainfall is above the second tertile; the state of Rio Grande do Sul, where the highest probabilities of below-normal and normal rainfall are expected; and the states of Bahia, Minas Gerais, Espírito Santo, Goiás, and north of São Paulo and Paraná, where normal rainfall is expected. Mato Grosso do Sul is the only state that presented more below-normal rainfall values than expected by the INPE/INMET.

Figure 13.12 shows the evolution of dengue cases in 2011 compared with 2010. The numbers reflect the percentage change in dengue incidence from 2010 to 2011. Fewer dengue cases were reported in the central part of Brazil. The dengue incidence increased from 2010 to 2011 primarily in the northern and northeastern regions as well as in the coastal areas of Rio de Janeiro and Espírito Santo. Most of these regions had above normal rainfall in 2011, which may represent one explanation for the increase in dengue. The above normal rainfall in the south did not

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[17] The 30-year rainfall average is considered the normal rainfall conditions, and the threshold is subsequently calculated for above and below normality. Since the INPE and INMET forecasts consider the tertiles of the rainfall distribution as thresholds, the same procedure is used.

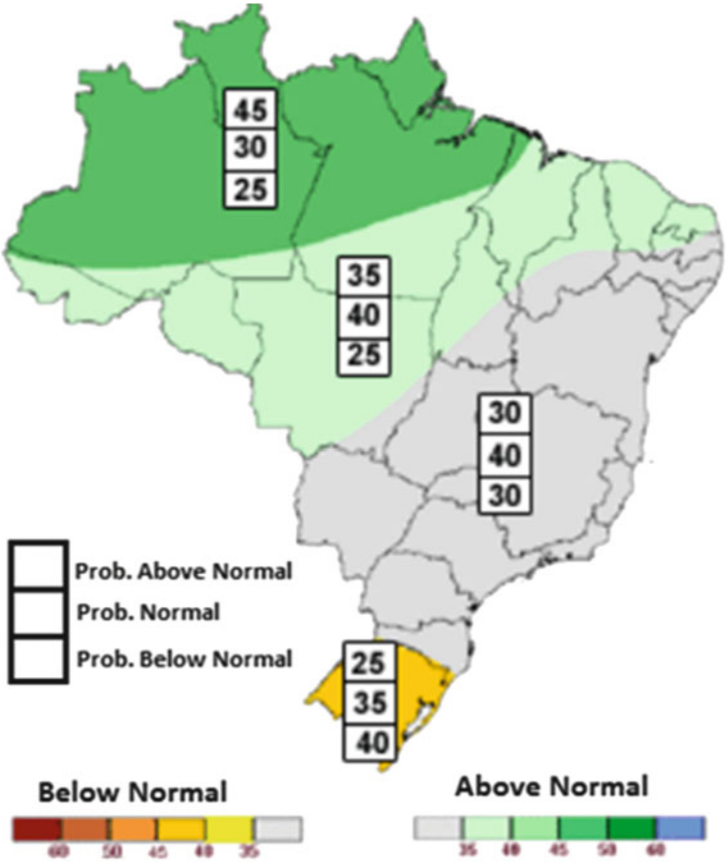

Fig. 13.10 Probabilistic forecast consensus of the total rainfall, Dec/2010 to Feb/2011, using the probabilities of normal conditions. Source: CPTEC/INPE/INMET (2012)

substantially influence dengue mainly because this region does not have a historical problem with dengue.

The short-term rainfall deviations from average may represent an important determinant for mosquitoes' short-term development. Once this effect is identified, it is possible to use the INPE/INMET rainfall predictions to anticipate the potential risk of dengue because of climate conditions. With other variables equal, climate is one of the main short-term shifters of dengue incidence.

However, as for all climate predictions, the observed climate may differ from the predicted climate; thus, the findings should be carefully discussed. From the previous exercise, it is possible that there may be an important relationship between these predictions and the increase/decrease in dengue. The northern region of the country, in which the INPE predicted above average rainfall in the summer of 2011, is one of the main areas affected by the dengue increase. The predictions are not precise for the Northeast region; however, the normality of rainfall was also

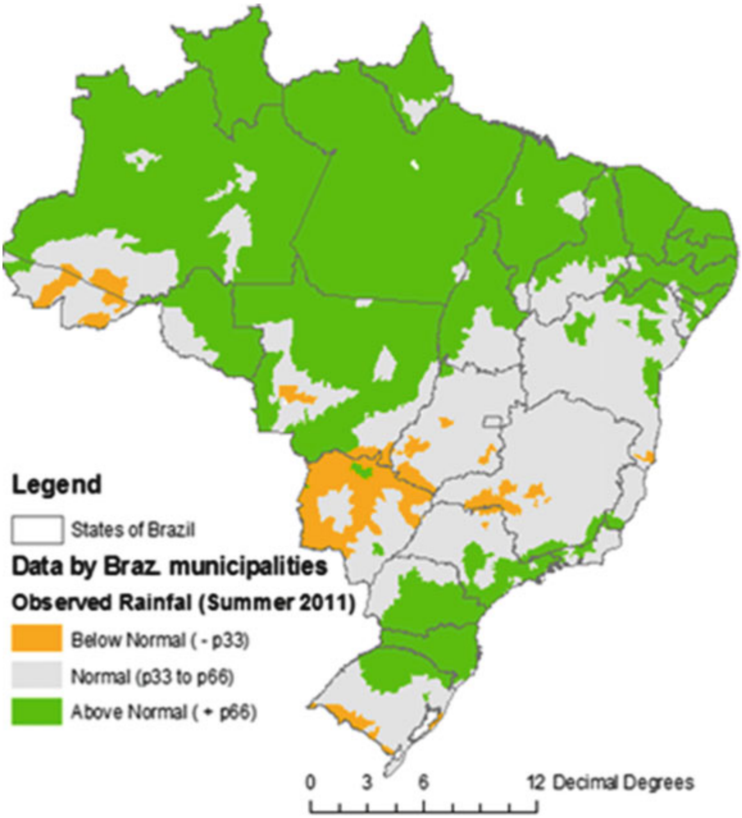

Fig. 13.11 Observed rainfall compared with the distribution tertiles, Dec/2010 to Feb/2011. Source: Data from INMET (2013). Prepared by the author

demonstrated for the Midwest and western part of the Southeast region, where dengue decreased in 2011. The study of Lowe et al. (2010) utilized a similar exercise using Brazilian micro-regions and a Generalized Linear Model and demonstrated that the reliability of the forecasts depends on the skill score of the forecasting system.

Social Vulnerability for Dengue

Other relevant information that can be derived from the model is the social vulnerability for dengue (Fig. 13.13). Disregarding the short-term climate influence and expenditures for epidemiological surveillance, the model generates the incidence rate of dengue that results from other variables: educational, demographic

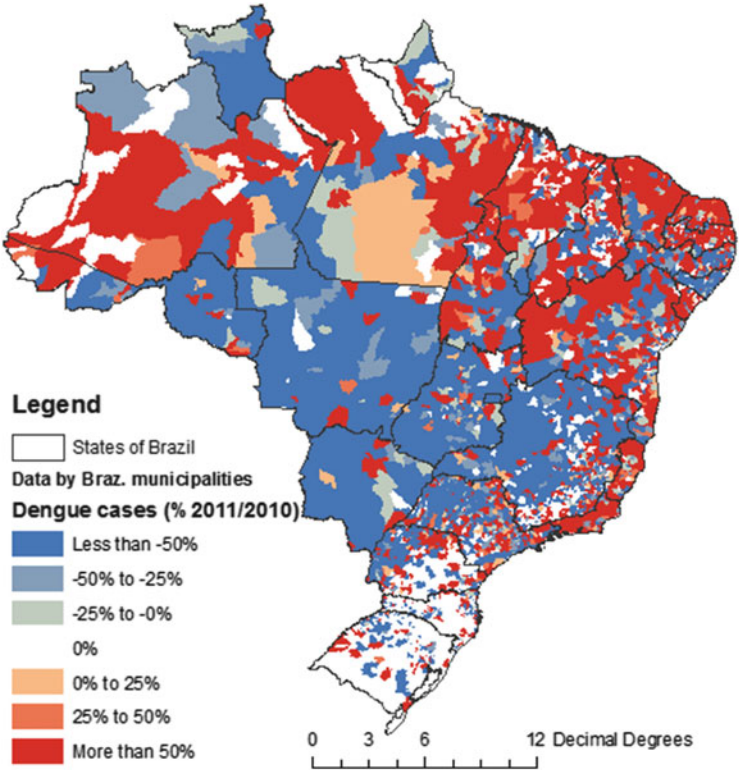

Fig. 13.12 Spatial distribution of dengue case variations, 2010–2011, Brazilian municipalities

and income variables; regional and social infrastructure information; and average environmental conditions.

The information presented in Fig. 13.13 can be interpreted as the current socioenvironmental vulnerability for dengue. Even cities with good social indicators may also be vulnerable as a result of the average climate conditions or urbanization level because urbanization leads to more rapid dengue transmission (Rio de Janeiro, west of Paraná, north of São Paulo, and Minas Gerais are good examples of this situation).

Discussion and Conclusion

This chapter aimed to identify the roles of climate, both seasonal and historical, on the risk of dengue epidemics in Brazil while controlling for socioeconomical and political influences on the disease as well as the immune status and spatial contagion of populations. It is indicated that climate conditions affect the transmission of dengue fever in the country and consequently the geographical distribution of the

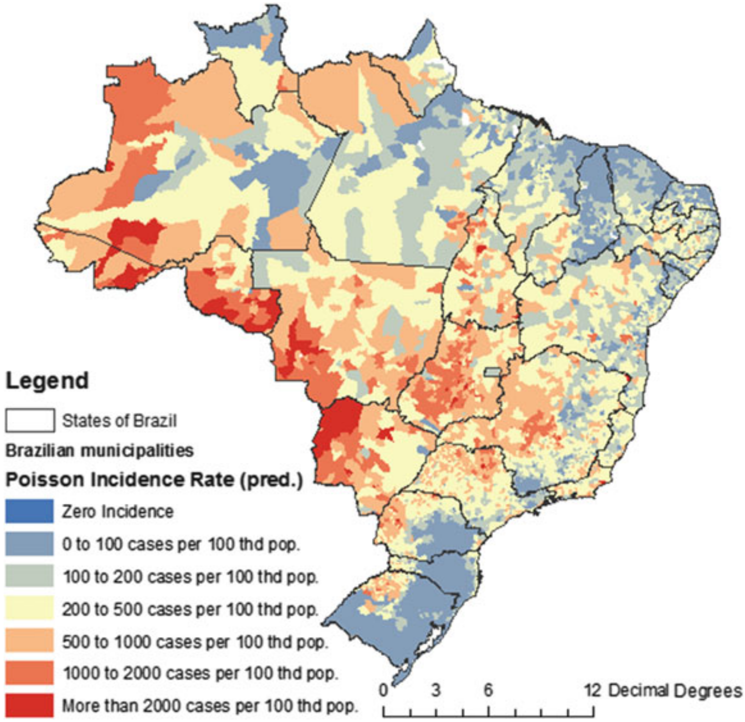

Fig. 13.13 Dengue incidence ratio predicted by the Poisson model, 2010, Brazilian municipalities

disease (long-term effect) as well as the occurrence of regional epidemics (short-term effect). The risk function of dengue was estimated while controlling for potential endogeneities.

By testing and understanding the previously described effects, this study intended to link two relevant agendas: the identification of ways to manage the current climate related risks and improve the understanding of future risks. This is the first study that considers both effects in the same model for Brazil while controlling for important socioeconomical and political determinants of the disease. Moreover, it also considered a non-linear relationship between climate and dengue incidence, which was supported by the literature as relevant in the analysis of these relationships.

Regarding the short-term marginal effects of climate on dengue risk, the findings indicated that the greater the deviation from normal rainfall conditions in summer, the greater the risk of dengue. Thus, the seasonal weather forecasts, as calculated by the CPTEC/INPE/INMET (2012), can be very useful to help prevent dengue epidemics in the summer and fall seasons. Lowe et al. (2010) presented similar results using a spatio-temporal model for microregions in Brazil.

Regarding the long-term effects, evidence suggested that as the long-term temperatures increase, the southern and central-southern states become substantially more vulnerable to dengue. It is noteworthy that there are no physical barriers (large water bodies, mountains, or deserts) within the country that could restrict species dispersion (Venkatesan and Rasgon 2010). In contrast, the increase in temperatures in the north and northeast regions may reduce the dengue risk because of the less favorable weather for mosquitoes. Policymakers are the only agents that can consider the sustainability of the country in the long run to plan specific actions. In this sense, once governments are aware of the expected climate change impacts, the adaptation measures comprise long-term measures that require urgent actions to provide the necessary lead time to build flexible solutions.

The findings regarding expenditures for epidemiological surveillance are an indication of the ineffectiveness of these expenditures because of the delay in incurring them. The current local system of monitoring dengue in Brazil is based on the observation of dengue cases in January and February, with occasional interventions that comprise spraying insecticides to kill mosquitoes and their larvae when an increase in the number of cases is identified. Apart from the increased cost, this procedure is not effective in reducing dengue locally.

In general, these expenditures are typically made at the municipal sites, which do not control infected mosquitoes that cross municipal borders. The evidence of spatial contagion from neighboring municipalities suggested that integrated actions are needed to control the spread of dengue fever during epidemics. Most of the literature indicates the importance of developing or improving current surveillance systems to control the disease. Therefore, these findings represent the basis of knowledge on which public health response, programs, and policy depend.

Quality surveillance ensures appropriate and targeted interventions. Climate information can be used to improve decision making regarding policies to prevent dengue in the country. The use of open-source information can be very cost-effective in the identification of populations in risk areas and the planning of integrated actions to reduce this important health problem in Brazil. The use of climate data in surveillance remains underdeveloped; however, these data have the potential to enhance the usefulness of this tool via the addition of predictive and explanatory power.

In regard to this study's contributions, the use of Brazilian data must be emphasized, as must the testing of both the average climate conditions and short-term climate shock non-linear impacts on dengue. The control and estimation of important determinants of dengue risk, such as local epidemiological expenses, time dependence and spatial contagious, as well as other social vulnerabilities, are also important contributions. Finally, this is the first study to project the expected climate change effect on the spatial distribution of dengue fever and to calculate a vulnerability index for dengue based on socioeconomic conditions and the average climate in Brazil.

Despite the novelty of some of the findings presented in this chapter, there are several limitations that encourage future research on this subject. The main limitation is the use of aggregated data without serotype information. In January 2014, the Ministry of Health in Brazil changed the dengue notification forms to include detailed questions regarding the test results. This improvement will be very helpful for future research on this subject. Another important limitation of the model is that is comprised a partial equilibrium model; thus, the effects must be interpreted with all other variables considered fixed. A general equilibrium model could be estimated to assess all direct and indirect effects of climate on dengue risk; however, this approach is beyond the scope of this study.

Therefore, future research regarding dengue fever analysis could include studies *in loco* as a good opportunity to understand dengue fever contagion by geocoding the cases and observing the local social conditions; this approach could better identify inequality in the sanitation infrastructure provision inside the municipality. The dengue vulnerability index is also a tool that can be better investigated because it gathers substantial information regarding the current susceptibility of dengue in the country. Another possibility for future research is to estimate the composition effect of climate conditions on dengue incidence, in which the climate effects interact with socioeconomic indicators.

Appendix: Brazilian Biomes

The Brazilian biomes considered in the analysis are shown in Fig. 13.14.

Fig. 13.14 Spatial distribution of Brazilian biomes

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Chapter 14
Climate Change and Health Vulnerability in Bolivian Chaco Ecosystems

Marilyn Aparicio-Effen, Ivar Arana, James Aparicio, Cinthya Ramallo, Nelson Bernal, Mauricio Ocampo, and G.J. Nagy

Abstract Climate change and variability is impacting health, across different spatial scales, ecosystems, and water supply and quality. In Bolivia climate change is operating in a framework of poverty and inequality. This chapter focuses on the Bolivian Chaco ecosystems water availability and indigenous health. An ecohealth research was launched to evaluate rural communities and their vulnerability and impacts to current and future climate conditions. The participatory-based approach incorporates community and indigenous organizations, local and national health, and meteorological services. Main observed impacts at Chaco are water stress and warming affecting watersheds, ecosystems and health. Water-borne diseases (WBD) and diarrheal diseases (DD) affected most children evaluated. An average decrease in rainfall of 5–12 %, up to 25 % in winter, especially at the middle and low watershed, is observed. Future increases in temperature (+1–2 °C for 2030–2050), modified rainy patterns and reduced water availability are expected. The both observed and expected warming and less rainfall are correlated with diarrheal vulnerability (VCC_{DD}) and the number of DD cases at rural and indigenous communities. Thus, increasing trends of WBD and DD are likely for 2030–2050. This experience was useful to design Chaco region climate change

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policies and indigenous health adaptation strategies focused on WBD/DD. These included: raising awareness about water and health climate vulnerability and impacts, increasing investments for water sources protection, establishing systems to compensate and protect watersheds and water springs, capacity building, WBD/DD prevention actions, and clean technologies for economic activities.

Keywords Climate inequality • Climate scenarios • Ecohealth • Indigenous health • Water availability and quality • Waterborne and diarrheal diseases

Introduction

> Human health has so far been neglected in public discussions on climate change, as debate has generally focused on the environment and the economic effects of reducing emissions. If climate change goes on unchecked we will see many deaths—we are seeing many deaths already—and you can imagine the human population could possibly go extinct if you take the effects of climate change to their extreme logical conclusion (Berry 2007).

Climate Change and Human Health

> WHO assessment takes into account a subset of the possible health impacts, and assumes continued economic growth and health progress. Even under these conditions, it concludes that climate change is expected to cause approximately 250,000 additional deaths per year between 2030 and 2050. Results indicate that the burden of disease from climate change in the future will continue to fall mainly on children in developing countries, but that other population groups will be increasingly affected (Hales et al. 2014).

There is emerging evidence of climate change effects on human health such as altered distribution of some infectious disease vectors (Smith et al. 2014, Fig. 14.1).

A WHO report estimates future global burden of disease as a result of climate change. For example, it estimates a 10 % increase in diarrheal disease than without climate change in 2030 (Shuman 2010). Increases in the occurrence or severity of extreme weather events could increase the risk of flooding and landslides (see Nagy et al. 2015). Decadal variability and changes in extremes have been affecting large sectors of population, especially those more vulnerable and exposed to climate hazards (Magrin et al. 2014).

Climate change will result in increased incidence of communicable diseases including vector-borne diseases, because their incidence is dependent on climate and water availability. In this sense, climate change extends the geographic and altitudinal incidence of Malaria, Dengue fever and other climate sensitive diseases. Climate change will also affect other sectors which are pillars of health: agriculture, food security, water resources and ecosystems, and contribute to pollution of environmental systems (Aparicio et al. 2007).

Counties are threatened by climate change with direct and indirect health implications for the achievement of countries and health-related development

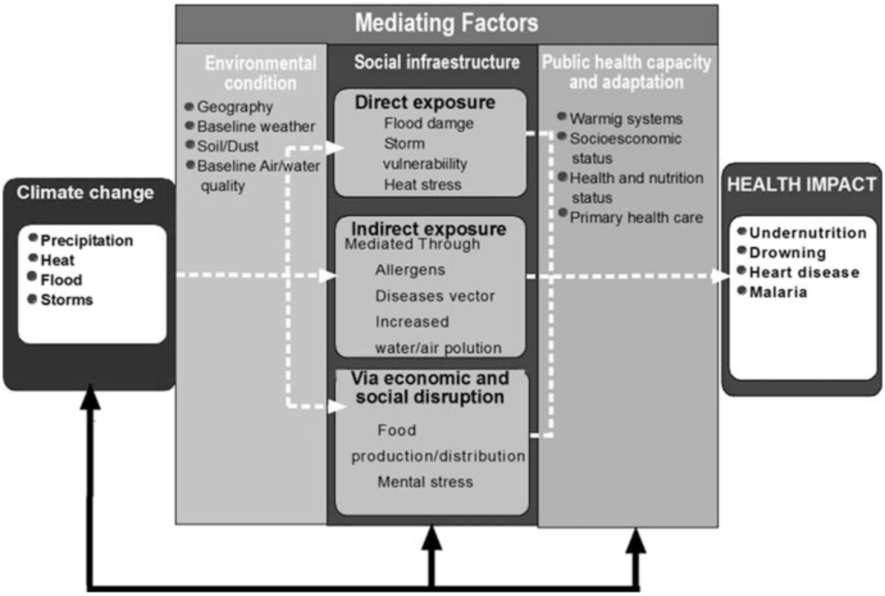

Fig. 14.1 Conceptual diagram showing three primary exposure pathways by which climate change affects health: Source: IPCC (2014a, b)

goals, including health equity. Many factors operate in a framework of inequality, compounded by failures in urban and rural planning, illegal settlements, constraints on basic services and pollution of environmental systems (Aparicio 2010).

Water Borne Transmissible Diseases and Diarrheas

> Climate change may bring some localized positive effects in health, but, the overall health effects of climate change are likely to be severely negative (WHO 2010).

Diarrheal disease is one of the most important global health problems. The near-term impacts, like damage or pollution of infrastructures as result of extreme events and disasters, or chronic effects such as water resource depletion by climate change effects, are reducing the water quality and overall availability of water. The safety and accessibility of drinking-water are major concerns worldwide, because improving access to safe drinking-water can result in improvements to health, particularly for children under 5 years old (C.U.F.Y.O). The epidemiological profile in developing countries is marked by diseases of current socio-economic inequalities. The access to safe drinking-water and sanitation for vulnerable groups, like indigenous and rural population, is still low (Aparicio 2010; PAHO 2011).

In Latin America 93 % have access to improved drinking water sources and 80 % have access to improved sanitation. However, these statistics do not reflect the quality of water or the disparities in countries, gender, income, and race which affect access to water sources and sanitation. Solid Waste Management and Wastewater and Excreta are also important to water quality and human health, impacting the prevalence of WBD (PAHO 2011).

In Andean countries, glacial retreat by global warming is reducing the quality and availability of drinking-water, and also threatens hydroelectricity supply (Nagy et al. 2006; Aparicio 2010). In Bolivia, 80 % of glaciers are retreating (Francou and Vincent 2007).

The risk factors for diarrheas outbreaks after disasters are associated with population displacement, the availability of safe water and sanitation facilities, the degree of crowding, the underlying health status of the population, and the availability of healthcare services, all of which interact within the context of the local disease ecology to influence the risk for communicable diseases and death in the affected population (Watson et al. 2007).

Increased precipitation will increase the risk of flooding and human exposure to pathogens, as contaminants are spread by floodwaters, producing WBD, the most common being a variety of diarrheal illnesses. Water scarcity is associated with diarrhea too. A study in 18 Pacific islands, considering average weather conditions over a 10-year period, found that all-cause diarrhea increased with decreasing water availability (Singh et al. 2001).

Health risks may arise from consumption of water contaminated with infectious agents, most of them sensitive to climate change. Since the early twentieth century, new infectious agents have emerged. Also, other pre-existing agents who were considered controlled re-emerged (Londoño et al. 2011).

Diarrheal disease transmission is known to be affected by temperature. Major viral agents such as rotavirus typically peak in the winter seasons in temperate countries. In tropical settings, rotavirus occurs year round and seasonality may be masked by high background levels (Parashar et al. 2003). Rotavirus infection is the most common cause of diarrhea in C.U.F.Y.O worldwide. While the incidence of rotavirus infection in developed and developing countries is similar, 80 % of deaths occur in developing countries (PAHO 2014).

Rates of diarrhea have been associated with high temperatures (Kolstad and Johansson 2011). Mostly, however, the specific causes of the diarrheal illness are neither known, nor are the mechanisms for the association with temperature. Exceptions include Salmonlla and Campylobacter, among the most common zoonotic food-and water-borne bacteria (Smith et al. 2014).

The climate change and its variability is affecting the water availability and quality in many parts of the world, resulting in a complex combination of climate and non-climate factors or health determinants (PAHO/WHO 2011), that are impacting human health.

Traditionally, the current evidence of the impact of climate on the epidemiology of WBD is considered under three headings; the impact of: (1) heavy rainfall events, (2) flooding and (3) increased temperature (Hunter 2003). However, few specialized literature related with dry lands (as Chaco regions), droughts and chronic effects of climate change on WBD is available. For instance, a Brazilian national assessment showed the North-East region as the most vulnerable to climate change impacts on health, due to poor social indicators, high level of endemic infectious diseases and periodic droughts that affect this semi-arid region (Confalonieri and Marinho 2005).

The aim of this article was to review and update research of the Climate Change and Environmental Health Unit (UCCLIMAS), Universidad Mayor de San Andres (UMSA), La Paz (see Aparicio-Effen et al. 2015) on waterborne transmissible diseases (WBD) in Chaco ecosystems. The research was based on an ecohealth approach focused on water availability and quality, head watershed ecosystem assessment, socio-economic status of populations and vulnerability, associated with environmental health and change, climate variability, and climate scenarios.

Indigenous Health and Climate Inequality

> Indigenous peoples remain on the margins of society: they are poorer, less educated, die at a younger age, are more likely to commit suicide and, in general, have poorer health than the rest of the population (IWGIA 2006).

Even though the indigenous populations represent an important group of cultures, religions, pharmacopoeia, traditions, languages and histories, they are marginalized worldwide in terms of access to education, justice and health. This is exemplified by the high incidence of diabetes among aboriginal Australian population (Hanley 2007), of suicide among Canadian Inuit youth (Health Canada 2013), and of infant mortality among indigenous children in Panama (PAHO 2002). This situation may be exacerbated by climate change, being a highly vulnerable group to its impacts, compromising their means of subsistence and habitat.

Study Area: The Bolivian Chaco Region "Chaco Boliviano"

The Pilcomayo River Basin and Ecosystems

The Pilcomayo River Basin (210,000 km^2 in Bolivia, Paraguay and Argentina, Báez et al. 2014) is located in the Chaco region (15–31° South) shared by four countries: Argentina, Paraguay, Bolivia and Brazil. The "Gran Chaco" is dominated by plains with few hills and small mountains, with sandy and clayey areas. The vegetation is characterized by low deciduous forests, thorn scrub succulent columnar 5–15 m tall, with distinct vegetation according to site geology. The Project study area includes Camiri, Machareti, Villamontes, Yacuiba and Caraparí

Fig. 14.2 Chaco regions: location of case studies

municipalities at "Gran Chaco" and "Chaco Serrano" with altitudinal ranges between 200 and 600 m (Fig. 14.2).

Human activities in the region are livestock, oil drilling, logging for firewood and charcoal, as well as an intensive and subsistence agriculture according to tenure of the land (Erickson 1988; Killeen et al. 1993; Ibisch et al. 2003; Bush et al. 2010). At present, this region accounts with economic resources from taxes from the natural gas industry but due to their low adaptation capacities they do not invest in the implementation of climate adaptation measures.

Climatic Setting

The Chaco climate is influenced by two high pressure systems: sub-tropical South Atlantic Anticyclone which contributes with warm and wet air and erratic and

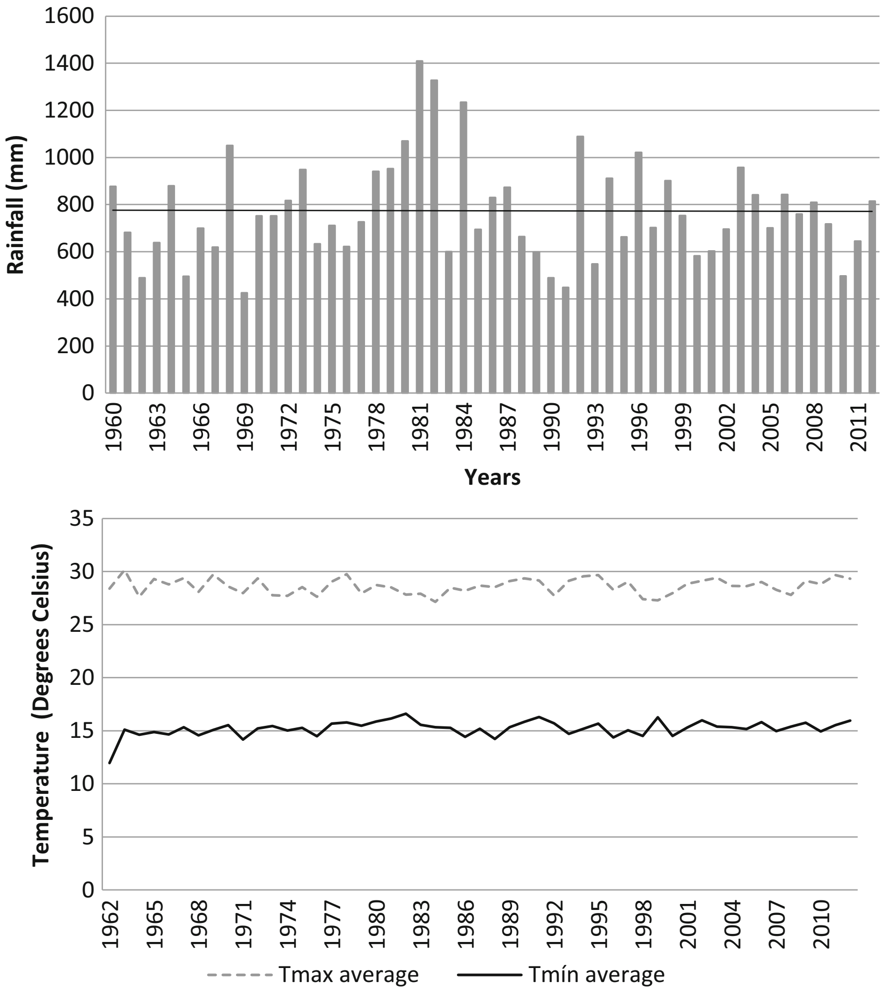

Fig. 14.3 Time-series (1960–2012) of rainfall (mm, above), and temperatures minimum and maximum temperature average (°C, below) at Northern Chaco (Camiri weather station). Elaborated by the authors from SENAMHI database 2015

concentrated rainfall, and Sub-tropical Pacific South anti-cyclone which brings secondary air mass after crossing the Andes "cordillera".

The region is characterized by high temperature and low and irregular precipitation distribution throughout the year. Rainfall distribution is erratic with long dry periods and frequent droughts. Summer time (December-March) is rainy totalizing more than 60 % of annual precipitation. In northern Chaco (Camiri) the annual precipitation is around 800 mm and in the South (Yacuiba) it is around 1200 mm (Fig. 14.3).

The temperature average is 22 °C (−1 to 44 °C) with normally erratic behavior precipitation concentrated in January and February. Camiri weather station (810 m. a.s.l), region, showed increases of 4.1 °C minimum temperature and 1 °C maximum temperature from 1960 to 2012 (Fig. 14.3) whereas precipitation decreased by 8.1 %.

Seasonal rainfall distribution shows long dry periods (Fig. 14.4) coincident with high temperatures and water stress (Fig. 14.5). Subsequent results are desertification trends due to fast soil humidity lost. These changes will enhance hydrological stress for rain-fed water supply, and extreme weather events, with negative effects in water stock systems in rural and indigenous communities which depend on livestock, being highly vulnerable to recurrent strong droughts which cause health human effects and the loss of cattle and crop production. Less rain could produce ecosystem deterioration with loss of water availability in the low watershed. In Chaco ecosystems, long dry periods, warming and decreasing or stable rainfall, would increase desertification with loss of biodiversity and reduction of water availability.

Because of climate change some regions will experience an increase in rainfall and flood risk, while regions that are prone to droughts may experience more extreme droughts (SDWF 2015).

El Niño Southern Oscillation (ENSO) warm phase "El Niño" is associated with rainfall decrease and temperature increase, especially during austral spring months (October-December). During El Niño 1997 event a severe drought and warming occurred from July to September. The Multivariate Normalized Index shows that ENSO 1997–1998 was the strongest in the past century (Fig. 14.6) (see Nagy et al. 2015).

Ethnics Groups, Cultural and Socioeconomic Characteristics

Bolivia is going through a major process of decolonization reestablishing the country into a new political scenario which has generated a set of changes and transformations in indigenous and native peoples' role. This process has resulted in new State Constitution (2009), and new model of state and society, surpassing the old monoculture state that favored only one language, one religion and a state structure which excluded the large multicultural majority.

The Weenhayek or Weenhayeey (plural) are found in Bolivia, Argentina and Paraguay. In Bolivia, they are located bordering Pilcomayo River and move from Villamontes town to Yacuiba in Chaco. They are fishermen, but also practice hunting, gathering of natural fruits, animal husbandry and subsistence farming.

The Weenhayek keep some semi-nomade habits, with internal migration (in Bolivia) and external to Argentina and Paraguay, where they tend to form families and get triple nationality. Some of them live in Tuntey neighborhood at Villamontes city. However, they follow a migration pattern City–Country and vice-versa in search of natural products, forest and river, improving their income, and

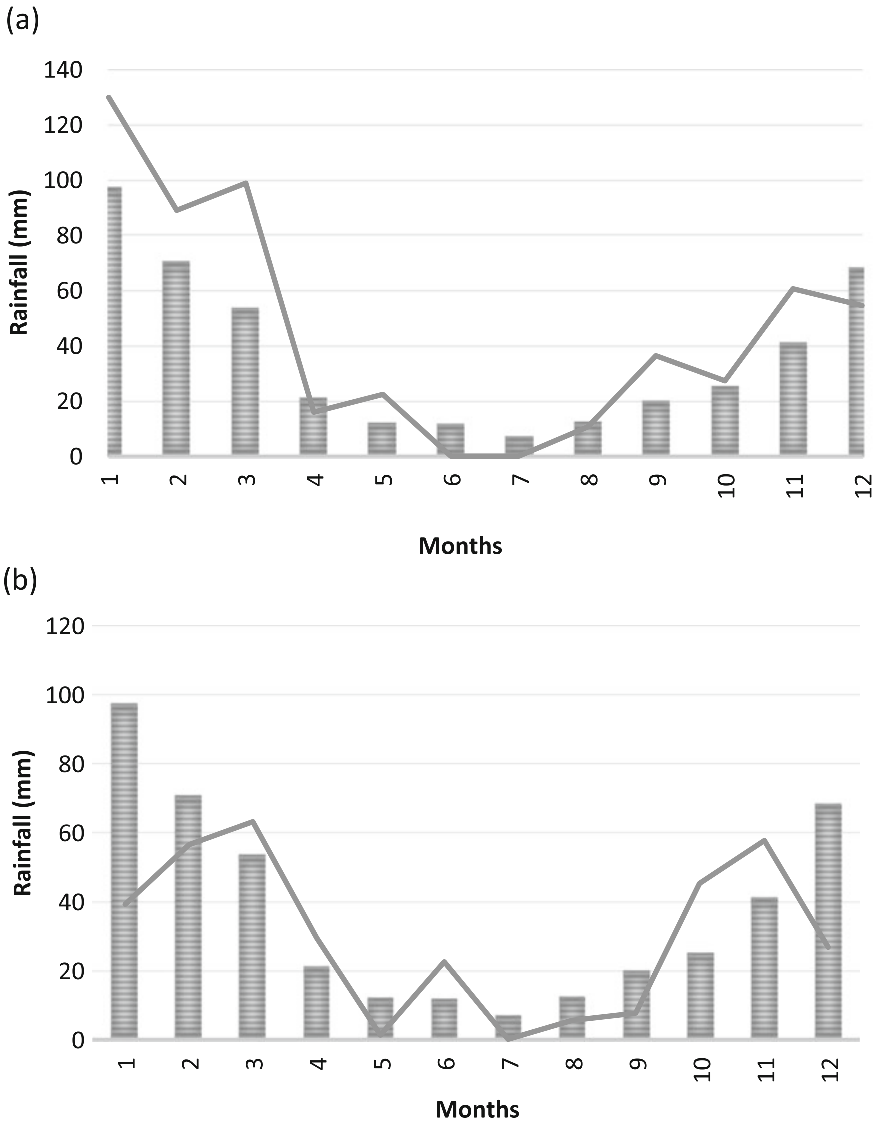

Fig. 14.4 Rainfall distribution (*Gray bar charts*: rainfall average). El Niño1997-98 (*Gray line*). (**a**) 1997 and (**b**) 1998

accessing to education and/or employment, which also explain the external migration.

In their culture the egalitarianism, reciprocity, freedom of movement, and a strong rejection of authority and domination prevails. "*They maintain the idea that "everything that a person needs, it's been already created by nature"* and that the

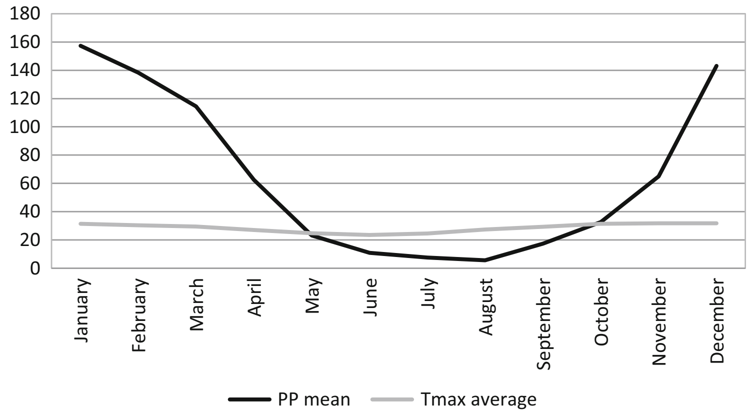

Fig. 14.5 Chaco seasonal rainfall (mm) (*black line*) and maximum temperature (°C) *(gray line*) distribution. Elaborated by the authors from SENAMHI database 2015

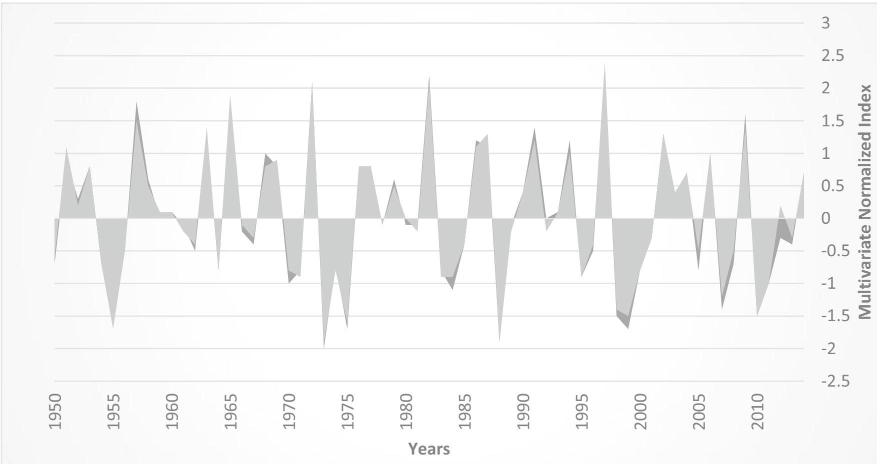

Fig. 14.6 Time-series of multivariate normalized index. Source: NOAA (2015)

spirits of the dead remain for a while on earth and can mobilize other relatives, so they usually leave their homes after a death" (Cortez 2005).

Approaches and Methods

Ecohealth Approach

Advancing the field of ecosystem approaches to human health (ecohealth) has been a major contribution of International Development Research Center of Canada (IDRC) in its efforts to improve the health of communities in the poorest regions of the world (Charon 2012).

Ecosystems are showing signs of being unable to provide the services people require of them (Hassan et al. 2005). The global environmental changes, their impacts and overexploitation of the earth's resources are showing socio-economic interactions, and have all contributed to our awareness of the interdependency of the human societies and the well-being of our planet.

"Ecohealth is a field of research, education and practice that integrates scientific evidence, professional expertise and community experience with a view to improving the health of humans, animals and ecosystems". "A focus on health—across humans, animals and other species—offers new opportunities to harness synergies across disparate efforts to address climate change" (Borbor-Cordova et al. 2008; EcoHealth 2014).

The ecohealth approach impulse transdisciplinary frameworks of health-research and partnership projects with stakeholders and affected communities. The ultimate objective of ecohealth research and practice is to develop environmentally sustainable, community-based interventions to improve the health of affected communities (Charon 2012).

A Chaco ecohealth research initiative funded by IDRC was launched to evaluate the climate change and variability health vulnerability for WBD considering climate, hydrological, ecosystem, and health characteristics of 17 urban, peri-urban and rural communities, focusing in Weenhayek ethnic group. A participatory-based approach was followed which incorporates community and indigenous organizations, local and national health system, and meteorological services.

Thus, a methodological approach to assessing human health vulnerability to climate change and variability (VCC) arises from the vulnerability criteria of the IPCC (2007) as vulnerability factors: exposure, sensitivity, the character and magnitude of climate change, and adaptive capacity:

$$V : f(Exp; Sensib; CMC; C_{R-A})$$

Where:

V	Climate change vulnerability
Exp	Exposure to climate change.
Sensib	Sensitivity.
CMC	Character, magnitude of climate change
C_{R-A}	Adaptive capacity

Herein, ecohealth approach incorporates disciplines (evolving transdiscipline) as vulnerability dimension for diseases research. Each vulnerability dimension: epidemiology, sociology, hydrology, biology, entomology, economics, or others are studied for a particular study object (diarrhea: VCC_{DD}) including a selected number of variables, which are analyzed considering complex and systemic thinking (Morin 2007) and by comprehensive evaluation (Lessem and Schieffer 2010). So the VCC_{DD} is the result of the interaction of vulnerability factors on vulnerability dimensions, with consequent variations in time and space, and magnitude.

The Vulnerability (VCC) (Fig. 14.7) framework is “a process in motion”, so that the evaluation of climate system has to consider past, current and future climate, where the character and magnitude of change between past and current climate (Delta 1) and the current and future climate (Delta 2) is estimated according to emission scenarios and different models.

This approach refers to an object of study (diarrheas), related to a discipline, science or sector, where their exposure, sensitivity and adaptive capacity is analyzed as well as the climatic and non-climatic pressures that influence the aforementioned object. It unfolds in a spatial field of analysis, which indicates the geographical change between locations of the region of the human system whose

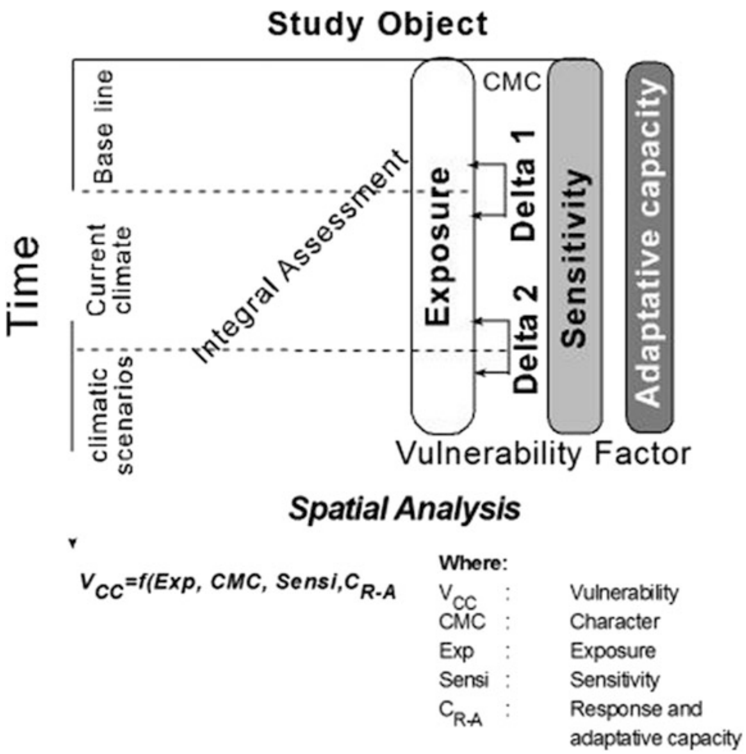

Fig. 14.7 Study object approach to assessing time-space integral climate health vulnerability

vulnerability is being evaluated. In this case, the region is the basin of the Pilcomayo River in the Chaco.

The time-space behavior of socio-economic and hydrological variables, the condition of the ecosystem, epidemiology and responsiveness of the health system, among others, allow understanding the VCC for diarrhea (VCC_{DD}) in the Pilcomayo watershed. Each discipline follows specific methodologies within the research process and through a deconstructive process, furnishing constituent blocks important for health. These blocks follow a constructivist process for building VCC_{EDAS} as a result from the interactions of vulnerability factors and dimensions for diarrheal diseases.

To set the climate regime of Chaco, a space-time analysis of meteorological variables was performed using data from each weather station as proposed by Ramallo (2006). Thus, several regional indexes were calculated to relate climatic anomalies with temperatures, precipitation and extreme events. The analysis on different time-scales allows identifying the main changes in climate seasonality and the relationship between interannual variability (VC) and ENSO.

The interannual variability was calculated as follows (Balme et al. 2006; Ramallo 2013):

$$\mathrm{Ii} = (\mathrm{Pi} - \mathrm{Pmoy})/\alpha$$

Ii = Precipitation indices in the year i
Pi = Annual precipitation in year i (mm)
Pmoy = Interannual precipitation (mm)
α = standard deviation of the studied period

Trends in precipitation and temperatures were calculated using the Pearson correlation and confidence levels at 95 %. They were used to explain the relationship between the annual rainfall and annual temperature with ENSO index.

Extreme events were selected from the average of the five most rainy or droughts years as threshold. This group of extreme events represents 15 % of total sample, which means that 1 year is characterized as extreme when surpasses 85 % of the total interannual average.

The seasonal variability analysis was made each 3 months linking the quarter and the annual rainfall (seasonal precipitation index = seasonal precipitation/annual precipitation/12). Thus, the seasonal cycle can be classified according to their annual cycle eliminating the influence of the annual rainfall (Espinoza et al. 2011).

In order to verify the water quality at each community samples in rural, periurban and urban regions were taken for bacteriological and physico-chemical tests at the UCCLIMAS laboratory and compared to the Bolivian standards.

Using the hydrological ChAc model (CEDEX 2006), the water offers were simulated for each community taking into account the soil and vegetation parameters to calculate the infiltration percentage in each basin (Ramallo 2006).

Future climates scenarios were generated with the LARS-WG stochastic model (Semenov 2014) which represents the extreme climatic events. Data generated are based on observed precipitation, maximum and minimum temperature, and radiation. The changes in probability function allow estimating the changes in extreme condition. For example, the probability of the maxima rainfall in climate change gives the needed information about the increase in magnitude and frequency of floods.

To characterize the basin, Pfafstetter methodology was used (Pfafstetter 1989), which assigns identifiers (IDs) for drainage units based on the topology of the ground surface. Each sub-basin was mapped and stakeholders were identified and selected, establishing relationships with water resource management entities.

To establish the water level baseline, a simulation was performed with the ChAc model (CEDEX 2006). After obtaining the flow of the studied sub-basins the simulation was performed using the data generated for the 2025 and 2050 Scenarios or Delta 2.

To compare different basins, the flow was converted into water level, so the influence of the size of basin was removed, using the following formula:

$$Le = \frac{V}{Area}$$

Where:

V = Volumen
A = Basin area

The formula was applied to the Pilcomayo Basin for future scenarios 2025 and 2050.

Results and Discussion

> Climate change is affecting the regional and local rainfall seasonal patterns; it is increasing the maximum and minimum temperatures, and climate variability and extremes. Although their current effects on water quality and availability are evident, in the long-term, without adequate climate change adaptation measures, this impact will be magnified (Aparicio-Effen et al. 2014).

Chaco Region Study Case

Time-series of precipitation did not show significant trend in Chaco region, which is in agreement with the Andean and Amazonian regions (Seiler et al. 2012). However, a significant increase in temperatures' maxima and a decrease in the minima, especially in Villamontes, Carapari and Yacuiba, were found. These trends began around 1999, which likely increased some diseases. Thus, the populations of Chaco region are vulnerable to WBD as a consequence of the observed and projected climate scenarios on all the elements of an eco-health approach.

Near Future Climate Change Scenarios

Climate change could be a major threat in the decades to come (Butler 2014)

Future climate scenarios generated with the LARS-WG stochastic model (Semenov 2014) for Chaco region show that increasing trends of minimum and maximum monthly and annual temperature are expected. The minimum temperature is expected to increase by 0.7 and 1.9 °C for 2020 and 2055 respectively. Maximum temperature is expected to increase by 0.9 and 2.1 °C for 2020 and 2055 respectively. The average monthly precipitation shows very small increase, which is not consistent across months and time-horizons (see also Nagy et al. 2015, showing some rainfall decrease according to recent IPCC RCP 4.5 scenarios).

Watershed and Water Availability

Over the last few years, the population of Bolivian Chaco has increased as a consequence of economic growth based on oil exploitation, which in turn increased water demand. Also, the strong deforestation in head waters, the deviation of rivers used for agricultural activities and the waste of water for oil exploration are posing new threats to water offer-demand equilibrium.

The watersheds are suffering the direct effects of climate change on water availability and quality and the indirect ones due to other sectors. Water sources are contaminated. In the urban and peri-urban zones there are companies in charge of the distribution and quality of drinking-water. They have water treatment plants, so the water quality is better than in the rural zone where water is just disinfected but not treated. In these communities, consumption is from the river when there is no water available from the drinking-water network system (DWNS). Bacteriological contamination was found by the authors (unpublished results) in the rivers and the water sources which come from animals or from communities in the basin heads.

Using Precipitation-runoff CHAC model (CEDEX 2006), the outflows of 16 communities were simulated showing that more than 60 % of water consumption comes from underground water. During the rainy season (December-March), the aquifers are recharged which means that a change in the precipitation regime timing or quantity during these months, would impact the hydrological balance.

The comparison between climate baseline (1985–1999) and current climate (2000–2014), shows that in rural and urban communities, the trends in water resources are not significant. However, in peri-urban communities there is a decrease between 3 and 15 % depending on the size of the basin which is explained by the continuous growth of population that increases water demand, as well as deforestation, soil erosion and the degradation of natural resources.

In the upper watershed the availability of water resources depends mostly on underground water; the physiographic characteristics and the use of soil makes it a good place for a strong infiltration. Also, in the basin head waters, there are wetlands which are regulators of the hydrological balance. During the rainy season they are recharged and during the winter they gradually release the water. Wetlands surface (as NDVI Landsat images analysis) is about 7.1 km^2 in the basin head, 10 km^2 in the middle basin, and 5.2 km^2 in the lower basin.

The outflows are stronger linked to the precipitation from December-February with more that 50 % of the annual outflows. Precipitation-runoff CHAC model shows strong interannual outflow variability in both regions which is not necessarily linked to climatic anomalies like ENSO.

The five studied municipalities: Camiri, Machareti, Villamontes, Carapari and Yacuiba, are located in the Pilcomayo basin whose natural dynamics is dominated by the seasonal climate (Fig. 14.8), with alternating dry (May to October) and wet (December to March) seasons causing great variability of flows.

Most people in Chaco (80 %) depend on groundwater resources which are affected during dry years. Moreover, the increase in economic activities is producing a significant advance of the agricultural frontier and an increase of the population which results in new stresses on the hydrological cycle.

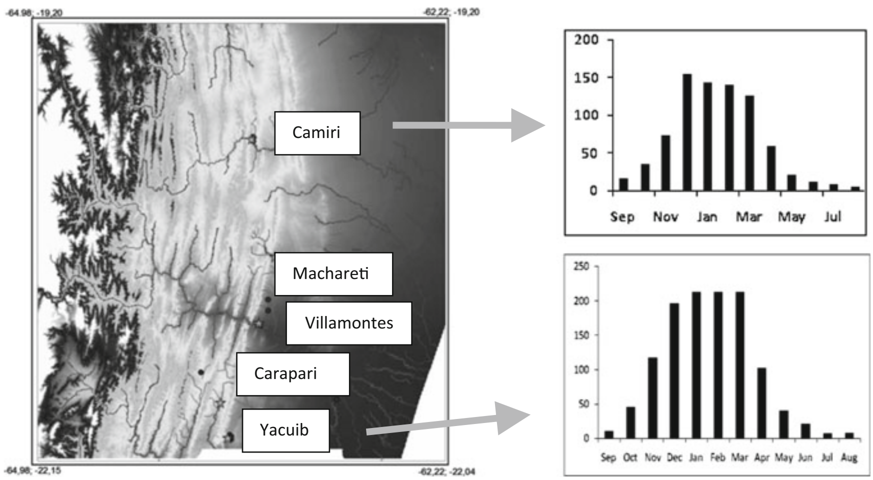

Fig. 14.8 Chaco watershed hydrological map. *Points* show studied communities and *stars* municipal capitals. Rainfall at Southern and Northern Chaco Boliviano is shown. Source: digital elevation model (90 m resolution)

Twenty years ago the water balance was stable. However, at present and especially in the near future this resource could be at risk. This is mainly due to anthropogenic factors such as alteration of the upper basin, population increase and over-exploitation of natural resources.

Water Quality

Physical, chemical, and bacteriological analysis (coliforms and *Escherichia coli*) were used to identify the degree of pollution for drinking-water in all communities included in this study and Pilcomayo River (Table 14.1) during humid and dry seasons.

The water samples showed that turbidity exceeded the permissible limits in most evaluated communities. Tiguipa and Boyuy rivers (Pilcomayo basin) had high levels of water pollution, with a major health risk to rural communities, especially in dry seasons or in frequent droughts, when drinking-water is taken from the rivers. The break in the water outlet is often associated with strong erratic rainfall events. Under a scenario of more extreme events in the near future (IPCC 2012), more frequent breaks of safe water supply are to be expected.

Rural and Peri-urban communities are more vulnerable to environmental bacteria and to *Escherichia coli* bacteria in humid and warm season, such as was the case in Peña Colorada and Avaroa that showed high levels of turbidity, total coliforms and *Escherichia coli*. These parameters are lower in dry season coincident with winter months (Table 14.2).

Parasitological analysis identified the presence of *Giardia lamblia* in water reservoirs of Tentamí (Guarani community). Lakes and rivers had organic levels above those permitted by Bolivian law, stronger in the rural and peri-urban communities (UCCLIMAS 2014).

Table 14.1 Villamontes and Carapari Water River and home water taps samples results. Elaborated from the authors from CCLIMAS Laboratory results

	River			Home water taps		
Parameters	Boyuy River	Peña Colorada (Pilcomayo river	Carapari (Pilcomayo river)	Boyuy	Peña Colorada	Carapari
Turbidity (NTU)	2.45	3.520	7.424	3.02	2.05	3.32
Total coliforms (U.F.C./100 ml)	9	7.5×10^3	2.5×10^6	7	5×10^2	5.5×10^4
Escherichia coli (U.F.C./100 ml)	9.2	2.4×10^3	1×10^5	5	7×10^1	1×10^3

Table 14.2 Villamontes communities' water samples results for humid and dry seasons

Parameters	Humid season		Dry season	
	Peña Colorada	Avaroa (Tuntey)	Peña Colorada	Avaroa (Tuntey)
Turbidity (NTU)	3.520	3.67	0.84	0.96
Total Coliforms (U.F.C./100 ml)	7.5×10^3	2.8×10^1	7	4
Escherichia coli (U.F.C./100 ml)	2.4×10^3	1	<1	<1

Table 14.3 Chaco region vegetation coverage by type and size

Plots	Neighborhood or community	Tree, shrub and grassland coverage	Leaf type: simple or compound	Plant leaves size—micro-foliated	NDVI
Urban	• Centro Sur • Juan XXIII • Virgen Fátima	Low	High	Low	Low
Peri-urban	• Fray Quebracho • Barrio Nuevo • Carapari, Avaroa, • Tiguipa Estación • Panamericano Alto	Medium	Medium	Medium	Medium
Rural	• Boyuy • Palmar Grande • Tentami • Urundaity • Purísima • Tiguipa Pueblo	High	Low	High	High

Head Watershed Ecosystem Results

> Climate change is modifying ecosystems and it's creating the environmental condition for climate sensitive diseases occurrence (Confalonieri and Aparicio 2011)

The vegetation type and the presence of indicator species of different human intervention (urban, peri-urban and rural) were evaluated at 168 sampling points from 310 to 1060 m above sea level. The vegetation types are associated with Chaco Serrano region. The tree, shrub and grassland coverage, leaf type and size differences, and NDVI are shown in Table 14.3.

The ecosystem preservation status was also evaluated by the proportion of bird associations, identified species (71) and number of individuals (1756) by type of area. Rural areas showed fairly homogeneous guilds, indicating a well-preserved ecosystem, unlike urban areas where the predominant group was omnivorous.

More than 90 % of the analyzed species belong to disturbed habitats (fragmented forests, agricultural areas and secondary forests), representing agricultural rural and peri-urban areas.

Waterborne Transmissible Diseases

In order to identify the causes of most frequent queries and WBD a retrospective analysis of 7 years and 200,284 clinical cases from Chaco (Yacuiba, Machareti, Camiri, Villamontes, and Carapari) Hospital was performed. Children from 0 to 5 years were most affected (51 %), followed by those from 5 to 20 years (20 %), from 20 to 59 years, (23 %) and from 60 to plus, (6 %).

Each disease was coded using the International Classification of Diseases (ICD-10) divided according to age groups. The most common diseases were constipation (K59, 0), abdominal pain (R10), gastroenteritis and duodenitis (K29), abdominal cramping pain (R10, 4), vomiting and nausea (R11), acute diarrheal disease—ADD S/D (A10,1)—and functional bowel disorder (K59,9), which are compatible with WBD and coincide with signs and symptoms most frequently reported by local population: pain, cramping, abdominal pain, diarrheas and constipation.

A clinical evaluation of all communities of who reported gastrointestinal diseases showed: diarrheal episodes (20 %), recurrent diarrhea (17 %), even 2–6 times per month, and diarrhea with mucus and/or blood (12 %). Diarrheas affected C.U.F. Y.O, with accumulated incidence of 34 % in 6 years. Machareti County showed the highest prevalence rate by 1000 C.U.F.Y.O.

The sources of drinking-water in Chaco are: DWNS (6.7–84 %), truck dealer (0.17–64 %), well (0.55–9.8 %), river or watershed (1.1–25.6 %), and another source (0.05–15.1 %). Accesses to basic services as toilet are low (21.16–44.6 %) and septic tank and well are used for stocks. Chaco infant mortality ranges from 43.28 to 54.87 %. In Carapari diarrhea is responsible for 39.25 % of infant deaths cause. Symptoms and cases of WBD were found in the whole watershed.

Water samples were taken from the DWNS, tanks, and home and community water storage. Water quality and parasitic analysis showed that several parameters were out National standards. Tiguipa community water taps samples were positive for *Escherichia coli* and Tentami water storage was positive for *Giardia lamblia* and *Eschericha coli*.

Most copro-parasitological samples in Chaco region showed high parasitism (88 %) (Table 14.4) related to viable cysts ingestion, contaminated water and food, lack of hygiene, poor socio-economic conditions, and poor water quality.

Diarrheas monthly seasonality shows cases all through year, including dry periods (coinciding with water quality deterioration) peaking during the rainy

Table 14.4 Chaco's parasites type of copro-parasitological samples

Category	Parasites	Positive samples (%)
Parasite	• *Eschericha coli*	30
	• *Blastocystis hominis*	18
Pathogenic parasites	• *Giardia lamblia*	40

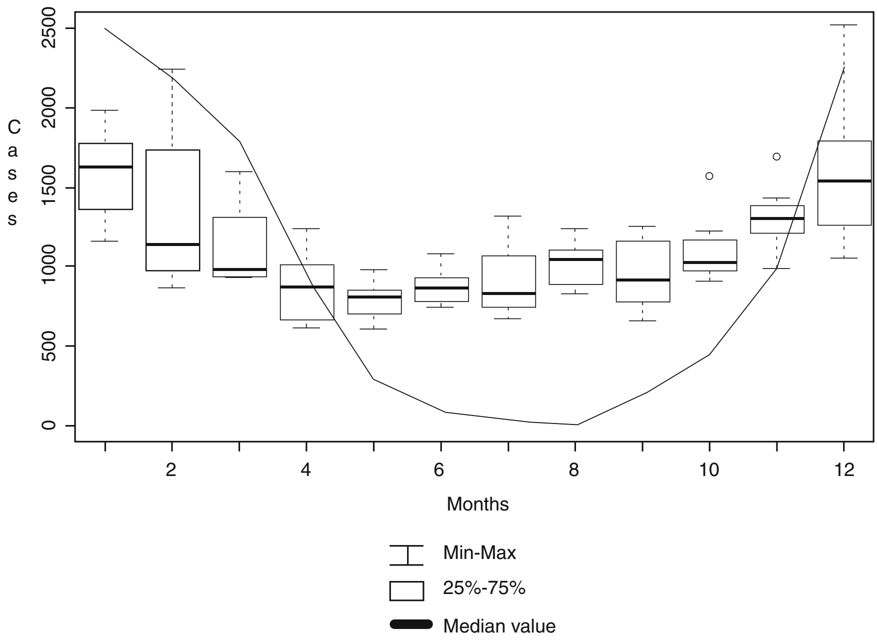

Fig. 14.9 Chaco region's rain and number of cases of diarrhea seasonality. Elaborated by the authors from Ministry of Health database

period (November-April) (Fig. 14.9), high temperatures and relative humidity. The decrease in the number of cases is coincident with reduced rain and temperatures. The increases of Chaco's temperature and precipitation coincide with increased risks of parasite and microbiological factors.

Productive Assessment

Climate change increases the likelihood appearance of many zoonotic diseases, whereas environmental changes allow for the development of new parasites and pests. Nevertheless, the health system net is not prepared to respond (Mills et al. 2010).

In Chaco summer time it is usual the death of livestock due to lack of food in the arid ecosystems with xerophytic vegetation. Droughts have strong impacts on livestock morbidity from September to December coincident with the highest temperatures related with livestock foot and mouth diseases.

Vulnerability Assessment

The VCC_{DD}, assessment followed the proposed methodology (vulnerability dimensions and factors, and the causality between variables and the diarrhea cases number) where vulnerability dimension variables results were analyzed for all communities grouped in urban, peri-urban and rural. The correlation matrix values (1 high—0, 1 Low) from all positive and negative correlations were grouped in levels of vulnerability (high, medium and low) interacting with vulnerability factors assessment outputs.

The peri-urban correlation matrix (Fig. 14.10) shows that total coliform parameter in water samples is highly correlated with diarrhea cases number (r: +0.9). The *Escherichia coli* positive samples, which are associated with average maximum temperature increases (Delta 1) between past (1972–2000) and current (2001–2014) climate, are correlated with diarrhea cases (r: +0.6). The rainfall decrease is also correlated with *total coliforms* and diarrhea cases (r: +0.6). On the other hand a negative correlation was found between accesses to solid waste services collection, washing hands, hygiene practices with *total coliforms* and diarrhea cases number.

Table 14.5 summarizes VCC_{DD} values resulting from vulnerability factors and dimensions scores for Chaco peri-urban communities. The character and magnitude of temperature changes are statistically significant ($p \geq 0.05$), whereas they are not for rainfall changes. However, due to temperature increases water loss is actually greater by evaporation.

The VCC_{DD} are greater for the communities in the rural area of the Pilcomayo watershed: Machareti, Camiri and Carapari municipalities. The other localities evaluated including urban and some peri-urban areas show an intermediate level of VCC_{DD} to climate change due to the decreasing availability and quality of water.

The occurrence of diarrhea is related to hygiene and sanitation especially in C.U. F.Y.O, being highly dependent on contaminated water sources, and the deficit in the management and disposal of solid waste.

Escherichia coli and/or *Giardia lamblia* were found in samples of tap water and water storage of various communities which coincided with high levels of VCC_{DD}. Parasitological analysis of soils in peri-urban areas of Yacuiba (Juan XXIII) was positive for *Ascaris lumbricoides*, *Strongyloides stercoralis* and/or *Trichuris trichiura* (Barrio Nuevo), which explains part of the intermediate level of VCC_{DD} found in this municipality.

Rural communities in which the Guarani and Weenayek ethnicities are included, had higher rates of parasitism in relation to urban and peri-urban areas, but in general, the soils and waters of the studied area were highly contaminated with different types of parasites, cystis, fungus and bacteria (Table 14.6).

Local assessment, interviews with key stakeholders, municipal statistics, expert opinions and Knowledge, Attitudes and Practices (KAP) surveys (see also Aparicio et al. in this Book) were carried out among a representative number of stakeholders including urban, peri-urban and Weenhayek communities, aiming to understand social and environmental health determinants.

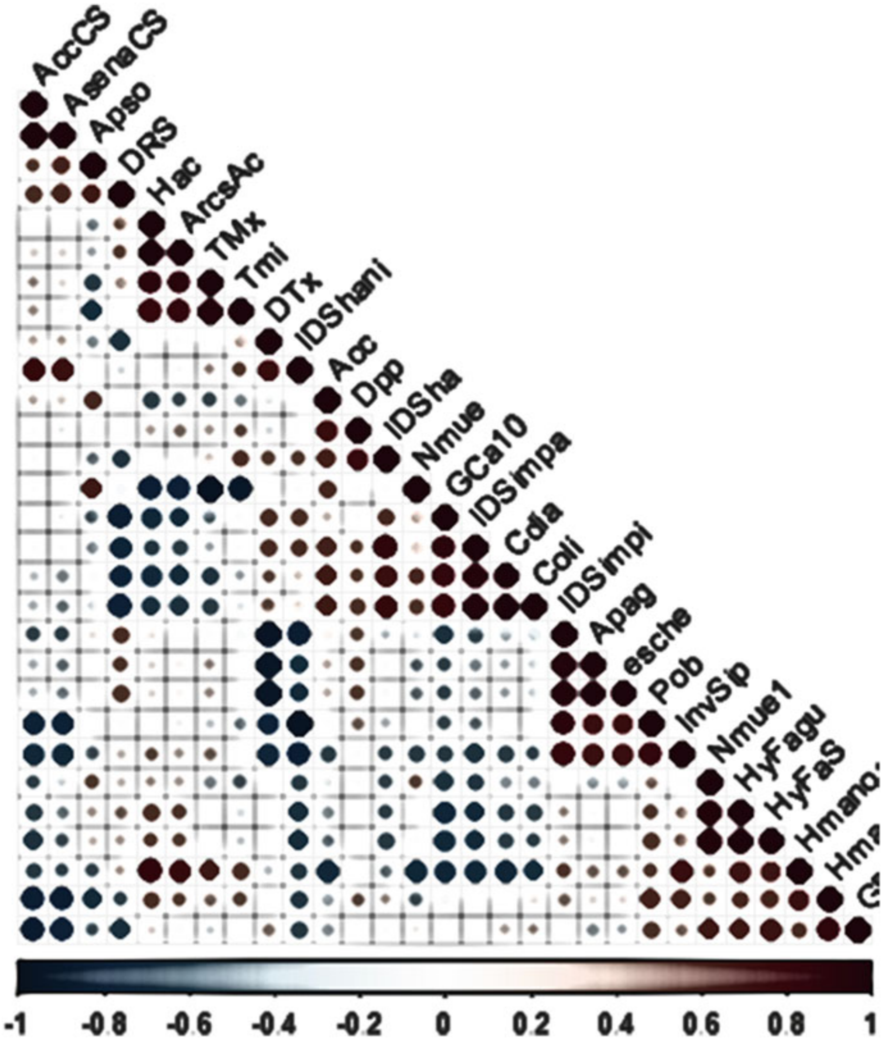

Fig. 14.10 Chaco peri-urban communities' correlation matrix for diarrheas. Elaborated by the authors

Table 14.5 Climate change vulnerability for diarrhea (VCC_{DD}) for Chaco peri-urban communities considering vulnerability factor and some evaluated dimensions

	Vulnerability dimensions			
Vulnerability factors	Epidemiology	Hydrology	Social	Ecosystems
Exposure	3	3	3	3
Sensitivity	3	3	3	3
Character and magnitude of climate change	3	2	3	3
Adaptive capacity	1	1	1	1
Total	**10**	**9**	**10**	**10**

VCC_{EDAS} Levels: High (7–10), Medium (4–6) and Low (1–3), Elaborated by the authors

Table 14.6 Chaco parasites type of water and soil analysis (UCCLIMAS Laboratory)

Department	County	Community	Parasite positive
Santa Cruz	Camiri	Panamericano Alto	*Giardia*
Chuquisaca	Machareti	Tentami	*Giardia*
		Tiguipa	*E. coli*
		Boyuy	*E. coli*
	Yacuiba	Purisima Weenayek	Parasites' eggs and cystis, fungus, bacteria

Indigenous communities with high rates of diarrhea have bad results in all indicators of physical and built environment (climate variables are the only ones similar for the three compared communities), human and social development, economic status, and intermediate results in governance. Thus, Weenhayek communities are highly vulnerable to climate health impacts. This critical situation in relation to socio-environmental factors in rural areas, as well as in peri-urban (moderate to high vulnerability) and urban areas (low to moderate vulnerability), is necessary to be addressed by authorities and communities itself in order to reduce WBD.

This status of the environment and services together with the KAP of the population, as well as weaknesses in the local adaptive capacity, increase the vulnerability of people in the Chaco against the effects of current climate variability and future changes.

Adaptation Strategies

To cope with Bolivian high vulnerability a "National Adaptation to Climate Change Mechanism" (MNACC) was developed (PNCC 2007) which considers five priority sectors including human health. Some of the programmatic areas for human health adaptation are as follows:

- Mainstreaming of climate change policies and health programs in national and sub-national institutions.
- Identifying current and future vulnerability.
- Building capacities.
- Encouraging a pro-active attitude on the part of national health system and social participation}

Chaco region adaptation process is currently at a first stage of development which began with the vulnerability assessment results presentation to social, political, health sector, and stakeholders. This participatory approach allowed defining the better human health adaptation options in terms of measures, strategies, and adaptation policies.

The Chaco community-based adaptation focuses on the empowerment, equity, gender approach and promotion of communities' health resilience.

Conclusions

The populations of Chaco regions are vulnerable to WBD and DD as a consequence of social, environmental and health determinants including the observed and projected climate scenarios

Chaco municipalities are suffering climate change and variability, as well as anthropogenic non-climate stressors, which cause health impacts such as water-borne transmissible diseases and diarrheal diseases. Evidences of these changes are: reduced water availability and quality; deteriorated watershed and ecosystems with both human and animal health consequences; decreasing rainfall and warming.

Near-future climate scenarios (2025–2050) project increases in temperature, whereas there is uncertainty with regard to rainfall (expected to be similar or less than current). Climate changes will likely affect the hydrological regime, human and environmental health, and economic activities in the Bolivian Chaco.

Occurrence of diarrheal diseases follows climate seasonal variability. The decrease in the number of cases coincided with the decrease in precipitations and the beginning of winter. This behavior seems to be related to observed climate change and variability impacts.

Occurrence of WBD is high in Chaco due to both water availability and quality. Oil exploitation drives population immigration to peri-urban areas increasing water demand, deforestation, rivers diversion, and agricultural frontiers advancement.

Water for human consumption is contaminated with parasites, bacteria and fecal coliforms in all sub-systems of drinking-water which produces high levels of WBD.

Despite the numerous programs developed to prevent Acute Diarrheal Diseases and the increased knowledge about their biological causes, there is a strong flaw in ecosystems status and hydro-climatic factors, and how they interact with other factors that reduce or increase diseases incidence.

The ecohealth approach shows that climate and ecosystem changes are increasing the sensitivity to developing WBD with observed impacts on both human and animal health, and livelihood.

The understanding of the increasing impacts of climate change and variability on water issues is a call for collective action to resolve the lack of access to clean water based on integrated management of water resources. The isolated actions of the health sector are insufficient to meet the challenge of providing safe water to the most vulnerable.

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Part III
Climate Change and Health: Education, Training and Governance

Chapter 15
Training Institute on Climate and Health: Mercosur Experience

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Abstract A key component of adapting to climate change and variability is the creation of a new generation of professionals able to understand the role of climate on disease and to quantify its risk in public health. Capacity building in different regions of the globe will help strengthen the decisions made in the health sector and is reflected in the reduction of climate risk.

The International Research Institute for Climate and Society (IRI), the InterAmerican Institute for Global Change Research (IAI), the Ministry of Public Health of Uruguay, the Intergovernmental Commission for Environmental and Occupational Health of (CISAT), and the Pan American Health Organization (PAHO) joined forces to organize the first regional Training Institute on Climate and Health based on the curriculum on climate information for public health developed and implemented worldwide by the IRI.

Participants from member countries of Mercosur region were trained for 2 weeks and regional working teams made up of climate and health professionals were

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formed and presented research projects to address climate sensitive issues on health in response to the objectives of the Mercosur Action Strategy to Protect Human Health effects of Climate Change. Projects were meant to strengthen and build regional networks of cooperation and participants were able to practically apply the knowledge and tools provided by the course to address relevant topics.

A lot of knowledge remains to be built in climate and public health and the field efficiency of the new approaches implemented is yet to be assessed. It is critical to continue training professionals and to provide spaces for networking and also to create collaborative programs that allow professionals from different institutions, sectors and disciplines to communicate and share their expertise to tackle climate risk.

Keywords Climate • Public health • Curriculum • Training and education

Introduction

Protecting public health from the impacts of climate is a challenging demand for the public health community, as recognized during the World Health Assembly in 2008 (WHO 2008) and the First Conference of Ministers of Health on Climate and Health (WHO 2014).

Public health practitioners, epidemiologists, health management workers, health professionals, researchers and health policymakers are increasingly concerned about the potential impact that climate variability and climate change could have on public health. However, many public health professionals are not yet aware of the ways in which climate information can help them manage the impacts of climate on their work. At the same time, climate and meteorology scientists are not aware of how they can fill the information needs from the public health sector.

The occurrence of emerging and infectious diseases and other public health consequences (like cardiovascular diseases, injuries or malnutrition) of the climate variability and climate change required the development of multiple entry points to tackle the problem. The process of developing climate-based tools and methodologies for public health e.g. early warning systems at the local level, for instance, requires a clear framework and partnerships built between those who supply data and information, those who use it and those who understand the societal consequences of both negative and positive impacts of climate variability and climate change. To date these relations have been hard both to build and to maintain. Interdisciplinary work and dialogue is necessary to bridge this gap.

Present approaches to incorporating climate data and/or climate information into public health planning, surveillance, monitoring and evaluation are limited. They are typically included as part of climate change mitigation and/or adaptation strategies, and often based on climate change scenarios developed from global climate models. These models focus on the long term, commonly extending out to 2050 and beyond. We challenge that, used alone; they are not appropriate for national adaptation policies, as policy time horizons for the latter are much shorter, usually 4 or 6 years. This indicates a need for planning based more on climate variability than climate change scenarios. It will also demand a planning process with a cross sectorial approach and strategies to increase the public health community's capacity to understand the role of climate on disease and public health outcomes and demand the appropriate climate data/information to prevent diseases. In this regard the approach of Health in all Policies (Stahl et al. 2006) could enhance the planning process that it is needed to better understand the role of climate in public health.

A key component of climate variability and climate change adaptation is the training of professionals to understand the role that climate plays in driving disease burden and impacting economic growth (Lowe et al. 2011).

The International Research Institute for Climate and Society (IRI)/Earth Institute at Columbia University is the premier global research and capacity building institution focused to enhance society's capability to understand, explore, anticipate, and manage climate impacts for improved risk management decisions in different sectors (Goddard et al. 2014). In the case of the Public Health sector, IRI aims to promote awareness and understanding the linkages between climate and public health, in addition to developing a set of prototypes to address and communicate these through the education and training of public health and climate professionals/researchers on the relationship between climate and public health in order to better manage climate risk (Mantilla and Thomson 2012). To this end, several initiatives have been developed to train climate and public health practitioners to understand, access, explore, model and translate climate information to inform public health decision-making (Mantilla et al. 2014).

Following on from the IRI Climate Information for Public Health: A Curriculum for Best Practices (Cibrelus and Mantilla 2010), several international and regional climate and public health courses and side events have emerged as can be seen in the following table:

Event	Dates	City/country	Organizers	Number of participants
Curso de Epidemiología Aplicada con Enfasis en Clima y Salud	22 September–3 October 2008	Bogotá, Colombia	Instituto Nacional de Salud. International Institute for Climate and Society	75
Climate and Health	31 November–5 December 2009	Addis Ababa, Ethiopia	International Research Institute for Climate and Society. Ministry of Health Ethiopia. National Meteorological Office Ethiopia	16
Training on Climate Information for Public Health	10–18 March 2010	Antananarivo, Madagascar	World Meteorological Organization. International Institute for Climate and Society	15

(continued)

Event	Dates	City/country	Organizers	Number of participants
Training Institute on Climate and Health	7–18 November 2011	Piriápolis, Uruguay	Ministry of Public Health of Uruguay. International Research Institute for Climate and Society. Inter American Institute for Global Change Research. Pan American Health Organization	22
Curso Andino en Clima y Salud|"Uso de Información de Clima para la Salud Pública"	19–30 November 2012	Quito, Ecuador	International Research Institute for Climate and Society. Universidad Central. Pan American Health Organization. World Meteorological Organization. Inter American Institute for Global Change Research	22
Modeling Tools and Capacity Building in Climate and Public Health	15–26 April 2013	Trieste, Italy	International Centre for Theoretical Physics. International Research Institute for Climate and Society	39
Third International Conference on Climate Services: Climate and Health	4–6 December 2013	Saint James, Jamaica	Climate Services Partnership—International Research Institute for Climate and Society/USAID	30
Four International Conference on Climate Services: Climate and Health	10–12 December 2014	Montevideo, Uruguay	Climate Services Partnership—International Research Institute for Climate and Society/USAID Ministry of Public Health of Uruguay World Health Organization Inter American Institute for Global Change Research	30

Source: International Research Institute for Climate and Society

This chapter will showcase the Training institute on Climate and Health[1] as the first initiative of this kind in South America in the framework of the Mercosur Action Strategy to Protect Human Health effects of Climate Change.

The training institute demonstrated the importance of having government and academic partnerships not only to organize contents, logistics but also to fund and implement the development of regional projects, which can be implemented for interdisciplinary groups and address issues relevant to the home countries' participants as well as for regional purposes in the context of the Mercosur Region.

Training Institute on Climate and Health: Mercosur Experience

The International Research Institute for Climate and Society (IRI), the InterAmerican Institute for Global Change Research (IAI), the Ministry of Public Health of Uruguay as technical secretary and President Pro Tempore of the Intergovernmental Commission for Environmental and Occupational Health (CISAT), and the Pan American Health Organization (PAHO) joined forces to organize the first regional Training Institute on Climate and Health in Piriápolis, Uruguay from November 7–18, 2011.

The Training Institute was funded by the IAI with resources from the US National Science Foundation (NSF). Co-sponsors were Uruguay's Ministry of Public Health, the National Meteorological Service, the Pan American Health Organization (PAHO), the International Research Institute for Climate and Society (IRI) and Canada's International Development Research Centre (IDRC).

This institute was based on:

(a) The curriculum on climate information for public health, which IRI developed and has implemented in several countries around the world.
(b) The experience of the IAI in developing Training Institutes and in fomenting interdisciplinary and multinational networks to stimulate regional cooperation.

[1] In the context of this chapter, training institute means train people in climate and health issues and promote the application of the knowledge and tools provided by the course to address relevant topics through the development of regional projects which allow the participation of professionals from Mercosur countries in climate and health research programs and conferences at regional and global level.

(c) The framework of action under the Intergovernmental Commission for Environmental and Ocupational Health (CISAT) Ministerial Resolution No. 12/09 "Climate Change and Health," and the Mercosur Action Strategy to Protect Human Health (Mercosur 2009) effects of climate change. Among the objectives of the commission are:

- Promote and support the acquisition of knowledge about the health risks associated with climate change,
- Raising awareness of climate change effects on health, community and the health team, promoting communication and dissemination of information with a multidisciplinary approach;
- Promote cross-disciplinary, interagency and intersectoral Climate and Health;
- Promote the strengthening and human resource development and
- Strengthen and build capacity health systems to develop, implement, monitor and evaluate adaptation measures, in order to improve responsiveness and be prepared to effectively address the risks posed by climate change.

Selection of Participants

The course targets professionals who play an operational and research role in public health planning, surveillance, control and evaluation of climate-sensitive diseases.

More than 40 applications were received from candidates from all countries of Latin American, including in particular member countries of Mercosur. Each of the candidates was asked to send a summary of his or her resume and a brief description of their interest and motivation to participate in the course with an emphasis on how it would relate to their area of work or study. The selection process was based on the following criteria:

- Professionals in health and/or climate from government and academic institutions
- Professional in the early or mid-career
- Financing capacity of their institutions
- Professionals from Mercosur member countries
- Skills in data analysis and resource management

Applications were made online, and the different networks of each affiliated organization were used to disseminate course announcement. Using the above criteria, 22 participants were selected. Participants came from Argentina (4), Brazil (3), Uruguay (5), Chile (3), Paraguay (1), Ecuador (3), Peru (1), Panama (1) and Bolivia (1).

Training Institute Description

The training institute had two stages. Stage one was a 2-week course designed to increase awareness, understanding, and the ability to manage climate-related impacts on public health. Using an approach deeply rooted in methodologies, information gathering, and the use of evidence for decision-making, this course provided a balance of concepts presented by experts from both the public health and climate communities.

The 2-week course had the following objectives:

- Understand the role of climate in the burden of disease and climate sensitive events,
- Demonstrate new tools for analyzing climate and epidemiological data (Data Library, R, Geographic Information System GIS)
- Understand how to improve the decision making process by making use of climate information
- Develop proposals for integrating multinational and multidisciplinary environment and health research or training projects under the Training Institute Seed Grant (TISG) of IAI.

The second stage was related with the development of a proposal for each team who was evaluated by a team of experts and awarded with NSF funds. The objectives of this phase were:

- Improve local and regional capacity to use climate information for health-related interventions in Mercosur countries.
- Promote multidisciplinary research and collaboration between experts and professionals from various sectors and countries.

Methods and Evaluation Instruments

The methodology of the course included lectures, practical exercises, group discussions, panel discussions, field trip and development of a proposal framed in CISAT's regional action plan, agreement of Ministerial Resolution No. 12/09 "Climate Change and Health," and the MERCOSUR Strategy to Protect Human Health from Climate Change.

Eighteen facilitators (including speakers and organizers) were responsible for implementing the curriculum, which had four modules: (a) Basic Concepts in Climate and Health; (b) Sources and tools for the analysis of climate data and public health; (c) Use of climate information in decision-making on climate-sensitive diseases (d) Ability to write proposals for research and training.

The lectures were geared toward a progressive understanding of the relation between climate and public health and practical methods for integrating climate knowledge and information into public health related decision-making processes.

The IRI Data Library was used in support of the training (Del Corral et al. 2012) as well as other information system such GIS and R.

The course evaluation process was designed to determine the strengths and weaknesses in the content and delivery of materials, and to provide the organizers with a vision of how to improve the structure and content of the course for future training institutes. Evaluations were completely anonymous, and conducted using Google Docs forms (http://docs.google.com).

The course evaluation system had several components, among which were:

(a) Daily quiz participants answered every day and their replies were sent the same day to the participants and the facilitators of the conference
(b) Daily assessment of the content and course structure, which was sent to the facilitators of the day for feedback on their performance
(c) The final evaluation that stressed on other aspects such as design, content, course transferability, utility development proposals and course logistics.

Results

As a result of this initiative, 22 participants from Argentina, Bolivia, Brazil, Chile, Ecuador Panamá, Paraguay, Perú and Uruguay were trained and four new working groups were established with professionals from the climate and health communities who developed four regional proposals which three of them were funded by NSF.

Regarding the results of the evaluation process of the training, participants rated the Institute as an excellent opportunity to meet and interact with professionals from other disciplines and countries, and as a valuable experience that enabled them to promote multidisciplinary work and collaboration between various experts and professionals from different sectors of several countries.

Here some of the results of the evaluation process:

The percentage of correct answers in the daily quiz, which ranged between 42 and 85 % response successful with an average of 60 %. This indicates that the retention of information was over 50 %.

Regarding the daily assessment, the range varies according to the category and the results are as follow:

- The facilitators were clear and easy to understand: 61–100 %
- The classes today challenged me to think in a different way: 54–78 %
- Classes filled my expectations: 75–93 %
- The timing and sequence of classes made sense: 80–100 %
- The resources, references and other materials were appropriate and helped me better understand the course content: 63–93 %
- The audio-visual aids used in classes were appropriate and useful: 79–100 %

Of the total participants (22) only 77 % (17) had complete response to the final evaluation. This assessment included a series of questions related to the fulfillment of the objectives, design, content, practices sessions, development of proposals under the Seed Program Projects and logistics among others. Below the results of some of the questions:

- The course objectives were achieved? Yes: 94 %
- Do you think that the Training Institute contributes to the creation of knowledge networks, research, and/or training? Yes: 94 %
- Are the course's facilitators achieve transmit their knowledge? Yes: 89 %
- Which of the modules was the most interesting/relevant to your work?

  Module 1: Basics in climate and public health: 19 %
  Module 2: Sources and tools for data analysis: 12 %
  Module 3: Using climate information in decision-making: 25 %
  Module 4: TISG Seed Program projects: 44 %

- Prepare proposal helped me better understand the course content. Yes: 89 %
- Have you participated in multinational and multidisciplinary projects or networks research? No: 67 %

Some of the participant testimonies are as follows:

> This is a new topic to be further explored in the health sector. I salute each of the presenters; the ideas they brought to the course have been very useful in changing the lens through which we view approach climate-sensitive disease.

> In my opinion the best contributions of the course was to know the experience of each country in the process of integration of meteorological and health systems. Our problems are the same, so that regional solutions can contribute to the improvement of processes in our countries, starting in our institutions, raising awareness among various actors, since the change of organizational culture is slow, but not impossible.

> We were able to form multidisciplinary research groups (in two excellent weeks) and then produced a proposal projects. Additionally, we were able to link the health and climate sectors, and were able to help our peers in the public health sector understand the technical language of meteorology.

> The project allowed us to evaluate the abilities of each group member and provided an opportunity for all to learn about the process of creating a research plan. It also gave us confidence that indeed research ideas can be developed between the health and climate sectors.

Although most of the evaluations highlighted the positive aspects of this initiative, there were also a number of recommendations made by the participants, among which are the following: Participants would have preferred more time for discussion with both the facilitators and each other, particularly to write the TISG proposal. In addition, some participants felt it would be useful to deliver into a smaller number of subjects and data analysis tools and have more clarity on a subject and the use of tools.

Proposals were meant to strengthen and build regional networks of cooperation and participants were able to practically apply the knowledge and tools provided by the course to address relevant topics.

The regional proposals developed by each group were designed according to the guidelines defined by the organizers under the Training Institute Seed Grant (TISG) of IAI. Each group presented its own proposal, which was then revised by a committee of experts from the climate and health communities. Coming out of the training four projects were presented and are listed below:

Project 1: Strengthening technical and scientific capabilities of Ecuador, Panamá and Perú to the development of applications in the area of climate and health.
Project 2: Climate variability and its likely impact on the health of cities in Latin America: Buenos Aires, Santiago, Montevideo, Salto and Manaus.
Project 3: Development of a system integration and management of health and climate for the district level.
Project 4: Diagnostic performance of diseases related to climate variability in border between Brazil and Uruguay.

Three project proposals were ultimately selected to receive seed funding from IAI (project 1, 2, and 4) with resources from the US National Science Foundation (NSF).

Here a brief summary of one the funded project entitled "Climate variability and its likely impact on the health of cities in Latin America: Buenos Aires, Montevideo, Salto, Santiago and Manaus" to showcase the work the participants developed during the training institute.

Team members came from Argentina, Brazil, Chile and Uruguay and worked in the field of meteorology, health and academic research. The project is part of the "Strategy of MERCOSUR action to protect human health from the effects of climate change," raised by the Ministers of Health (MERCOSUR/RMS/AGREEMENT No 12/09). The general question guiding this proposal was how climate variability is related to communicable and non-communicable diseases in the cities of Buenos Aires, Manaus, Montevideo, Santiago and Salto. The main objectives of this study were to know the available meteorological and epidemiological information of the cities under study and to evaluate the relation between communicable and noncommunicable diseases and climate variability (inter-annual and inter-seasonal variations) in those populations. The study also analyzed extreme weather events (heat and cold wave and rainfall floods) and its impacts on human health. A quantitative methodology was followed to analyze the association between climate and communicable and non-communicable diseases. It focused on exploratory analysis techniques such as frequency, measures of central tendency and dispersion. In addition, bivariate correlation techniques were carried out in order to seek statistical relations (Orti 2000). As conclusions, the study has collected relevant meteorological and health information that can contribute to the strengthening of the health system preparedness and response by the systematic collection, processing and analysis of the data obtained. Additional, this study formulates a heat stress index and a common methodology to be applied in different cities of the

MERCOSUR region and generates new hypothesis to be tested in future research on this issue. The limitations of the study were the weakness of the health information system with respect to the comparability of time and spatial data across cities was identified. Besides, the different temporal and spatial scales of health data in relation to climate data made their comparison difficult. Therefore, it is necessary to encourage a collaborative work between the national meteorological agencies and the public health ministries of each country.

Regarding the impact on the participant's institutions, the training institute has managed to put on the agenda of the environmental health divisions, the subject of climate and health. It has also enhanced the partnership between meteorological services and health ministries. As an example of this partnership in Argentina they are developing an "Atlas of climatic characterization of Argentina at state level 1980–2010". Besides this the heat stress index that was developed in Project 2, nowadays is calculated operationally in the National Weather Service of Argentina and published on the website every 10 days (Servicio Meteorológico 2015).

In addition, the training institute strengthened the capacities of ministries of health of all Mercosur countries, to contribute to the generation of evidence, identifying gaps and weaknesses in the reporting system and uptake data.

The work of interdisciplinary teams also favored the generation of interagency alliances and networks of experts who are providing concrete proposals for decisions makers when adopting health indicators and climate, as well as incorporating the theme of health within National Climate Change Response Plans. All of which have contributed to comply with the objectives of the Strategy of MERCOSUR action to protect human health from the effects of climate change.

The institute also resulted in the establishment of a new node in the network of climate information for action in the public health sector, which IRI initiated 7 years ago at its first Summer Institute on Climate Information for Public Health in New York (IRI 2009).

Finally the Training institute plays a critical intermediary role between knowledge generation and informed action. Alumni of the institute have created various mechanisms to transfer their climate and health knowledge at regional and local levels.

For example, Silvia Fontán led the first virtual course on Climate and Health for public health professionals of the Ministry of Health of Buenos Aires city based on what she learned. This course has been an inspiration for other health institutions that are using their structure and some of its modules to train their staff. She was a lecturer and facilitator in the Andean Course held in Ecuador in 2012.

Carolina González was the responsible to incorporate the heat stress index developed during the training as a tool of the climate services portfolio of the National Meteorological Service of Argentina.

Graciana Barboza is representing the Ministry of Health of Uruguay in the Technology Needs Assessment (TNA) national team. This assessment aims to identify, evaluate and prioritize the technological means to both mitigation and adaptation to climate change in order to achieve the sustainable development goals. The TNA national team will use the definitions of "cold waves" and "heat waves" developed in Project 2 and the methodology learned in the Training institute to related extreme events such as “flood and drought” and “Early Warning Systems” (Ministerio de Vivienda, Ordenamiento, Territorial y Medio Ambiente. Dirección Nacional de Medio Ambiente 2014).

Lastly, Francisco Chesini is currently the team leader on climate and health at the Ministry of Health in Argentina. Specifically, he had participated in some epidemiologic studies about climate and health like “Mortality by malignant melanoma and non-melanoma skin cancer in Argentina (1980–2012)” which is in press at the moment.

Conclusion

The Training Institute on Climate and Health was a valuable experience for participants, promoting multidisciplinary research and collaboration between experts and professionals from various sectors and countries.

The training institute improved local and regional capacity to use climate information for health-related interventions in Mercosur countries. This activity contributed to the development of the objectives of the Mercosur Strategy to Protect Human Health from Climate Change, agreed by Ministers of Health in 2009.

The training institute also demonstrated the importance of having partnerships not only to organize, fund and implement the course but also to develop proposals, which can be implemented for interdisciplinary groups and address issues relevant to the home countries’ participants as well as for regional purposes.

The development of projects served as a catalytic mechanism promoting the development of new collaborative activities among professionals and institutions of the Americas, as well as providing ways to disseminate useful knowledge for the Mercosur countries and societies.

The projects also strengthened the creation of regional networks of cooperation and to help participants apply the knowledge and tools provided by the course on practical projects addressing climate and public health issues relevant to the participating countries.

The organizers of the training institute have learned that involving government public health and climate professionals as well as academic institutions from each country or region is an effective way to build critical mass on climate and public health related issues, while also engaging with government agencies and encouraging their continued involvement.

Even though there were a lot of positive outcomes of this Mercosur’s training institute, it is clear that a lot of knowledge remains to be built in climate and public health. It is critical to continue training professionals and to provide spaces for networking and also to create collaborative programs that allow professionals from different institutions, sectors and disciplines to communicate and share their expertise.

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Gilma Mantilla is a medical doctor by training with over 25 years of public health experience on designing and implementing public health policy; health promotion and disease control programs and infectious disease surveillance and control systems. In the last 10 years with extensive engagement in policy processes involving the development of effective demand for climate information including the implementation of innovative tools and protocols for creation, integration and dissemination of knowledge and information related with climate and public health. She also contributes to applied research to produce risk profiles of selected climate-sensitive diseases by country and region and development of partnerships to assess and verify climate and health information.

Education and training have been key components of Gilma's work; she has organized training courses, developed curriculum and trained international public health staff in public health management and public health policy. Lately she has organized training courses and developed curriculum on Climate Information for Public Health local and internationally. Currently she is an

adjunct researcher at International Research Institute of Climate and Society at Columbia University.

Carmen Ciganda is the Director of Environmental and Occupational Health Division of the Ministry of Public Health of Uruguay since 2005. She is medical specialist in Clinical Toxicology graduated from the Faculty of Medicine of Uruguay. She has completed postgraduate Intensive Medicine and a Masters in Environmental Sciences at the Faculty of Sciences. She was a lecturer at the School of Medicine from 1986 to 2002, and has been an expert consultant in the Health Area UNEP Chemicals and POPs issues. She was a co-author of the National Profile of Climate and Health in Uruguay Change and she is also the focal point for the Intergovernmental Committee on Environmental and Occupational Health (CISAT) of Mercosur, where she has been implemented some of the key points defined in the Regional Strategy on climate and Health, She has publications related to environmental and occupational health, as well as numerous papers presented at scientific congresses and national/international conferences. She is a member of the Uruguayan Society of Community Health and represents the Ministry of Health in the National Response to Climate Change in Uruguay.

Graciana Barboza has a degree in nursing from the University of the Republic in Uruguay. Currently she works at the Ministry of Public Health Uruguay in the Environmental and Occupational Health Division, where she serves as a health manager. She is also a representative from the Ministry of Health at the National Climate Change Commission. She has been involved in several research projects such as: WHO study on persistent organic pollutants in breast milk and monitoring impacts on health in relation to air quality.

Francisco Chesini has a degree in Environmental Health and a post-graduate qualification in sanitary engineering. He has worked in municipal solid waste management and healthcare waste management. Since 2012 he leads the "climate change and health" operative area in the Argentinian Ministry of Health. He has also been a university professor in the Universidad Autónoma de Entre Ríos.

Laura Frasco has a degree in Anthropology. Currently she is in her second year of Ph.D. in Social Anthropology at the High Institute of Social Studies (IDAES) at the National University of San Martin (UNSAM) where she is conducting a research about the conditions and infectious diseases related to the working activity being held by children, as extractors of precious stones in port Wanda (Misiones city).

She also works as a teacher of Anthropology at the National University of Matanzas and has been working on climate change and social vulnerability research projects in the past years.

Silvia Fontán has a degree in Sociology and a specialization in Environment Management. She works at the Health Ministry of Buenos Aires City, Department of Health and Environment where she is leading the project Green and healthy Hospitals for Buenos Aires City Government. In 2013 she led the first virtual course on Climate and Health for Public Health professionals of the Ministry of Health of Buenos Aires city.

She has been lecturer and facilitator in regional and global forums and courses on Climate Change and its impact on human health. She is also a consultant for the Ministry of Education in Argentina.

Currently she is a professor and researcher of Communitarian Assistance at Health Department of University of Matanzas and doing her first year of Ph.D. in Urban Studies at Universidad General Sarmiento.

Carolina González has a bachelor's degree in atmospheric sciences oriented to synoptic meteorology. She has worked at Agro-meteorological Department of the National Meteorological Service of Argentina since 2004. The activities developed in the Department contribute to Climate Services proposed by the World Meteorological Organization.

Celmira Saravia has a degree in Agronomy (engineer agronomist) and a Master in Agricultural Science. Currently she is Ph.D. student at Facultad de Agronomía de la Universidad de la República, Uruguay, where she is conducting a research about the impact of climate variability on animal production. She has been a professor of Agrometeorology at Facultad de Agronomía, Universidad de la República, Uruguay since 1993, where she is also a researcher working in Biometeorology. Her research interest is on thermal stress in animals in grazing conditions and the relation between climate variability on animal wellbeing and human health.

Chapter 16
Improving Disaster Risk Reduction and Resilience Cultures Through Environmental Education: A Case Study in Rio de Janeiro State, Brazil

Marcos Barreto de Mendonca, Teresa da-Silva-Rosa, Tulio Gava Monteiro, and Ricardo de Souza Matos

Abstract Landslide disasters are increasing in frequency, magnitude and degraded territory as a result of disorganised land occupation and extreme rainfall events. Consequences such as deaths, injuries, homelessness and social harm are much worse when they occur in vulnerable communities. Socio-environmental disasters occurring in Brazil have highlighted environmental education as key to disaster risk reduction strategy. Based on the idea that the urbanisation process in Brazil contributes to socio-environmental vulnerability and environmental injustice, this chapter discusses the contribution of environmental education projects as an example of strategy for landslide disaster risk reduction since they can motivate inhabitants to participate in disaster risk reduction activities and, hence, to practice participatory risk management, empowering citizenship and strengthening community resilience. The studied project consisted in anon-formal education experience and took place in a landslide risk community in Niterói, a city situated in the metropolitan area of Rio de Janeiro, Brazil. The project involved geotechnicians, researchers of different backgrounds, young residents and members of a local non-government organisation and aimed to analyse this experience as an effort to face climate impacts.

Keywords Disaster risk reduction • Resilience • Vulnerability • Environmental injustice • Environmental education

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Introduction

In Brazil, landslide and flood disasters due to the association of environmental characteristics to human agglomeration are nothing new (Brandão 1992). Nevertheless, according to IPCC (2012), the increase in magnitude and frequency of mass movements is greatly related to consequences of climate change, namely extreme rainfall events. In recent decades the frequency of disasters has risen, and the 2011 event in the Mountain Region of Rio de Janeiro State is noteworthy (World Bank 2012; Avelar et al. 2013)—considered a mega-disaster—and the floods and landslides of December 2013 in the State of Espírito Santo (A Gazeta 2013). Located on Brazil's coastal belt (Fig. 16.1), these areas are highly influenced by different geographical, geomorphological and geological factors and human actions resulting from uncontrolled urban sprawl (Mendonca and Guerra 1997). The aforementioned factors are important conditioners of the environment's degree of susceptibility to different events. Therefore, in light of expectations that improper land occupation will continue, along with the State's difficulty in reducing degrees of risk in the short or medium term, the directly affected population needs be mobilised and empowered to participate in mitigation of the problem.

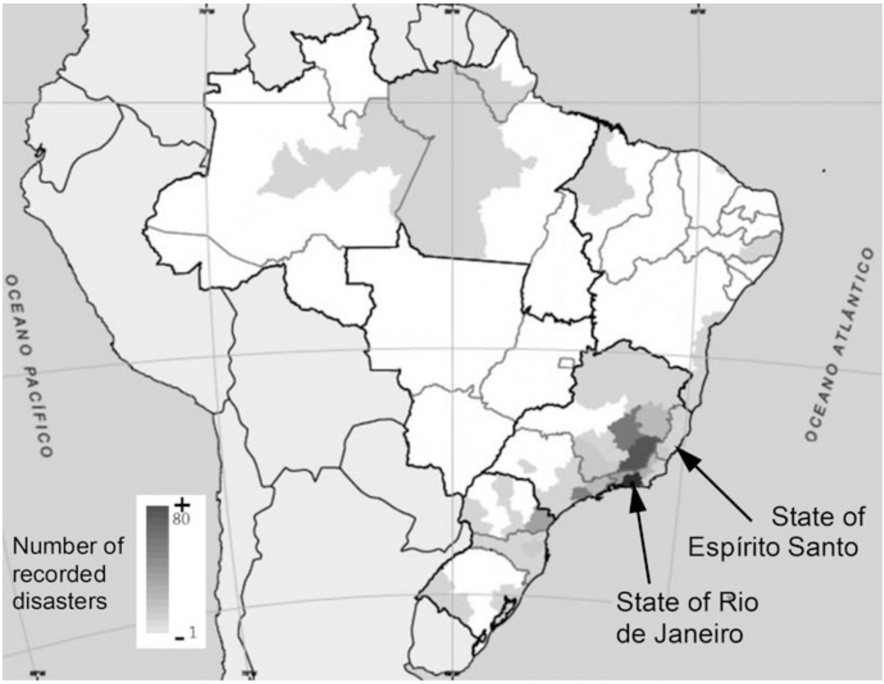

Fig. 16.1 Location of states of Rio de Janeiro e Espírito Santo on the mass-movement disaster map in Brazil during the period 1991–2010 (CEPED/UFSC 2012, modified)

In order to achieve this aim, education in disaster risk reduction (DRR) has a fundamental role in light of its capacity to bring about a shift in values. Environmental education (EE) can be seen as a strategy for mobilising and empowering society with the aim of encouraging a citizenship conscious of its role in respect of ecological sustainability. Taken as the *new* outlook on the real situation, such education emerges as a strategy to aid DRR. In this sense Anderson and Holcombe (2013) state that it is cost-effective to educate communities about the risks they face, providing them with access to knowledge and resources in order to develop community-based preparedness and disaster risk mitigation programs. Nevertheless, it is necessary to discuss the content, methods and specific objectives that DRR education actions should adopt, and specific studies around the issue are required.

This chapter describes and analyses a non-formal EE project run in an area at landslides risk, with a population rendered vulnerable by historically established socio-environmental conditions—the Maceió Community in the city of Niterói, Rio de Janeiro Metropolitan Region, Brazil. It is therefore hoped that this chapter will lead the reader to reflect upon the urgency of actions involving populations living in situations of socio-environmental risk and the possibility of their being vectors of significant shifts towards DRR in the face of those meteorological events that continue to afflict them.

Modernity, Cities and Environmental Injustice: General Backdrop to DRR

Socio-environmental vulnerabilities among communities are, historically, born of a process of development and urbanisation characterised by intervention and domination of a biogeophysical base. Transposing the idea of Santos (2002) on neglect by the positivist tradition, one might say that the "modern city" ignores the biogeophysical structure on which it is built through a development process which inherently leads to socio-environmental inequalities. The case of Brazilian metropolitan regions illustrates the aforementioned assumptions when one associates negligence of the physical environment and local human characteristics with urbanisation to international city standards (Santos 1985), from the 1960s on. Through development and urbanisation, much-coveted Modernity brings "progress" to such land areas, which may be viewed as a vector of annihilation of such a location (Morin and Kern 2010). At times this may happen quickly and possibly also slowly, but always leads to the destruction of local traditions and wisdoms as if there had never been any *Other*, a pre-existing *Subject*.

Transferring this idea to the case of processes in slowly developing areas, urbanisation in Brazil gives rise to unequal land occupation, with no market value achieved for the socio-environmentally vulnerable population. During such a process, land occupation becomes *unsustainable* and, as it is brought about by unjust development, social exclusion of portions of the population in large metropolises is superimposed onto naturally sensitive areas, such as permanent preservation areas, mangroves, sandbanks, river banks and hillsides (Brasil 1988).

Considering such a situation, the modern city is seen as a hegemonic alternative, "disparaging other possible alternatives" pre-existing in such areas. The modern city fragments the local reality, affecting spaces and exposing its populations to risk, reflecting the western way of thinking and leading to an interpretation of the world which ignores the biogeophysical bases of a given location. What can be observed on the land is the materialisation of a hegemonic, dominating rationale, which breaks with other pre-existing rationales—the case of environmental rationale (Leff 2006). The modern city is imposed upon this "vacuum", revealing an "indolence of reason" (Santos 2002). Modern *planning* is viewed as being guided by a specific project which becomes social in nature and brings, within its scope, progress—a project aimed at imposing solutions upon a certain "disorganisation", based on the concept of homogenised spaces rather than a natural tendency for "self-diversification", a post-modernist characteristic (Harvey 2004).

Destabilising homogeneity resulting from the modern city project brought by development initiatives becomes evident through socio-spatial segregation, largely involuntary, on the part of less favoured social groups (Da-Silva-Rosa and Mattos 2012). In this way, the modern city intervenes in the biogeophysical space to enable expansion of the city itself—straightening rivers, reclaiming hills or mangroves and occupying hillsides. On one hand, this provides for value addition to new spaces and, on the other, leads to a devaluing of spaces in which the market has no interest. Such spaces become the targets of an array of socially vulnerable individuals, placed involuntarily in situations of environmental vulnerability owing to the difficulties faced by, or inability of government in responding to public demands, giving rise to destabilisation by disorganised occupation.

The differing levels of vulnerability among a social group to possible impacts caused by a geohydrological event reveal the environmental inequality between different groups. Some are able to prepare and react more readily that others, such as those with their assets insured. What generally happens is that the more afflicted population comprises that *army of highly socio-environmentally vulnerable individuals*, occupying hillsides, riverbanks or mangroves. When they become the target of more socio-economically vulnerable groups, such areas provide a new facet for the injustice afflicting them. Environmental issues and risks are thus associated to social problems, thereby constituting environmental injustice. Torres and Marques (2001) attest to the assumption of environmental risk overlapping with poor socio-economic conditions in their study on the city of São Paulo.

It is specifics such as these that demonstrate the uniqueness of environmental injustice in Brazil, a movement which emerged in the United States in the 1980s as an aspect of the "wave" of environmentalisation of social struggles in line with a higher proportion of environmental damage in areas occupied by black people (Acselrad 2010). Only at the end of the 1990s did the movement spread to Brazil following creation of the Brazilian Environmental Justice Network where, in the twenty-first century, the concept of environmental injustice is overlaid by an outlook focused more on traditional communities and on more socio-environmentally vulnerable social groups. As such, environmental injustice, according to Acselrad et al. (2009), is the unequal manner in which environmental harm caused by the productive system is distributed, concentrating such aspect on more socially vulnerable populations. Conversely, environmental justice has generally taken the form of minimising environmental inequality, primarily in respect of appropriation and use of resources or exposure to risk.

It is in this context of the urbanisation process and environmental injustice that reducing the risk of disasters, as provided for in the objectives of the Brazilian National Prevention and Civil Defence Policy (Brasil 2012), involves understanding of the complexity inherent in the process of historical vulnerability construction. Priority must be given to prevention actions involving populations of higher socio-environmental vulnerability, and such prevention encompasses all the complexities in the relevant context—identifying education as a DRR strategy to achieve a sustainable, resilient and fair society.

Environmental Education for Disaster Reduction

In the light of such a context, development of a participation culture becomes a necessity, with priority given to cross-contamination of knowledge between academia and local communities with a view to raising awareness and developing proactive attitudes among populations that historically live in a situation of high socio-environmental vulnerability. EE emerges as a strategy to contribute to encouraging active participation of such populations in DRR-based decision-making processes, as such education contributes to

> [...] assist us in understanding the environment as a set of social practices permeated by contradictions, problems and conflicts which weave the intricate network of relations between human life habits and their particular ways of interacting with the physical-natural elements around them, of giving them meaning and of managing them. (Carvalho 2008)

In the DRR context, therefore, understanding of the interactions between communities and the natural elements is crucial. It is believed that from this perspective, communities will be enabled to participate in the process of formulating DRR strategies, as they will come to have an understanding of them. A proposal of the Stockholm Conference Final Declaration, structured on the Tbilisi Conference (UNESCO 1977), EE emerges as an innovative, challenging aspect, seeking to encourage citizens to assume their responsibilities, rights and duties and to understand their close relationship with the environment in which they live. To this end, the Declaration seeks to define a new world and human vision, this latter to be understood as part of nature, which will make for an understanding of human activities within the natural system (Da-Silva-Rosa 2009). Such vision raises questions on analysis of the real situation through the interdisciplinary aspect of its initial proposal (*id*.). Within this reflection, Jonas (1995) contributes with his concept of responsibility as the primary moral element before materialisation of human actions in a technological context (Da-Silva-Rosa 2009).

In Brazil, the National Environmental Education Policy (Brasil 1999) establishes the public authority's obligation to promote such education at all levels of schooling, along with public awareness-raising for environmental conservation as a means of encouraging participation, a fundamental principle of the Tbilisi Declaration (UNESCO 1977). According to Loureiro (2012), "Transformational Environmental Education emphasises education as a constant, everyday and collective process by which we act and reflect, transforming the reality of life". So that EE is not enough merely to make its content available to the citizen, but rather that it should stimulate reflection on the values and skills required to construct a human-environment relationship on new building blocks—in this context, meaning DRR education in risk areas.

On this basis, the National Prevention and Civil Defence Policy (Brasil 2012) carry the paradigm of prevention, putting the idea of resilience firmly at the forefront of the Brazilian DRR agenda. As a risk management component proposed by the Hyogo Framework for Action (UNISDR 2007) and reaffirmed by the Sendai Framework (UNISDR 2015), this paradigm elevates DRR to a new level, requiring that actions be defined, as Jonas (1995) suggests, *before* the event occurs. Noteworthy among the five priorities, DRR actions proposed by the Hyogo Framework for Action (HFA) are awareness of risks in order to achieve readiness for action and the requirement to understand and be mindful of the risk situation in order to react to or tackle it. The educational process is an integral part of DRR, and it is believed that only in this way will communities be prepared to act in the event of imminent disaster. Finally, the close relationship between this theme and EE is observed.

In this way, the involvement of different actors among the population becomes a more primordial risk management aspect, reinforcing EE as an essential strategy for awareness-raising and environmental citizenship based on critical, inter-disciplinary reflection on the complexity of the environmental crisis in contemporary life and its relationship with the development model, which is at the origin of construction of socio-environmental vulnerabilities. Environmental awareness among citizens should therefore be reinforced as the fruit of an educational process to understand the complexity inherent to the development-nature relationship and construction of vulnerabilities, in which the human being is an inherent part of the risk management process.

It is worthy of mention that, despite the efforts outlined in HFA, reports on national progress in Framework implementation in the period 2009–2011 indicate that few countries reported the inclusion of DRR-related themes and topics in teaching, revealing a lack of understanding regarding the nature of DRR in curricula and of how it should be developed and implemented (Selby and Kagawa 2012). It was observed that educational activities analysed in such reports basically consisted of including the theme in some curricular disciplines, with little evidence of interdisciplinary action and community involvement, highlighting the need for interactive, participative and practical learning on the subject. Furthermore, "day-to-day social and pedagogical practices need to be considered as possible spaces for future projects, redefinition of the political dimension of our existence" (Reigota 2008). What therefore becomes evident is a requirement for advances towards definition of a methodology or an educative process for DRR through critical studies on the real situation and more practices in the light of what was previously revealed.

The three modes of education—formal (regular school), non-formal (outside educational institutions) and informal (daily activities related to work, family life or leisure)—can incorporate disaster education (Shaw et al. 2011). According to these authors, knowledge on DRR can be transformed in risk-reducing behavioural change when disaster education involves family and community learning associated to school education. Lidstone (1996) suggests that instead of the current emphasis on the physical nature of disastrous events, disaster education (DE) should concentrate on the student's involvement in the context of disasters in order to encourage them to regard themselves living in a dynamic physical environment and be engaged in the real-world problems in their communities. Therefore, it must confer great importance for non-formal and informal education in order to develop a culture of disaster preparedness in the communities.

Experimental Educational Project in the Community of Maceió, Niterói

General Characteristics of the Project Implementation Region

Educational practices were developed in the Maceió Community (Niterói, Rio de Janeiro Metropolitan Region), affected by landslides disasters (Fig. 16.1). Such practices were implemented following the occurrence of severe disasters in the decade commencing in 2010.

The community is situated in the central region of Niterói (approximately 700,000 m^2), with relief in the form of a valley contained in the *Maciços Costeiros* (Coastal Massifs) geomorphological context, with abrupt southerly slopes and sharp rocky peaks, where land occupation, primarily in hillside areas, is significantly disorganised, with evidence of deforestation, cut-and-fill for construction of housing and roads and sewage discharge direct onto the land. With approximately 4500 inhabitants (2010), the community finds itself in a precarious situation in terms of basic infrastructure: 71 % of residences receive their water supply from wells or springs; 53 % have a septic tank; waste and rubble is frequently dumped onto the land and most of the dwellings are precarious. Consequently, the natural characteristics associated with this land occupation give rise to significant landslide events, noteworthy among which were those of April 2010 following a period of

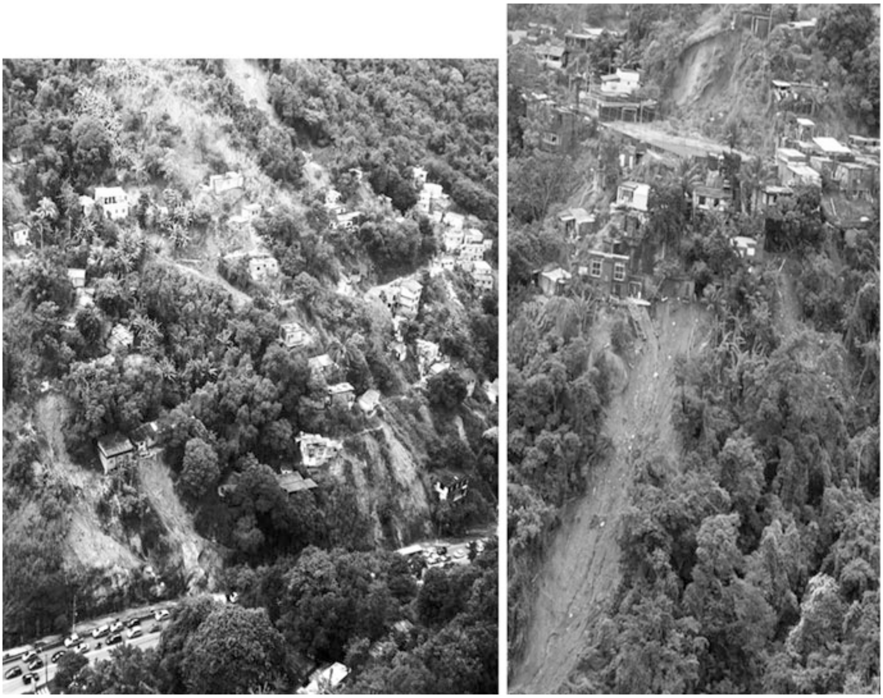

Fig. 16.2 Landslide scarring in the community studied following the events of April 2010

heavy rainfall, causing loss of life, material losses and serious adverse social effects (Fig. 16.2).

Methods and Activities

The disaster education (DE) project presented in this chapter was completely independent of any official disaster management institution. It was run outside formal educational institutions (non-formal mode) and the main purpose was to study pedagogical tools considering real-life context of the community having academicians, local institutions and local populations working together. It was assumed that DE should break the school boundaries and be linked to the community and family (Shaw et al. 2009).

The work was carried out in partnership with the local non-governmental organization (NGO) *Oficina do Parque*, which acts in the area of artistic and vocational education. This partnership made use of the NGO's physical structure and instructors to run the activities with the residents. The project's basic methodology was primarily based on prior knowledge on how residents deal with the topic

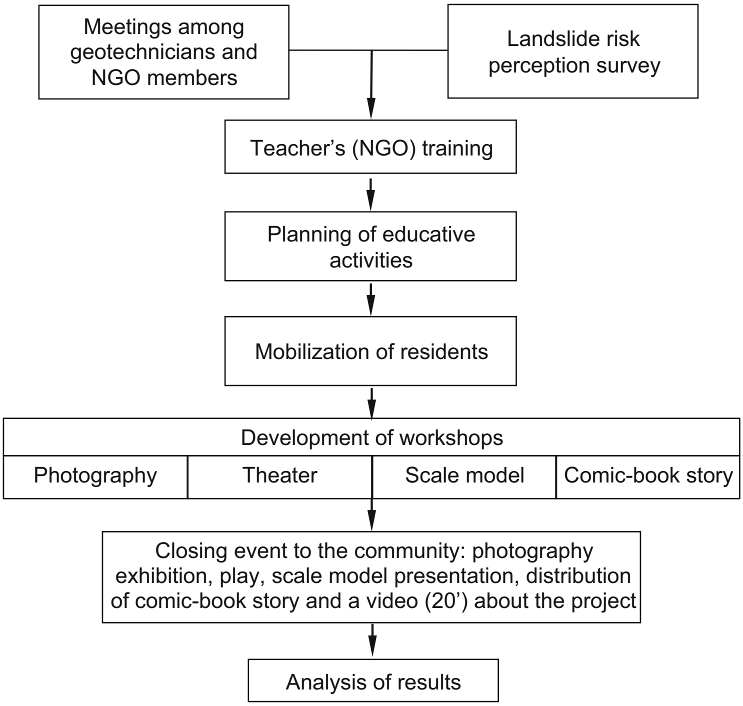

Fig. 16.3 Scheme of DE stages carried out in Maceió Community

of landslide disaster; interaction with the NGO; planning of educational activities; training of teachers, carrying out workshops and a closing event (Fig. 16.3).

In order to approximate to the reality of residents, and have a better idea of how they deal with risks and engage with other stakeholders actors involved in this theme, a risk perception survey was conducted in the community, which enabled gathering of information to aid planning of educational activities (Mendonca and Pinheiro 2012). A questionnaire was applied to a total of 50 residents with a view to gauging opinions and conduct in respect of landslides, their causes, the influence of human actions, the ranking of this type of threat against others to which the population is exposed and personnel/institutions responding in emergency situations. The population has not been previously involved in any mode of disaster education.

To this end, this work revealed the following:

1. Playing down of the landslide risk by residents, without their going so far as to fully deny it—70 % of residents cited such hazard in periods of heavy rain—comparing everyday problems: lack of basic sanitation, deficient public transport—and opportunities available in the location—77 % highlight the advantage of the community being a peaceful place to live;

2. Despite 92 % of residents having experienced landslide disasters, they attach little importance to such type of hazard—only 10 % believed such a threat to be important;
3. Little importance given to certain human actions such as deforestation and hillside cut-aways;
4. Distancing and abandonment by public agencies involved in disaster management; and
5. The impotence of residents in execution of DRR prevention actions.

Before planning the activities and pedagogical tools, training session was held by Geotechnics teachers from the Federal University of Rio de Janeiro (UFRJ)—Polytechnic School together with members of the NGO, covering the general context of the problem, a general view of landslides, human actions inherent in disorganised occupation, signs of imminent landslides, prevention and the general attitude of the population to the issue. This stage aimed to train the NGO teachers on this specific subject as they normally give classes about artistic activities. After that, UFRJ and NGO teachers worked together in order to design the educational activities and their tools. Workshops were then planned with a view to fostering critical thinking among students on their daily lives. Before starting the workshops, the community leaders were contacted and an opening event was held aiming to sensitize the population to participate in the project.

Educational activities were run with formation of community resident groups interested in theatre, art, photography and model workshops, with landslide disasters as the central theme, at the NGO headquarters. Based on Lucena (2008), efforts were made to generate new approaches drawing on skills in the community itself and bring about the formation of a disaster risk reduction culture. In classes of between 6 and 11 students, primarily young people between 10 and 14 years of age, activities ran for 2–4 months. In all workshops, scientific language was avoided, drawings were intensively used and the content depended on the students' knowledge and their own experiences.

The activities were aimed at encouraging a better understanding among these young people of their problems and surrounding area, enabling reflection on their own life situations, as suggested in the Tbilisi Declaration (UNESCO 1977). Freire and Shor (1986) state that, in this context, "individuals take charge of their own lives through interaction with others, generating critical thinking about the situation, favouring construction of personal and social abilities and bringing about the transformation of social relationships of power". In addition, efforts were made to create a channel of communication between workshop instructors and young people to enable their development through association of respective knowledge, thereby seeking to reflect on the theme and encourage participative management in DRR actions. Despite the theme being established and guided by a technical team, the final products of each workshop were shaped in an integrated, interactive manner involving the residents themselves. In the theatre workshop, a text was produced from discussions held and situations experienced by the young participants, in which actors represented fatalities as a disaster consequence and government

Fig. 16.4 Photos of the interactive model constructed during community activities

neglect of the issue was highlighted. During the photography workshop, participants produced photographic records of their interest areas based on discussions with the Geotechnics teachers, in respect of scarring from previous landslides, their consequences, different human actions contributing to instability on hillsides and signs of imminent land rupture noticed during field trips in the community. In construction of the scale model (Fig. 16.4), material elements of the site (physical geography, topography and hydrography) were drawn upon to provide a basis for fun and reflective group discussion involving participants as suggested in Valencio et al. (2009). It was an important tool to understand the dynamic process of human occupation and how it affects landslide susceptibility. An actual 250 m × 250 m area of the community was reproduced to scale 1:150, with existing features—rivers, rock masses, land cutaways, houses, streets, steps, disposal of wastewater and landslide events. The art workshop opted to create a comic-book story on the theme (Fig. 16.5) where residents were encouraged to elaborate a story closer to their reality.

To close out the project, an event was held in which all activities were presented to the community, thereby serving to raise awareness among the community and

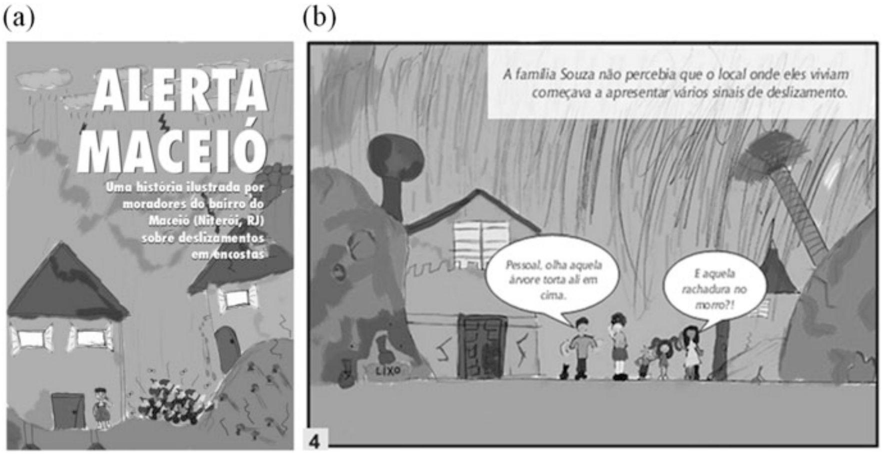

Fig. 16.5 Comic-book story produced during the art workshop: (**a**) cover (**b**) one of the inside pages

invited public authorities on the theme, in addition to a video illustrating the different stages of the project with testimonies from residents, technicians, a social assistant and educators.

Discussion on Outcomes

It is worth highlighting a number of points regarding educational activities carried out, namely:

– The training stage made possible the first step of exchanging experiences as NGO teachers were used to the community reality. Beyond being experts in the workshops, they transformed the technical point of view of academicians into a more affective language.
– The methodology used enabled integration of DRR into fun-based educational activities normally used in educational processes. These could be adapted to the theme, provided the personal skills of participants are demonstrated.
– The practical, reflexive learning, experience-based characters of educational activities and the consideration of local knowledge, held during workshops is in line with the recommendations of Shaw et al. (2011).
– Joint construction involving technicians from the university, members of the NGO and residents favoured direct action by the latter in an "*enterprise*" linked to their own daily life and land area.
– Interaction and reflection on daily life were included as necessary stages for the transformation of individuals and their relationship with their surrounding area. In this way young people could acquire the skills to better understand their role within the community, an important aspect of DRR action.

- The interactive model enabled grouping of the different educational aspects involved, such as natural conditioners, human actions, signs of imminent landslide and the consequences of landslide occurrence. Such instructive resources facilitated understanding of the dynamics in the entire process from commencement of land occupation to the occurrence of disasters, covering the full circle of the issue, in line with Lidstone (1996) and Valencio et al. (2009).
- It was possible to develop a risk communication process (Shaw et al. 2009) where the workshops were considered two-way interactive tools for sharing risk information amongst researchers, NGO teachers and local people. This was an effort to achieve the proposition by Shaw et al. (2009) that communication between scientists and local people should be facilitated in order to enhance research practices.

Finally, it is worth emphasising that these activities were geared towards contributing to empowerment of young people through enhancement of individuals as social actors, fostering participation in transformation of their social environment in the quest for improved environmental and social equality (Wallerstein 2006). In this sense, the products were aimed at expressing the individual and collective experience of this community through its young people.

Final Considerations

In Brazil, the high degree of social vulnerability among certain groups as a result of the late development process has made it difficult for them to settle in areas with better infrastructure and access to public social policies. This, coupled with neglect by the State, has to some extent forced such inhabitants of Brazilian urban centres to occupy low market value areas.

In this particular case, the risk perception survey demonstrates the finding that such groups, in the light of their social conditions, tend to play down the risk in relation to the everyday difficulties to which they are subjected. Feeling abandoned by those public agencies responsible for execution of DRR actions, they feel incapable of changing their situation. Such helplessness puts the citizen's conscience in check—the recognition of oneself as an agent of change, finding oneself in a certain situation and being capable of making significant difference. DRR provides discourse on prevention weighted by the necessity for changes in the conditions of socio-environmental vulnerabilities, historically constructed by a socially unjust, ecologically unsustainable development model. To this end, it becomes essential for such vulnerable groups to take part in socio-environmental educational projects with an end to establishing a channel of communication on the theme of risks and to equip them to better deal with their living conditions.

Educational activities provided in the Maceió community (Niterói, RJ, Brazil) enabled the setting up of a channel of communication on landslide risks between different actors—academicians/local teachers and local teachers/residents.

Pedagogical tools and activities were provided in a joint effort with residents, with such integration producing results. Efforts were made to practice a proximity management model so that all considered the real-life context and felt they could be agents of change in respect of DRR, empowering people for participative management. The tools consisted in developing fun-based educational activities with landslide disaster as the main theme.

The interaction among different actors involved in this kind of experience allows us to say that a disaster education can occur both externally and internally, where internal education is based on the exchange of experiences among members of the local community; while the external aspect is based on the exchange of experiences between them and members of external institutions (academicians and public managers), as similarly observed by Ivanov and Cvetković (2014).

The final results showed that this kind of educative project is feasible through association among academicians and local institutions with public support. This non-formal education should be carried out in conjunction with formal and informal education in order to be transformed into risk-reducing behavioural change, as suggested by Shaw et al. (2004) and finally raise a DRR culture. In the DRR context, environmental education has the potential to provide a new outlook on facing disasters, in which future generations must be the protagonists. Despite their experimental nature, projects such as that in the Community of Maceió can contribute to the proposition of a continuing action methodology in the DRR arena of education.

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Chapter 17
Climate Change and Health Related Challenges as a Trigger for Educational Opportunities to Foster Social Knowledge and Action

David Dueñas i Cid and Lídia Ochoa i Cañigueral

Abstract The potential consequences of climate change to our health and wellbeing pose relevant questions and real challenges need to be tackled. These real challenges can be used as strong triggers to initiate action-oriented learning processes.

With the aim of identifying these outcomes, we propose a chapter focused in those educational responses that are being developed to promote a generational transformation which can enhance social knowledge and bonding, having an empowering impact over communities, leading to their transformation and improvement.

This chapter includes interesting initiatives and international trends that are worth disseminating. We have organised them by category and topic. These projects are described in order to identify their structure, function and impacts. Our purpose is to summarize the main socio-environmental education trends that are being developed and the impacts that they are having in different communities and areas, focusing on experiences that involve, not only formal education agents, but also informal education, NGOs and communities, and above all Service Based Learning Methodologies.

Keywords Climate change education • Service based learning • Health • Health promotion • Social transformative practices • Sustainability

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Introduction

The lifetime of this current generation is expected to be both turbulent and exciting: (1) We are experiencing the emergence of the era of digital technology and building a world based on a permanent connectivity and the reduction of distances which could lead to an increase of human capacities; and (2) we are facing a period in which environmental crisis and problems could occur with severity and violence. These would pose some real global and difficult challenges to human societies. This generation, then, is building a new future full of opportunities resulting from technology and is called to make important decisions for their peers and for future generations, who, with all certainty, have the right to decent environmental and living conditions.

Although much has been written about the connexions between Climate Change (CC thereafter) and Society, and without aiming to review all the theory about this topic, we consider relevant to highlight some general ideas that should help to shape our theoretical point of departure.

In the first instance, it is necessary to mind on the intrinsic complexity of natural and social systems, and, especially, the difficulties that exist to make them run smoothly (Dueñas 2011). Even assuming that there are many other aspects to highlight in this complex relation, we will limit our discussion to two general ideas. Firstly, that both systems are interdependent. It is impossible to understand the evolution of the social system without considering the natural environment in which it exists. Furthermore, we cannot understand the impacts on the environment without a deep analysis of social transformation. This interdependence is strongly determined by the different working speeds of both systems: Earth system (Garcia 2004) works through phases of resource production and waste disposal that are totally different from those that society demands to fulfil its needs. From this point of view, the limited context in which humanity lives, should determine the possibilities for using resources and should be one of the cornerstones of the roadmap to decide how to manage the goods in the present and, especially, in the future. As a matter of fact, this is what sustainable development is about: using today's resources without undermining tomorrow's. Secondly, this interdependent relation is determined by a high level of uncertainty. The intrinsic difficulty in acquiring holistic and systemic knowledge, which is due to the fragmentation of science into different knowledge areas and the amplitude of the research field, leads to the creation of partial knowledge's which are difficult to integrate and manage in a complex and dynamic system. This could lead to unexpected results from actions that, a priori, were considered harmless.

In connection with this complex frame, contemporary environmental problems, which can be summarised in: increase of environmental impacts (Rees 1992; Ewing et al. 2010), "peak oil" (Bermejo 2008; Sempere and Tello 2007; Heinberg 2005; Roberts 2004), freshwater scarcity (Singh 2002; Oñate and Peco 2005; Blanco et al. 2005), decline in biodiversity (Leff 2007; Hansen 2010; Ehrenfeld 2003) and climate change (Stern 2007; O'Neill et al. 2014; Urry 2011) have significant features which allows us to distinguish them from previous environmental problems: Firstly, they are difficult to solve (Ludevid 2009), as their resolution stems? from a joint effort of several different agents which nevertheless fails to sufficiently guarantee their complete resolution. Secondly, they are global-reaching problems, resulting either from a spate of local problems or a consequence of the scope of its effects. Furthermore, even if every problem previously listed could be identified and understood separately, the fact that they are coexisting leads to an overlapping of causes, effects and solutions that makes it difficult to detect the paths that could lead to their solution. In addition, they result in an increase of human created risks (Beck 1998). And finally, they can have irreversible effects and insolvable impacts if we are not able to find solutions and act accordingly on time.

This complex relation can be also seen in the area of health in six specific points (Costello et al. 2009) (1) changing patterns of disease and mortality; (2) food; (3) water and sanitation; (4) shelter and human settlements, (5) extreme events; and (6) population and migration. As a result, not only global health standards will be affected as a whole, but they foresee an unequal individual impact according to social class and economical status that will increase global inequality: poor people will have more difficulties to adapt to environmental changes (Beck 2002, p. 98). For this reason, we adopt a broad definition of "health", including not only the direct impacts on individual health, but also the effects on individual and collective well-being (El Zoghbi and El Ansari 2014). Following World Health Organisation's definition, health should be understood as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO 1946). At the same time, the Human Development Report (UNDP 2007) stated that *the toxic combination of bad policies, economics and politics is (...) responsible for the fact that a majority of people in the world do not enjoy the good health that is biologically possible*. As long as environment and society relations are part of a complex and uncertain scenario, health cannot only be considered from the medical perspective. Unsustainable practices which lead to endangering environmental conditions can be connected to global and individual inequality and, as a result, with health issues as well.

The potential consequences of climate change in our health and wellbeing pose some relevant questions and become real challenges we need to tackle. These real and contextualized challenges can be used as strong triggers to initiate action-oriented learning processes.

With the aim of identifying these positive outcomes, we have selected several educational responses that are being developed to promote a generational transformation which can enhance social knowledge and bonding, having an empowering impact over communities, leading to their transformation and improvement. These projects are described in order to identify their structure, function and impacts.

Education for Sustainable Development as a Response to Global Challenges

This combined approach to health, environment and society opens the door to develop or promote actions that even if they are not dealing directly the core of the problem (as that would involve a global agreement that, up to now, had been impossible to achieve), can help to build the grassroots for a better and sustainable future. In this scenario, there are different levels of action to focus in the fight to cope with the challenges that CC poses to humanity, from the international policy arena to the individual sustainable behaviour. These different levels have a common driving force in the educational system, understood as a far-reaching and influential system that play an important role in human socialisation process and, as a result, can help to reshape a sustainable future.

Major challenges can only be tackled through an educated and committed society. Citizens around the globe need to be prepared and feel empowered to play their role in what should be a global common goal: the sustainable development of healthy, educated, complex and diverse communities living in safe and healthy environments. We strongly agree with this highlighted statement included in "Learning the Treasure Within" commonly known as the "Delors Report" (Delors et al. 1996): "Education must simultaneously provide maps of a complex world in constant turmoil and the compass that will enable people to find their way in it." And we could add the strength and confidence to act accordingly, as individuals and communities.

As stated in the chapter 36 of Agenda 21 (promoting Education, Public Awareness and Training), education is critical for promoting sustainable development and improving the understanding in individuals to address environment and development issues. Agenda 21 (in chapters 25, 27 and 28) also highlighted the importance of participation (including children and youth, NGOs, local authorities and so on) in decision-making processes. This aspect is also mentioned in the final report of UN Decade of Education for Sustainable Development, *Shaping the Future we want* (Buckler and Creech 2014), in which one of the key findings and trends is the importance of stakeholder engagement for ESD, including political leadership and multi-stakeholder partnership. This is part of the post-2014 DESD agenda.

As a matter of fact, public participation and shared community projects have several advantages in an ever changing environment and society. CC will result in important policy changes. These will be necessary measures which will suggest that, as far as possible, a social consensus will be necessary for the success and efficiency of these measures. It is not easy to determine where the limits lie in any society and harder still to understand the point at which these are reached, but it is much harder to move and act collectively to avoid the brutal consequences of reaching those limits.

DESD (UNECE Decade of ESD 2005–2014) share the vision of "A world where everyone has the opportunity to benefit from education and learn the values, behaviour and lifestyles required for a sustainable future and for positive societal transformation." and set as their main highlights the central role of education and learning, the importance of links and networking, the exchange and interaction among stakeholders and the need to foster increased quality of teaching and learning in education for sustainable development as well as to develop strategies at every level to strengthen capacity in ESD.

The role of education as transformational processes fits perfectly into the CC and health challenges issue. Relating to CC and Health, ESD must bring to the awareness of learners the crucial need for international agreements and enforceable quantified targets to limit the damage to the atmosphere and check harmful climate change. ESD is a key means to build a global lobby for effective action. The aim of sustainability has redefined the role of schools and their relationship with the community. A school (or any educational institution) which is committed to ESD is committed to teaching for the future, inviting its students and teachers to enter into the "culture of complexity", into the use of critical thinking as a way of exploring and confronting challenges, the clarification of values, to reflect on the value of action and participation and into the revision of its teaching materials and methods in the light of ES (Breiting et al. 2005). ESD seeks a transformational educational role in which people commit themselves to a new way of looking at the world, a new way of thinking, learning and working. People need not only the ability to explore the relationships between their own lives, the environment, social systems and institutions, but also to become active, decisive participants in the process of change (Tilbury and Wortman 2004).

There are several definitions for teacher competences related to ESD in schools, such as the "Environmental competence" defined as the "Competence which permits to contribute towards the integration of the environmental dimension in teaching-learning processes, within the framework of education for sustainability" (Junyent and Ochoa 2006). Environmental competence should be closely tied to the competence of action: action in schools and in the community. The UNECE expert group on competences in education also pointed out the need of achieving transformation in their report named Learning for the Future (2012).

It is in this common ground shared by the educational purposes and the community needs where Service Based Learning can be found, created or/and promoted. In Service Based Learning two goals are met: participants learn something while helping to improve a real situation. We consider this learning strategy a process in which the educational action fosters societal transformations through a direct intervention.

Learning Experiences: Selected Cases

We present some educational experiences that, in keeping with our scope, are focused either on climate change, health promotion or both. With these selected cases, we aim to show how education can be geared not only towards knowledge acquisition, but also towards solving other problems that affect our environment and health. Our case studies have been selected on the basis of their potential to point out the opportunities that can be found in action-oriented educational processes in different contexts. Although there are an increasing number of educational projects which have CC or health promotion as their main topics, the vast majority of them focus on the pedagogic content and not on the immediate transformational action. We do not doubt the importance of this types of projects, on the contrary, but we strongly believe that these should be accompanied by educational projects based on direct action, in which the transformative intervention is both an effect and the learning environment.

This is the main reason why the selected cases studies are mainly SBL projects, with some features linking learning with social or environmental transformation. They differ, however, in context and the focus and/or the challenge with which they engage. Our range of case studies is far from exhaustive, but our select sample can serve to exemplify the basis on which these areas can be promoted and disseminated.

As UNESCO states (UNESCO 2012), the main challenges that environmental education is working on, are: (1) Inclusive integration of CC responses into school education; (2) Strengthening CC education for community resilience; (3) climate proofing education infrastructure; and (4) empowering students for responding to climate change. In a similar way, the Talloires declaration (ULSF1990) highlights 10 action points that Universities must take into account to face environmental challenges: to increase awareness of sustainable development; to create an institutional culture of sustainability; to educate for environmental responsible citizenship; to foster environmental literacy for all; to practice institutional ecology; to involve all stakeholders; to collaborate for interdisciplinary approaches; to empower primary and secondary schools; to broaden service and outreach both nationally and internationally; and to keep the movement working.

Some of the previously raised points (and, above all their moral and political background) can be directly linked to the emergence of inclusive and multi-focused experiences such as those we discuss in this chapter. However, due to the limitations of space, we shall discuss the main points of each selected experience and propose some keywords to identify them. For further information, we strongly recommend to check the original source.

Experiences From Institutions and/or NGO's

UNESCO

CC is a key priority for UNESCO and, as they state in Education Sector responses to Climate Change (UNESCO 2012), *it is clear that education—formal and non-formal, from primary through to tertiary and adult education—has an important role to play in addressing this change (p. 4)*. With the aim of disseminating good practices developed under their protection, they compiled and described a diverse list of international experiences held in the Asia-Pacific area focused in four different areas of intervention: (1) Climate proofing education infrastructure, (2) Capacity to respond to displacement and migration streams, (3) Education sector adapted to seasonality changes and (4) Re-orienting teaching and learning. According to our scope, we will briefly explain two interesting experiences that can be included in the fourth area of intervention:

Gender Responsive Participation in Sri Lanka (UNESCO 2012)

In Sri Lanka, women in marginalized communities have taken an active role in the planning of an integrated program for drought risk reduction, better land use and water management. Their aim is to improve livelihoods by using their knowledge and experience to work out locally appropriate strategies to manage their environment, and to use their knowledge to avoid or mitigate the problems that climate change-related hazards can provoke. The process of social mobilization particularly that of women as equal and responsible partners, has enabled the communities to improve and diversify their livelihoods, taking measures that both sustain their survival and decrease the risk of drought and landslides. In addition to employing traditional knowledge, the program in Sri Lanka also benefited from increased women's participation. This is a great example of multi-stakeholder involvement, including vulnerable sectors, in planning and management fields. It is both an intervention and a learning environment for planners, engineers and local communities, empowering women to take action in front of potential CC hazards.

Keywords: NGO, Community, Integration, Risk reduction, Water management.

Sandwatch (UNESCO 2012)

Sandwatch is a grassroots international network of schools and community groups working together to monitor and conserve local beaches and near shore environments. The aim is also to generate a greater resilience to climate change amongst these communities. This work is coordinated by a non-profit organisation The Sandwatch Foundation, which seeks to modify the lifestyle and habits of children, youth and adults on a community-wide basis, and to raise awareness about the fragile nature of the marine and coastal environment. They also promote the need to use the environment wisely through an educational process in which school students and community members learn and work together to evaluate the problems and conflicts facing their beach environments and to develop sustainable approaches to address these issues.

This case has the double potential of raising awareness and educating while transforming practices. Getting to know better their environment improves the chances of mitigation and adaptation as well as risk awareness related to CC related dangerous episodes in sensitive areas such as coastal regions.

Keywords: Primary Education, Community groups, Awareness, Coastal environment.

United States' Environmental Protection Agency (EPA 2011)

The Environmental Protection Agency in the USA promotes the development of SBL experiences with kids to combine the acquisition of knowledge and good habits in relation to the environment and the development of community services. SBL presents different experiences to link the education of children with government and business, neighbours and schools. Their activities are connected to the promotion of recycling, composting, goods reuse, waste management and refurbishing.

This is another example which highlights the multi-stakeholder approach. Linking and building relationships between diverse agents leads to a broader knowledge and empowerment awareness. It also fosters the sustainable practices needed to mitigate CC and health promotion through the acquisition of good and safe habits.

Keywords: Children, Schools, Community, Waste management.

Gikinoo'wizhiwe Onji Waaban: USA (G-WOW 2014)

The "Gikinoo'wizhiwe Onji Waaban" (Guiding for Tomorrow) or "G-WOW" Initiative is a unique approach to increase awareness on how climate change is affecting Lake Superior's coastal environment, the communities in the area, their cultures and economies. It integrates scientific CC research with site-specific evidence of how CC is affecting the traditional Ojibwe lifestyles of people from different cultures. It also forwards American Indian perspectives and involvement to address issues of CC by directly engaging with these communities, educators, and students. G-WOW also provides learners with knowledge about what they can do to mitigate or adapt in the light of a changing climate. The educational resources for this initiative consist of information packs with practices and suggestions for students and/or teachers to help build Service Based Learning experiences within the Lake Superior region and the Ojibwe Ceded Territory of the Great Lakes (USA).

This is a clear example of CC awareness in order to foster improvements and adaptation through educational projects which integrate traditional and American Indian knowledge and perspectives to generate a multi-stakeholder approach.

Keywords: Kids, Schools, Traditional communities, Resources for educators, Climate change adaptation, Preservation of traditional lifestyles.

Experiences From University Linking Education and Professional Development

Universitat Rovira i Virgili (Marquès 2011; URV 2012)

As part of the framework of the program for the development of Service Based Learning experiences in the University Rovira i Virgili, some local SBL practices have been carried out in the last years covering different topics and involving several local, national and international partners.

We wish to draw attention to the task developed by the Environmental Law Clinic, as part of the Master in Environmental Law. This project has a long and successful trajectory, evidenced by the 42 different cases and the 23 clients assisted since 2005, of which 17 are NGO's and six public administrations. Law students offer legal support to those partners who cannot afford the costs of private legal representation when faced with a myriad of environmental problems. The services offered by students, who are supervised by the institution's teaching staff include: writing legal reports and statements, writing local legislative proposals and conciliation and mediation in environmental issues. Some of the activities developed (CEDAT 2014) are briefly explained here. In 2010 postgraduate students, in collaboration with Engineering Without Frontiers (ESF) and the Department of Sanitation and Environmental Management of the Francisco de Orellana Municipal Decentralised Autonomous Government (Ecuador), were asked to improve the Single Environmental Ordinance of the Francisco de Orellana canton. The Single Ordinance was adapted for the Ecuadorian regulations on environmental issues and shaped to respond to the reality and the possibilities of the Canton in order to facilitate its application and improve the environmental situation and the welfare of the population. In 2009, the Environmental Law Clinic developed a Training and Intervention Group for Sustainable Development in Cajamarca (Perú), with the aim to provide legal advice on the complaints process for mercury pollution by the Yanacocha Mining Company SRL and the transport company RANSA SRL in San Sebastián de Choropampa, Magdalena and San Juan, Province and Department of Cajamarca (Peru). The goal was to determine the most suitable legal procedure for establishing the responsibility of the agents involved and restore both the human rights of the people affected and the environment damaged. And in 2008 they collaborated with New Water Culture Foundation (Andalusia–Spain) in a legal report on the modification of the Statute of Autonomy of Andalusia on aspects pertaining to water and, in particular, the competencies transferred to the Autonomous Community relative to the basin of the River Guadalquivir.

The abovementioned project is an example of how the educational sector can provide practical responses to real problems affecting communities or organisations that would otherwise be unable to deal with them. Furthermore, the project generates added value in developing apprenticeships and work experience in real contexts. The added value of this practice is linked not only to the wide range of issues faced by their support provision, but also to the educational benefit for students and affected communities. We consider it to be an excellent practice to be reproduced in different fields.

Keywords: Higher education, Legal support, Real context of apprenticeship.

Universitat de Girona

In the field of University cooperation and volunteering there is a lot of room for new projects aiming at improving current situations in diverse contexts and topics. At the University of Girona, UdG from now on (Catalonia, Spain) we can find several interesting projects which meet the characteristics mentioned above. All of them are framed in the Service Based Learning philosophy. We have chosen the "Organic Solidary Vegetable garden initiative" because it fits perfectly as an example of educational processes that can be used as a trigger to address climate change consequences related to human health. This vegetable garden initiative is the core of a project about social inclusion and reinsertion through vegetable farming. It combines organic agriculture with social inclusion and education (both for university students and primary school pupils). There are four main institutions involved in the project: one local shelter for homeless people (la Sopa), which depends on the Girona's City Council, a Foundation for the social inclusion of intellectually disabled people (Fundació Ramon Noguera), and the UdG. Farming is carried out by a collective team of users from these three institutions and everything harvested is donated to the solidary community kitchen of la Sopa which feeds those who are most vulnerable.

The advantages and positive outputs of this project consist in a wide range of results. In the short-term, the project helps to decrease the costs of the community kitchen thanks to the vegetables harvested. In the mid-term, it fosters new boundaries and understanding between people coming from very different backgrounds whilst also offering a daily endeavour and training in organic agriculture to socially vulnerable collectives. These activities also lead to increased self-confidence, self-esteem and empowerment in these individuals. All of these features are crucial for personal wellbeing. For university and primary students this means their discovering of a tough reality whilst developing an understanding and the procedures with which to improve the harshness of the world around them. In the long-term, this gardening project can contribute to the wider benefit of society in many other important ways. These include the training of socially and environmentally sensitive professionals and the establishment of a network of urban vegetable gardens and gardeners would encourage far more self-reliance in the event of food distribution shortages. For more information visit https://hortecosolidari.wordpress.com/ and http://www.udg.edu/cooperacio/OficinaCooperacio.

Keywords: Higher education, Social inclusion, Urban agriculture, Intellectual disabilities, Solidarity.

Universidad Nacional de Córdoba: Argentina (PricewaterhouseCoopers 2009)

The Faculty of Agricultural Sciences of the Universidad Nacional de Córdoba (Argentina) developed the project "Dissemination of medicinal and aromatic plants cultivation to promote the generation of sustainable production entrepreneurships". Under this program, students developed workshops and activities with local farmers to spread the possibilities of cultivating traditional medicinal and aromatic plants, to educate and inform about how associative experiences and entrepreneurships could be fostered and to educate in, amongst other areas, market and business strategies.

This is a good example that combines current knowledge and techniques whilst also integrating and adding value to traditional heritage and knowledge. The project also links sustainable agricultural practices to health care and local economy.

Keywords: Higher education, Community improvement, Sustainability and Business, Traditional knowledge.

Sustainable Healthcare Education Network: UK

This English network of academics, doctors and health-care students has developed what they refer to as three simple learning objectives to communicate the links between medical practice and a more environmentally and socially sustainable world. The network carried out a national consultation that included all UK medical schools, Royal Colleges, post-graduate deaneries and major medical organisations. They generated a consensus around three basic ideas: the value of ecosystems and the anthropogenic threats to human and planetary health, the link between sustainability and the quality improvement agenda and the ethical dimensions of sustainability related to the inverse care law to CC. Furthermore, these objectives have been included into existing curricula in several specialities such as public health, primary care, paediatrics and emergency medicine, etc. More information can be found visiting the Centre for Sustainable Healthcare (Oxford, UK) website.

This initiative has been selected as an example of how ESD needs to be implemented as a core content and process in health professions education. Not only due to the high probability of adverse health impacts from CC, but also because actions to reduce emissions often have more immediate health co-benefits (for example the reduction of high health costs caused by fossil fuel power stations' pollution).

Keywords: Medical education, Learning objectives, Sustainability.

All the examples mentioned above show a great potential rooted in the relationship between future professionals, who will play an important role in an unstable climate situation with unexpected effects, and local communities. Such a relationship is based on a shared knowledge, understanding and proven experience in finding common solutions with the participation of multiple stakeholders, and in integrating traditional and culturally diverse perspectives and approaches. Even though all of the cases deal with several like challenges, they may also differ in their main focus. Some of these cases are more focused on resources planning and management (Sri Lanka and Argentina cases), whereas there are examples which put more emphasis on integrating traditional and indigenous knowledge (G-WOW and Argentina cases). Other cases are content based to foster habit changes to mitigate and adapt (EPA and Sandwatch), related to formal curricula (UK network case) or focused on improving living conditions and integrating vulnerable sectors of society (Sri Lanka, URV and UdG cases).

Conclusions

CC and health promotion challenges offer the opportunity to foster generational transformations which can enhance social knowledge and bonding, with an empowering impact over communities, leading to their transformation and improvement. We will need strong but flexible communities, formed and willing to construct social learning to adapt efficiently to a changing environment.

Education changes across time and space. Some of the CC challenges are supposed to be present in more or less intensity depending on the region. Furthermore, the capacity to cope with them as well as the strategies that could be the most efficient also differs from place to place (from community to community). Education has many purposes including enabling learners to fulfil their individual potential as well as contributing to social transformation. That means that context and local relevance are essential in education related to CC and health promotion. In spite of their differences, all educational programmes should be based on five fundamental pillars of learning to provide quality education and foster sustainable human development (four as set out in the Delors Report, plus a fifth with a SD dimension): learning to know, learning to do, learning to live together, learning to be and learning to transform oneself and society.

All the examples mentioned in this chapter help to prepare contemporary and future generations for the upcoming challenges, some of the most pertinent ones related to the consequences of climate change. Community based and SBL projects in education can be considered as triggers that serve to shed light on problems whilst simultaneously offering shared solutions. Here we find the most valuable learning possible: we, as individuals, can contribute to transform our communities and therefore society. These local transformations are, in fact, a very powerful learning environment for both individuals (students, pupils, citizens, professionals, etc.) and educators (Ochoa and Geli de Ciurana 2012). This becomes ever more powerful when considered as environments for social learning (Mulà 2011). CC poses relevant situations with enormous consequences to human health and wellbeing, and every individual and professional can play an important role. For instance, future nurses, doctors and emergency specialists could make a significant contribution in unstable climate future scenarios and help to protect population health if they participate in educational programs which prepare them (Barna et al. 2012).

We should take advantage of these real and contextualized challenges and turn them into strong triggers to initiate action-oriented learning processes. They have a double impact: on one hand, promoting a content-based knowledge about health and environmental issues whilst also fostering more conscious attitudes and behaviours. On the other hand, they also cause positive effects on the communities where they are being implemented: more self-conscious and sensitive individuals and societies capable of finding shared solutions in complex and uncertain present and future.

SBL always connects educational goals and/or needs with community development dilemmas and challenges. They become the perfect learning environment for ESD. Service Based Learning shares some of the characteristics that a high quality ESD education must meet (Tilbury and Wortman 2004): Interdisciplinary and holistic, value-driven, critical thinking and problem solving oriented, multi-method, participatory decision-making and as stated before, locally relevant (without forgetting the global framework and general needs). Educational projects have the potential of a double impact: on one hand, promoting a content-based knowledge on health and environment issues whilst also fostering more conscious attitudes and behaviours. On the other hand, they might also cause positive effects on the communities where they are being implemented.

As long as the chosen topics and projects for SBL accomplish those characteristics at the same time as they also contribute to improve the local conditions (environmental, cultural, social and economic), they can become important learning processes in which communities decide and act while they strengthen their relationships, response capacity and resilience.

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Chapter 18
Community, University and Government Interactions for Disaster Reduction in the Mountainous Region of Rio de Janeiro, Southeast of Brazil

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Abstract In January 2011, an extreme rainfall event took place in the Mountainous Region of the state of Rio de Janeiro causing a catastrophic landslide that resulted in more than 1500 deaths. This event marked a new challenge for disaster reduction in Brazil and introduced several measures for risk management. The dialogue gap between government and the local population could possibly explain the failure of the current risk management model, pointing at the urgent need to integrate actions from the government, the civil society and universities. Nonetheless, a top-down government model still prevails, and communities at risk remain distant from decision makers. This lack of interaction led to local self-organization, like the Córrego Dantas Neighborhood Residents Association (CDNRA), greatly affected by the 2011 disaster. In 2014, CDNRA and the GEOHECO research team started to develop new tools for a better dialogue with the local government. These groups recognized two fundamental needs: (1) to integrate both scientific and popular

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knowledge in developing a new methodology for risk evaluation and management and, (2) to integrate effective risk management actions with the actions of other disaster-related institutions, including universities, communities, NGOs and the government. Invited institutions attended the *1st Seminar on Landslide Risk Management at the Córrego Dantas Neighborhood*. As a result, a multi-institutional network (called **C**órrego **D**antas **RI**sk **MA**nagement **N**etwork) was founded to provide new tools for the identification of potential landslide disaster areas, as well as to introduce a new design for planning, according to the interests of the community. In this chapter, we describe former procedures and local studies, which have guided the development of CD-RIMAN and the establishment of its main goals.

Keywords Landslide • Disaster • Risk management • Multi-institutional network • Scientific/popular knowledge

Introduction

Landslides are becoming increasingly relevant in Brazil because of their magnitude, frequency and social, economic and environmental consequences. The data indicate a significant increase of these events and their consequences between 1991 and 2010 (UFSC 2012). Landslides were concentrated in Southeastern Brazil (81.7 %); in the State of Rio de Janeiro alone there were 365 official deaths in 505 landslide events.

The numbers are low compared to the deaths caused by landslides occurred in the mountains of the state of Rio de Janeiro during the very extreme rainfall of January 2011. This catastrophic event caused thousands of landslides in the municipalities of Nova Friburgo, Teresópolis and Petrópolis. Extensive debris flows propagated throughout the main valley bottoms, reaching down valley municipalities of the middle Paraíba do Sul river valley (Coelho Netto et al. 2014).

Extreme rainfall events are becoming more frequent in Southeastern Brazil, mirroring climatic variations in the last decades, as observed by Figeiró and Coelho Netto (2011). The authors showed a secular trend of lower annual precipitation levels based on long term rainfall records of the Resende Station, located in the hilly lowlands of the middle Paraíba do Sul river valley (in the state of Rio de Janeiro). They also pointed out subtle variations in the daily frequency distribution throughout the twentieth century by comparing the average of each decade, as it follows: while the frequency of rainfall below 20 mm/day is dropping, extreme rainfall totals above 100 mm/day are increasingly more frequent towards to late 1990s.

The official number of deaths and missing persons for the January 2011 disaster reached more than 1500 people. One of the areas most affected by landslides was the Córrego Dantas watershed (54 km^2) in the municipality of Nova Friburgo (Coelho Netto et al. 2011).

Since then, special attention has been given to landscape recovery and rehabilitation (Shadeck et al. 2013). Technical and scientific efforts are focused on developing models that attempt to assess landslide susceptibility and risks. However, there are still gaps regarding the inclusion of popular knowledge in analysis models and the dialogue between public authorities and the vulnerable communities.

Unfortunately, a top-down relationship between the government and communities, which makes it harder for a trust-based relationship toward the execution of local actions to develop (Macedo 2013), still prevails. The implementation of integrated risk management models requires policies and joint actions among universities, public administrators, civil society organizations and communities, as established by Brazilian law and public policy. Overall, it appears that the coordination between these spheres in Brazil is still in its infancy.

This situation led to the creation of local organizations such as the Córrego Dantas Neighborhood Residents' Association (CDNRA). In 2014, CDNRA and the GEOHECO research team started to collaborate and to join efforts for a better dialogue with the local government. These groups recognized two fundamental needs: (1) to integrate both scientific and popular knowledge in the development of a new methodology for risk evaluation and management and, (2) to integrate effective risk management actions with other disaster-related institutions including universities, communities, NGOs and the government.

To reach the initial goals, a *1st Seminar on Landslide Risk Management at Córrego Dantas Neighborhood* was organized by GEOHECO and CDNRA. Several institutions attended the meeting in November 2014. As a result, a multi-institutional network called **C**órrego **D**antas **RI**sk **MA**nagement **N**etwork was founded to develop new tools for the recognition of potential landslide disaster areas and to propose a new planning design based on community interests. In this chapter, we describe former procedures and local studies, which guided the development of CD-RIMAN and the establishment of its main goals.

The Connection Between Research and the Local Community

The Geo-Hydroecology Laboratory (GEOHECO/UFRJ) has been working in the Córrego Dantas basin since 2011. Its mission is to understand the triggers and propagation of landslides as to support a new methodology for evaluating landslide susceptibility and risk.

The Córrego Dantas Neighborhood Residents' Association (CDNRA) has been discussing the area's reconstruction, taking action to prevent the occurrence of new tragedies and mitigating their consequences.

For 3 years, researchers and community members acted in a disconnected way. However, the need to incorporate local knowledge into susceptibility and risk analyses and bring scientific knowledge into community discussions created a synergy between the two groups. A dialogue has been developing with the goal of reducing the risks and consequences of new tragedies.

The development of this relationship falls within the concept of the Ecology of Knowledge (Santos 2006). The idea valorizes both scientific and local/popular forms of knowledge. It recognizes the importance of heterogeneous knowledge and of the interaction between these different types of knowledge to produce new knowledge (Santos 2007).

For risk management, the capacities of local communities must be strengthened in order for them to make their own risk management choices and to ensure that key community stakeholders participate in all stages of management (Ikeda et al. 2008).

According to this approach, risk management requires working in networks to connect residents, local institutions, researchers and governments. Building these networks is a robust and flexible strategy that provides better results than the standard practice of increasing the level of control through formal administrative structures (Comfort 2005).

The strategic-situational planning approach focuses on sustainable development and stimulates plural knowledge. This approach seeks to establish governance mechanisms covering environmental, social and economic policies and to generate proposals and integrated management actions (Possas 2001).

The development of Geographic Information Systems (GIS) from a bottom-up approach that effectively includes community participation can also contribute to the improvement of the dialogue among different knowledge types, facilitating the development of agendas that serve the interests and the territory of these communities (Cinderby 1999; Weiner et al. 2001).

The main goal of this chapter is to discuss and assess the development of the dialogue between researchers and community members toward the creation of the Córrego Dantas Risk Management Network (RIMAN-Córrego Dantas), based on the joint achievements of these groups.

Methods

The methodology is based on the idea of research-action, which can be defined as participative research carried out to produce knowledge and understanding of a scientific object as part of the practice (Ketele and Roegiers 1993; Engel 2000).

This chapter was based on the researchers' perception that there was a need to include the knowledge of local communities in the risk analysis of landslides, and to enable communities to appropriate the knowledge produced by researchers.

To establish the dialogue, researchers searched for local actors that worked with risk management. The CDNRA work was recognized reference. Therefore, researches contacted CDNRA representatives to discuss partnership possibilities. In order to make both proposals clear for each other, CDNRA representatives invited GEOHECO/UFRJ researchers to participate in their association meetings.

Nova Friburgo Master Plan

The dialogue was established after the request to support the discussion of the Nova Friburgo Master Plan: members of GEOHECO/UFRJ acted as advisers along with CDNRA in a meeting to discuss it. The main goal was debating the importance of the Master Plan as an important territorial management tool and to introduce spatial data to support the discussions.

The neighborhood zoning scheme was reviewed collectively based on a GIS created with the participation of the community. The GIS joined information produced by official institutions, businesses and information shared by the community, as recommended by Cinderby (1999), using the Google Earth software.

Licensing the CDNRA Headquarters

The second request of the local community was for support for the authorization of the construction project for the new CDNRA headquarters. This involved analyzing documents and legislation, carrying out fieldwork to measure the exact distance between the Dantas stream and the planned construction area, and preparing a technical document to support the discussion with the public authorities.

Building the RIMAN-Córrego Dantas

Researchers and community members realized that a forum for broader discussions on risk management at Córrego Dantas needed to be created. So, they sought to bring other institutions into the partnership and started the development of a multi-institutional network.

The first step in building this Network was to identify the institutions acting in the region and those with a vested interest in acting. This identification was performed by interviewing representatives of partner institutions and the CDNRA, as well as by conducting Internet and bibliographic research.

Based on this identification, a seminar involving institutions and the local community was held on November 17, 2014. The seminar was organized based on the methodology of strategic and situational planning. It was divided into two parts. In the morning, institutional representatives presented their work on disaster management. In the afternoon, participants were divided into three groups guided by one participant, each of whom drew up Network missions, goals and courses of action. The work of each group work was discussed in plenary sessions to collectively establish the characteristics of the Network.

Research Assessing the Relationship Between Communities and Institutions

In addition to developing the Network, the research team conducted research assessing the relationship between local community and the institutions working in the Córrego Dantas Creek area.

The research consisted of 110 interviews. One questionnaire was filled per household with one of the residents, and the location was recorded with a GPS device.

This neighborhood is estimated as having less than 500 households (Lacerda in press), which means that the sample was greater than 22 %. The interviews were conducted from December 2014 to January 2015.

The survey encompassed issues related to public policies and housing policy. Questions about the neighborhood's main problems were asked: whether any public agency related to civil defense visited the households, whether there was an official report or notification of risk, whether the residents agreed with the report, and whether residents would to accept being relocated.

These interviews sought empirical evidence on the community's adherence to official disaster reduction programs and provided an overview of the community's internal level of mobilization.

Results and Discussion

The first contact with representatives of the CDNRA was marked by a lack of trust in the proposed dialogue with the community on scientific and popular knowledge and results for the local community. The reason for this mistrust is connected to the disjointed and short-term actions carried out after the tragedy by several institutions. Moreover, when local communities attempt to dialogue with science, the relationship is oppressive because scientific knowledge generally disqualifies popular knowledge (Santos 2006).

Another factor in the relationship was the suspicion that the actions proposed were tied to the State Institute for the Environment (INEA), which, after the 2011 disaster, had an adversarial relationship with local residents on the basis of real estate negotiations which sought to dislodge the population from areas classified as being at hydrological risk areas.

The participation of researchers in CDNRA meetings was crucial in overcoming this lack of trust.

A collective project was created to provide follow-up and define the community demands that could be supported by the researchers. The first demand was to support the discussion on the new Nova Friburgo Master Plan.

Nova Friburgo Municipal Master Plan

The Córrego Dantas neighborhood is mentioned in the current Master Plan, but the plan does not refer to the neighborhood's official limits. Therefore, before starting the development of a zoning proposal, it was necessary to identify this delimitation. Approximately 50 community residents contributed in the process, a number above the average participation in regular CDNRA meetings.

The residents have come to recognize the neighborhood's spatial extent and to visualize the current Master Plan zoning. With the visualization of zoning classes they were able to work on the meaning of each of these classes according to building parameters. Later, they were able to review each of the neighborhood areas.

Two aspects of the discussion on the Master Plan zoning scheme should be highlighted: (1) the huge facility and interest of the community in implementing a GIS tool to understand and discuss different aspects of the neighborhood; (2) the importance of the 2011 event in forcing residents to refine their perceptions of the environment. This resulted in significant proposals for changes in the zoning scheme (Fig. 18.1).

Because of the recognition of the environmental services provided by these areas, there was no doubt about maintaining ZEI zones in the neighborhood. ZEIs are public and private areas whose environment and urban landscapes need to be protected and recovered. The main change was an abrupt reduction of the ZOE areas. ZOEs are areas of low demographic density to be prioritized to increase population density and urban development. This class stimulates population increase, and the Córrego Dantas's citizens not only remarked that they need a "better neighborhood," not a "bigger neighborhood," but also recognized that dozens of landslides scars occurred inside the current ZOEs. These two facts resulted in the conversion of most ZOEs into ZTs and ZUCs and the reclassification of the current urban area of the neighborhood in to a ZUC. ZTs allows lower demographic densities than ZOEs, but does not stimulates urban growth, while ZUCs represents the recognition of the main area of the neighborhood as an established urban area that needs to be improved and whose expansion needs to be controlled. Another change was the inclusion of a ZER corresponding to the waste landfill area. This landfill receives waste from the entire municipality of Nova Friburgo, and there are conflicts related to the landfill's activities, its environmental impacts and recent expansion. The fact that the landfill was classified as a ZER means that the population recognizes the area as degraded zone and wants its environmental rehabilitation. Another important discussion was regarding the current profile of the neighborhood. The current master plan allows the construction of large industrial projects along RJ-130 (a state highway), which crosses the area. These are entirely incompatible with residential use, and Córrego Dantas's citizens suggested non-residential activities compatible with residential use.

This new zoning proposal and the document supporting the changes were the result of the dialogue between popular and scientific knowledge. That was an

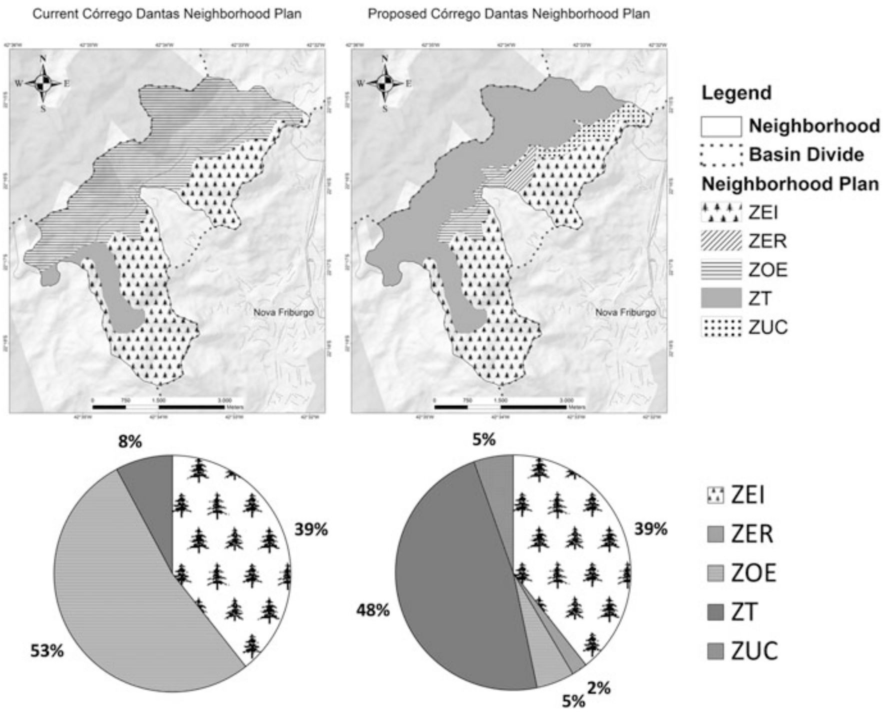

Fig. 18.1 Zoning of the current neighborhood plan (*left*) and proposed neighborhood plan (*right*). *ZEI* zone of environmental interest, *ZER* zone of environmental rehabilitation, *ZOE* zone of orientated expansion, *ZT* zone of transition, *ZUC* zone of urban control

ecology of knowledge that generated concrete results and empowered communities to discuss local land use.

Headquarters Authorization Process

Another focus of this dialogue between knowledge types was the authorization for the construction of CDNRA's headquarters. Land had been donated to the association, which was constructing a new building when the tragedy took place in 2011. Since the area was hit by debris flows, the competent authorities required a construction permit based on the new (done after the disaster) classification of the area as under risk of flooding.

There were many problems with the Municipal Government of Nova Friburgo and INEA, which were responsible for building permits. Dialogue between the public authorities and the community was difficult, which affected the process.

Researchers and community members analyzed documents related to the process. Then they created an all-encompassing list of the legislation governing the permit process and the local land-use, and compared this to the documents. Since zoning maps of the area existed but the mapping methodology was not available, the researchers contacted the INEA to understand the zoning of the area, which had been conducted by the agency.

Researchers and community members concluded that, given the legislation, the construction was uncertain because the public authorities had not set the relevant parameters for issuing a construction permit. In particular, the *non aedificandi* area around the Dantas stream had not been defined, which is a key parameter.

A report with the main conclusions and questions put forth by residents and researchers about the construction permit issuing process was drafted. Most of the questions related to the lack of information provided by public authorities.

The document was presented to the competent bodies and supported discussions on the permit issuing process. It described CDNRA members' participation in the dialogue with public authorities, which was of great importance for the granting of the permit.

The jointly-prepared document and the previously-performed zoning system was new knowledge, developed collectively between researchers and community members.

RIMAN-Córrego Dantas Development

The need to build a multi-institutional space to discuss social and environmental disaster management in Córrego Dantas led to the development of RIMAN-Córrego Dantas. Therefore, in order to promote inter-institutional dialogue, the *1st Seminar of RIMAN Córrego Dantas* was organized.

At first, 15 institutions or groups that should attend the seminar were identified. However, representatives of three of these institutions were unable to attend, so 44 representatives from 14 institutions or groups attended the meeting.

Conservation International Brazil
Córrego Dantas Neighborhood Community Protection Unit
Córrego Dantas Neighborhood Residents' Association
Geo-Hydroecology Laboratory
Hands on Program (Partnership between the Rio de Janeiro State University and the Rio de Janeiro State Secretariat of the Environment)
Angra dos Reis Institute of Education/Fluminense Federal University
Mapping Laboratory, Geography Department, Federal University of Rio de Janeiro
Marine Geography Laboratory, Geography Department, Federal University of Rio de Janeiro
Nova Friburgo Municipality Civil Defense Services
Oswaldo Cruz Foundation
Pedro II School
Polytechnic School/UFRJ

Territory and Citizenry Group, Geography Department, Federal University of Rio de Janeiro

For the meeting, GEOHECO/UFRJ researchers had to work with centralized management to develop the collective process. This management was based on establishing a working relationship between the institutions and the community. This process had the support of the other institutions and the local residents.

At the seminar, institutions got to know other groups interested in acting in Córrego Dantas and which had a potential for collaborating to form the Network. In addition, the mission, objectives and main lines of action guiding the development of the Network and of a consolidation project were built collectively, as shown below:

Mission *To promote the association of knowledge from public, private and community organizations to reduce geo-hydrological risks.*

Objectives

- *To develop a risk management model integrating public, private and community actors.*
- *To promote the development of a culture of risk reduction.*
- *To stimulate the exchange of knowledge between different actors.*
- *To develop mechanisms to generate and disseminate information and knowledge.*
- *To promote mechanisms for territorialized management and governance.*

Areas/Lines of Action The lines of action were established within three main areas: *Diagnosis and Monitoring; Education and Coping* (Table 18.1).

The mission shows that the focus is on acting coordinatedly to create synergy between institutions and enable their activities according to the model advocated by several authors (Comfort 2005; Ikeda 2006; Ikeda et al. 2008).

The first goal shows that the focus of the Network is to develop an integrated model of disaster management to overcome the challenges of Córrego Dantas and other areas with similar problems.

The other objectives, the areas and lines of action cover the four phases of natural disaster management (Alexander 2007). However, most of the actions in goals 1 and 2 are almost entirely related to risk reduction.

Some lines of action established in goal 1 also meet the restoration and reconstruction phases, especially in terms of generating information to guide land use planning processes.

The objective of goal 3 is emergency preparation and management. Line of action *Alarm and alert system improvement*, for example, relates to preparation specifically. *Strengthening municipal institutions* and *Strengthening NUPDECs* are central for emergency preparedness and management, as per the legal framework for disaster management in Brazil.

Only reconstruction actions were not covered directly by the lines of action, which reflected the absence of institutions acting in these areas in the seminar.

Table 18.1 The Network's collectively-defined goals and lines of action

Goals	Lines of action
(1) Diagnosis and monitoring	Susceptibility diagnosis
	Risk diagnosis
	Social and environmental diagnosis
	Institutional mapping
	Rainfall monitoring
	Geological/geotechnical monitoring
	Erosion monitoring
	Water quality monitoring
	Risk perception survey
	Vegetation cover and land use survey, monitoring and analysis
	Information production
	Geoinformation system
	Study of landslide triggering mechanism
	Scar inventory (historical)
(2) Education	Curriculum in education at the various levels
	Studies of previous experiences in education
	Educational methodology development
	Pedagogical concept and guidance
	Survey of institutions involved in educational activities
	Interaction with educational institutions
	Development of educational materials
	Training and Education (simulation)
(3) Coping	Integrating with the instruments
	Improving the alarm and alert system
	Encouraging measures to be undertaken by residents to reduce risk
	Strengthening municipal institutions
	Strengthening NUPDECs
	Online GIS

The seminar also resulted in a short-term agenda for the Network as indicated below:

- *Drafting the seminar report*
- *Preparing a preliminary version of the Network development project based on the seminar results*
- *Reviewing the project collectively to be discussed and consolidated within the Network*

Fulfilling this agenda showed the importance of managing the Network through a centralized process. The group of GEOHECO/UFRJ researchers wrote the seminar report and created the initial version of the consolidated project.

The methodology adopted in the seminar facilitated the collective discussion and enabled community representatives to play a role. In the plenary session, each representative introduced his/her institution and the contributions they can make to disaster management in Córrego Dantas. Subsequently, participants were split into three groups to discuss, respectively, RIMAN's mission, objectives and lines of action. Then, the conclusions of each of the groups were discussed so that the end result represented a view of all participants.

Community representatives were able to talk about their perspectives and risk management-related issues. They participated in the three groups. Finally, CDNRA's president, ensuring a prominent role of the association, guided one of the groups.

Placing local residents at the center of the discussion is crucial because it reverses the traditional rationale according to which scientific knowledge is central and popular knowledge is secondary or invisible (Santos 2006).

That was highlighted in the case of disaster management, since studies show the need for dialogue between scientific/institutional knowledge (governments) and popular knowledge to address challenges (Comfort 2005; Ikeda 2006; Ikeda et al. 2008.).

After the seminar, an e-mail group was created including representatives of invited institutions. The group was moderated by researches and, thanks to the group, other institutions joined the Network officially. Through the group, both the report and the project for the Network were shared. In addition, a representative of the Oswaldo Cruz Foundation (FIOCRUZ) announced the possibility of providing 8000 € to the Network, and the representative of CI-Brazil suggested that the Network participated in a multipliers training program on climate change and adaptation offered by the institution.

Assessment of the Relationship Between Communities and Institutions

In addition to developing the Network, the research team made progress regarding the local community thanks to research focused on assessing the relationship between this community and institutions that work in the Dantas Creek Basin. This research supports the development of the Network because it allows the most important institutional weaknesses related to this collective project to be perceived, as well as and to consider strategies to strengthen them.

In the survey of the problems in public policies and housing (Table 18.2), infrastructure was the most mentioned aspect. This indicates that the neighborhood suffers from fundamental problems, some with pre-disaster origins (pavement, garbage collection, sanitation, transportation, etc.), and other with post-disaster origins (reconstruction of streets, bridges, removal of deposited materials, removal of rubble from demolished houses, etc.). We would like to point out the relevance of

Table 18.2 Priority problems indicated by the population of Córrego Dantas neighborhood

Problems	Total
Infrastructure	41
Other disaster	30
Conflicts with the government	23
No problem	14
Not answered	9
Health	8
Other	6

The total number of responses is greater than the total number of persons interviewed, because each people could respond regarding more than one problem

the answer "other disaster" since it indicates that there is a perception of the need to prioritize initiatives on the disaster issue.

Conflicts with the government was another problem with a high number of mentions. This demonstrates empirically the difficulties of the relationship between the community and official agencies. Generally, these problems are associated with the top-down model that these bodies impose on communities without hearing their demands and without paying attention to their knowledge.

As to the performance of public agencies, 60 households interviewed (55 %, N = 110) had been visited by public emergency management agencies and 50 (45 %) never received any visit from an official representative. Given that the Córrego Dantas community was one of the most affected areas in the tragedy of 2011 (Coelho Netto et al. 2011), the percentage of households that did not receive a visit can be considered high. Once again, this shows a weakness in the relationship between the government and the community.

Of the 60 homes visited, 52 % received an official report indicating that they were located at a high-risk area. However, the criterion of the report favored the state of imminent terrain rupture, rather than an assessment of potential conditions such as susceptibility and at-risk elements. This is a problem since it does not address areas where no events took place because of the spatial variation of critical rainfall in January 2011, although these areas indeed have the conditions for that.

The assessment of the residents' position on risk reports and relocations reinforces the perception of mistrust regarding the government. There is a high percentage of residents who received these reports and who do not agree that their homes are at risk (44 %). Another 16 % question the validity of the report. Therefore, 60 % of the residents do not trust the government reports.

Questioning the possibility of being relocated further highlights our perception that there is resistance to public authority. Sixty percent of residents who received reports indicating that their homes were at risk did not agree to be relocated. These results point clearly to a gap between the understanding of the risk to which they are exposed and their willingness to leave their homes. Their resistance is understandable for various reasons. First, the government's assessment of the value of homes plus the compensation for the expenses of relocation fell short of the residents' demands. Second, the dialogue on the process also fell far short of residents' needs.

Moreover, during the interviews, residents were explicit about their attachment to their neighborhood. Therefore, resistance to relocation is permeated by a feeling of identity, of an emotional bond to the territory, as well as other subjectivities that have not yet been considered by public authorities as important variables.

Final Considerations

The disaster of January 2011 deeply marked the history of risk management in Brazil. The establishment of public policies for integrated management became the main goal.

However, the development of integrated risk management models remains a challenge, and mistrust between communities and the government is usually the rule. The field research conducted for this study reinforced this perception.

Similarly, scientific knowledge has been used to support the perspective that popular knowledge is of a lesser importance. This makes the dialogue between different knowledge types difficult.

Thus, a plural dialogue between scientific, institutional and popular knowledge as a basis for integrated risk management is still a distant reality. The proposed development of the RIMAN-Córrego Dantas follows this model.

When scientific research on disasters emerged independently in the region, the researchers created stronger ties with the local residents. Residents are fighting for better living conditions. Despite that, our study showed that when authorities do not open the possibility of adjusting and improving prevention and risk management systems, the accumulated knowledge serves no purpose. Both efforts, when developed in isolation, create relevant results. However, they prove to be limited in resolving problems.

The link between scientific and popular knowledge, in a process that can be classified as the Ecology of Knowledge (Santos 2006), leverages the result of the work of both groups and allows advancing the central goal of the risk management process, that is, reducing the consequence of disasters driven by natural phenomena.

The dialogue between different types of knowledge resulted in an institutional process of coordination that also included the knowledge of government institutions. Those with institutional and scientific knowledge, who usually do not recognize popular knowledge, have started to see that the knowledge of local residents is valuable, which, in turn, helps making popular knowledge visible, as defined by Santos (2007).

Therefore, it is crucial that the RIMAN-Córrego Dantas is developed in a process that ensures the active participation of local residents in a bottom-up model that includes the dialogue among researchers, the community and government institutions.

This integrated model is the key to effective risk-management processes, as demonstrated by scientific studies (Comfort 2005; Ikeda 2006; Ikeda et al. 2008).

Advocating policies in this area is critical. Thus, the process of building the RIMAN-Córrego Dantas is promising as a model to be replicated in other parts of Brazil.

Having a centralized management is crucial to ensure the Network's continuity far beyond meetings among participants. However, political centralization cannot reduce the participation of some groups in favor of others, as this tends to undermine its development.

This model is still being consolidated; many challenges still have to be overcome before we can confirm that this is a successful model to be replicated.

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Chapter 19
Climate Change and Health: Governance Mechanisms in Traditional Communities of Mosaico Bocaina/Brazil

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Abstract This chapter addresses socio-environmental challenges, health and traditional communities in the context of climate change. The study regards a protected area, the so-called Mosaico Bocaina, in the municipalities of Angra dos Reis and Paraty, in the state of Rio de Janeiro, and Ubatuba, in the state of São Paulo, where traditional communities from three different ethnic groups live (indigenous, quilombolas and caiçaras). The knowledge of nature and of the physics of climate change (including its causes, consequences and characteristics) isn't always accompanied by the understanding and science of how climate change affects the well-being and health of populations. The analysis of the public policies and science production for the field concluded that the situation for the region in question is no different from that of other regions in Latin America: (1) public policies have not become effective interventions against climate change in general, and the interest in its implications over the health of populations is recent; (2) the science of climate change is insufficient, especially regarding its effects over the health of populations, whether in this specific region or more encompassing scales;

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(3) there is no information on how traditional communities perceive climate change, their impacts on health and well-being and tackling strategies. This chapter seeks to contribute to the knowledge of the impacts of climate change on the health and well-being of traditional communities, focusing on the governance tools required to address it. What strategies have traditional communities been using to deal with it? How does the official agenda of efforts reflect the socio-cultural perceptions and mitigation and survival strategies of traditional communities? Qualitative methods of participant observation that combined participation, observation, informal open interviews and analysis of documents were employed. The results generated territorialized knowledge in the social, economic, political and cultural dimensions of climate change and their implications on the health and well-being of traditional communities, as well as allowed the identification of governance mechanisms and socio-cultural strategies that can be used to mitigate, adapt to and help avoiding climate change.

Keywords Climate change • Extreme events • Bocaina • Traditional communities • Climate governance • Health

Introduction

The vulnerability of a population depends on its density, economic development, level of equality, food availability, local environmental conditions, pre-existing health status and the public health care system (Woodward et al. 2000).

The ideas of vulnerability (see Füssel and Klein 2006, and, more recently, Soares et al. 2012), adaptation, adaptive capacity, resilience, exposure and sensitivity are interrelated and have wide application to global change science (see Smit and Wandel 2006). As to climate change (CC) vulnerability, resilience and adaptation—as well as the impact of CC on health (see Haines and Patz 2004)—it is particularly necessary to understand not only the specific vulnerabilities and adaptation capacities of traditional communities, but also their traditional knowledge, to fully comprehend both CC and adaptation to CC (Füssel and Klein 2006). Traditional knowledge is increasingly recognized as valuable for adaptation to CC, bringing scientists and traditional communities together to collaborate and exchange knowledge (Williams and Hardison 2013; Ford 2012).

The Convention on Biodiversity, approved at the United Nations Conference on Environment and Development (also known as "The Earth Summit"), recognized the crucial role of traditional communities in the preservation and conservation of ecosystems because they are intimately dependent on natural resources (used mainly for their subsistence), make intensive use of family labor and low-impact technologies (predominantly derived from ancestral knowledge) and are, usually sustainable (Tomanik 1997; Arruda 1999).

CC has generated interest not only in the roles and responsibilities of traditional communities in adaptation and mitigation, but also, therefore, in the identification of their needs. That is a challenge for governance and CC adaptation (Tran et al. 2014). There is also need to develop specific health indicators that consider CC sensitivities for traditional communities and to create adaptation plans (Donatuto et al. 2014). Traditional communities and the impacts on their land should deserve special attention because they are located at vulnerable environments and because of their continuing reliance upon resource-based livelihoods and health impacts (Ford 2012). Measures against CC and CC Governance schemes—understood as a broad range of options for coordinating adaptation and mitigation (see Fröhlich and Knieling 2013)—are particularly needed in this context.

The goal of this study was to assert that—in the context of CC and extreme climate events—socio-environmental issues impact the lives and health of traditional communities (indigenous, quilombolas and caiçaras) at the Mosaico da Bocaina region (in the states of São Paulo and Rio de Janeiro, Brazil), and to discuss scenarios of adaptation and both existing and potential governance strategies.

CC, Extreme Events, Vulnerability, Socio-environmental Risk, Adaptation and Health

The urban/industrial civilization not only developed greatly in many fields, but also produced a continuous degradation of ecosystems (the acidification of oceans, the biodiversity losses and extinction of species) and increasing social inequality (hunger, dislocated population) and conflicts between and within countries (IPCC 2014; World Bank 2014). Moreover, the increase in extreme climate events—especially concerning rainfall regimes, should increase the number of vectors of communicable diseases in southern countries, intensifying the negative effects of CC on these populations (Ebi 2009).

Despite the published literature about causes (Kerr 2013) and attributing weather extremes to CC (Hulme 2014), it is consensual that CC and Global Warming (GW) will be accompanied by increased frequency and/or intensity of extreme events. Populations adapt to the local prevailing climate via physiological, behavioral, cultural and technological responses. However, extreme events often stress populations beyond those adaptation limits, which makes understanding the health risks from these events very important (McMichael et al. 2006). Therefore, we need to identify existing vulnerabilities, not only regarding living and health conditions of the population, but also concerning the response capacity of health services to correctly assess the magnitude of the potential risk.

The definition of "vulnerability to natural disasters" is generally understood as the characteristics of a given population, a system or a set of assets that makes them more or less susceptible to the negative impacts of a threat. Such aspects or factors can be physical, demographic, socio-economic, cultural, environmental and institutional, depending on the approach used. The way these factors are considered varies according to the priorities and perspectives of countries and political organizations, as well as depends on the availability of information for analysis (UNISDR 2013). Therefore, vulnerability is determined both by social, material and environmental conditions and by institutions and governance schemes, such as, for instance, the ability of a political system to implement adequate, large-scale public policies (Engle and Lemos 2010; Twomlow et al. 2008).

The difference in the level of vulnerability between countries also exists between the social groups within countries. CC impacts social groups differently and with a different intensity, which makes the fight against poverty and inequality even harder (Barcellos et al. 2009; World Bank 2014).

The perception of this inequality concerning the impacts of CC (IPCC 2001, 2007) catalyzed an international movement for Climate Justice, which follows the processes of desertification, extreme climate events (intense rain, heat waves, etc.), sea level rise, among others while trying to remedy and/or eliminate existing or imminent injustices in the distribution of environmental benefits/harm, suggesting strategies and public policies to reduce risks based on a holistic, preventive and territory-based approach that is anchored in social participation, the empowering of communities, intersectoral and interinstitutional cooperation, the collaboration between the public and private sectors with the goal of changing the current models of production, consumption and use of natural resources (Shepard and Corbin-Mark 2009; Tyree and Greenleaf 2009; Setti and Gallo 2009).

Although efforts have been made to improve the understanding of the determinants of the vulnerabilities to disasters, one of the most common approaches has been the number of people affected, the number of deaths and the economic impact directly linked to a threat (UNISDR 2013), disconsidering social, cultural and environmental processes, that is, the macro determinants of health (WHO 2011; Buss et al. 2014).

The greater vulnerability of the poor to environmental factors (deforestation, changes in natural drainage, living in areas at risk) and the absence of adequate mitigation schemes also determine the health of the population (WHO 2011). Therefore, social, environmental, economic, cultural, ethnic/racial, psychological and behavioral factors influence the occurrence of health problems and its risk factors, and are called "social determinants of health" (CNDSS 2008). From an epidemiological perspective, CC represents a series of exposures to several risk factors generated by a change in the environment caused by an accumulation of greenhouse gases (Barcellos et al. 2009).

Besides the deaths directly linked to extreme events or their impact on the local infrastructure or natural resources, CC can lead to more malnourishment, to a dissemination of waterborne or vector-borne diseases and to an increase in the frequency of cardiorespiratory diseases, due to air pollution (OMS 2008; OPAS 2009; IPCC 2014; Silva et al. 2014), as well as to a greater number or intensity of heat waves (Coumou and Rahmstorf 2012).

Vulnerability and Adaptation of Traditional Communities

Given the perspective that CC will cause health impacts, populations in socioeconomically underprivileged conditions with little access to social services will be the most exposed to extreme climate events, water shortages, variability in the availability and the price of food and variations in specific natural resources (Bursztyn 1995).

The IPCC report on Impacts, Adaptation and Vulnerability to CC (2014) highlights an increase in the risk of risk factors for the most vulnerable groups—namely populations that depend directly on natural resources affected by variations in the climate: coastal populations, indigenous populations and traditional communities (IPCC 2007, 2014). These vulnerable groups are at risk because of CC, even though they have a crucial role in controlling deforestation and, therefore, CO_2 emissions (Ricketts et al. 2010).

Studies have shown that traditional communities are effective in resisting deforestation pressures in Brazil, one of the most important emitters of deforestation-related greenhouse gases, which would be worse if indigenous and quilombola communities had no legal rights over their land (Nolte et al. 2013; WRI 2014).

The notion of "traditional communities" emerged in the context of the creation of conservation areas for communities that live in these areas, called "traditional" for keeping century-old traditions living on subsistence agriculture or fishing (Santos 2003).

Indigenous populations settled in Brazil around 10 or 11,000 years ago. It is estimated that there were between two and five million people (in a total of 1400 different ethnic groups) living in Brazil when the Europeans arrived. Today, there are 600,000 of them in 25 ethnic groups (Kayser 2010).

The so-called "quilombola" communities include descendants of African slaves that have similar cultural traits until today. The quilombolas were, originally, fugitive slaves that settled in free land, generally in isolated places, but also in land they conquered, inherited, were donated, were given as payment for services carried out for the State or for simply for settling there (Giddens 2010).

Non-indigenous, traditional populations are the product of intense interbreeding between Europeans, indigenous peoples and slaves. Among those, the "caiçara" developed specific ways of life that depend on natural cycles, the knowledge of biological cycles and natural resources, as well as include specific technologies, symbols and myths. These communities have specific epidemiological profiles (mostly associated to chronically malnourished situations). Chronic malnourishment cases (Orellana et al. 2006; Mondini et al. 2009; Marques et al. 2010; Gava et al. 2013; Coimbra 2014) may be worsened by changes in climate patterns and their impacts on biodiversity and agroforestry ecosystems which they depend on for food. Specifically for the quilombolas, food safety issues are related to new living and consumption habits (Cordeiro et al. 2014) coupled with environmental changes caused by CC.

As to caiçara communities, one of the major risk factors regards outdoor activities and unfavorable socioeconomic factors. Skin lesions and ophthalmological problems—which could be aggravated by an increasing exposure to radiation caused by global warming (Van der Leun et al. 2008)—are relevant public health parameters for the group (Mello et al. 2012).

CC is perceived in this communities in: "the transformation of the landscape, variations in sea water temperature, weather unpredictability and the presence of a large number of tourists" (Seixas et al. 2014). "Moon phases and wind direction were very reliable to signal that rain was coming," "it has been getting hotter, which makes it harder to work on the field," "perceived variations in the volume of rainwater in reservoirs," "families have been forced to buy foods they usually grew themselves," and "the loss of agrobiodiversity", such as, for instance, "a decrease in the varieties of beans" (Ferreira et al. 2009).

Study Area

South America

Droughts affect almost all countries in South America. They are usually caused by a deficit in precipitation for long periods of time (months or years) (World Bank 2014). The consequences of that for the development of Latin America and the Caribbean will be serious as important economic losses occur—affecting livelihoods in rural communities, subsistence and extensive agricultural activities—, harvests drop, water resources change and sea levels raise that together with the acidification of oceans, the rising of the seas, the tropical cyclones and the changes in temperature will affect coastal livelihoods (World Bank 2014).

There are many problems and deficiencies which have been contributing to the high degree of vulnerability of Latin American countries to CC [that are available at the United Nations report South America: a regional view of disaster risk (2013)]. Among others, the following ones may be listed: poor or non-existing CC governance systems; limited awareness on the causes and consequences of CC; endemic poverty; limited access to capital and global markets; continuous ecosystem degradation; complex disasters and conflicts; unplanned urbanization; limited capacity (personal and institutional) to address the problems and their many ramifications (Leal Filho and Mannke 2014; see also Leal Filho et al. 2014).

The capacity of South and Central American countries to adapt to CC improved especially because of the reduction in poverty levels, but there is still an elevated and persistent level of poverty and socioeconomic inequality in most countries in the region, which results in poor access to drinking water, sanitation and adequate housing, especially for the most vulnerable groups (World Bank 2014).

Brazil

In Brazil, the estimate is for an increase of up to 2 °C in the average temperature, which would reduce the country's agricultural production—up to 70 % for soybeans and 50 % for wheat, in 2050. Precipitation should decrease 22 % in the Northeast until 2100, causing food shortages and violent social conflicts (IPCC 2014).

Natural disasters in Brazil are associated to: droughts; sudden flooding; gradual flooding; hail; frost; windstorms and/or cyclones; tornados; forest fires; landslides; linear erosion; fluvial erosion; and marine erosion. Almost all disasters registered in Brazil—in state of emergency and public calamity decrees and the data of the National Civil Defense Secretariat—are directly or indirectly related to climatic processes, involving wind, rain and the lack of rain which, therefore, can lead to landslides, floods and droughts (Freitas et al. 2014). At the South, Southeast and Northeast regions there have been more flash floods caused by prolonged or intense rainfall, affecting populations that live close to rivers. Many floods happen suddenly and, in some cases, the rain that contributed to the floods also causes landslides (Freitas et al. 2014). The impact will be potentially greater in low-income populations, causing an increase in malnutrition, in the morbidity and mortality associated to heat waves, storms, floods and fires, to a shortage of drinking water and a change in the spatial distribution of epidemic diseases such as dengue, malaria and cholera.

Changes in the use of land and habitat fragmentation—e.g. deforestation—contribute significantly to a worsening in environmental conditions and should intensify the negative effects of CC. The two activities that usually determine the expansion of farming and livestock areas in the country (cattle and soybeans) are at the borders of the Amazon (IPCC 2014).

Rio de Janeiro and São Paulo

The Southeast region in Brazil is very vulnerable to extreme rain because of its high population density and because it is subjected to meteorological systems that can cause either intense rain or droughts (Marengo and Camargo 2008). The cases of intense rain in the Southeast of Brazil have been linked to synoptic-scale systems like weather fronts (Lima et al. 2009; Vasconcellos and Cavalcanti 2010) and the South Atlantic Convergence Zone (SACZ) (Liebmann et al. 2001; Carvalho et al. 2002; Lima et al. 2009).

In the state of Rio de Janeiro, CC can be observed in the increase in the temperature and the occurrence of natural disasters, such as floods and landslides caused by intense rainfall, as well as in health-related issues, such as an increase in the number of cases of dengue fever, leptospirosis and an increase in mortality (Nobre 2011).

The current water crisis that threatens the Southeast region of Brazil has been caused by many factors (population growth; growing water demand, especially by industries; the environmental degradation of water springs; unplanned urban expansion; losses in distribution; the population's lack of awareness regarding the problem and a lack of political will to solve it), which show that the issue is not simply caused by rainfall deficiencies.

The Mosaico Bocaina

The Mosaico Bocaina was created in 2006 (DOU 2006) with the goal of stimulating the shared management of conservation units (in the Serra do Mar, Serra da Bocaina, the northern coast of the state of São Paulo, the upper part of the Paraíba river valley and the Ilha Grande Bay, at the southern coast of the state of Rio de Janeiro) and contributing to the preservation and conservation of natural and fishing resources, as well as promoting sustainable development in this region between the states of Rio de Janeiro and São Paulo (Gallo and Setti 2012).

The region encompasses 216,000 hectares of forests under special conditions of management and legal protection, including 24 traditional communities in three different segments, including 12 caiçaras, 7 indigenous and 5 quilombolas communities and their buffer zones. The region is part of the Serra do Mar's Biodiversity Corridor, one of the areas with the highest levels of biodiversity in the Atlantic Forest (Gallo and Setti 2012).

The region has a subtropical climate with little temperature variation throughout the year, although the months of January, February and March have more precipitation and the period between April and August is drier, with more wind during the winter.

Tourism became the main economic activity of the region, in detriment of artisanal fishing and according to a study carried out by of the Special Secretariat for Aquaculture and Fishing, currently the Ministry of Fishing and Aquaculture, the estuarine and marine fishing in the region is predominantly industrial now, approximately 70 % of the total number.

The occupation of the region happened diversely, including urban, unplanned expansion, with vastly negative environmental impacts (such as the land filling mangroves and cutting down forests for residential occupation), and the preservation of areas in which occupation is restricted and supervised by environmental agencies.

In order to protect the region and the rights of traditional communities, the Angra dos Reis, Paraty and Ubatuba Forum of Traditional Communities (FTC) was created in 2006 under Decree 6040/2007, the National Policy for the Sustainable Development of Traditional Peoples and Communities (DOU 2007).

The FTC protects the region by participating in the implementation of public policies that place adequate value in traditional culture and knowledge, as well as by campaigning for the resistance of these communities and on behalf of affirmative actions against restrictions imposed by the National System of Conservation Units, the influence of capital, the illegal seizing of land for construction projects, the predatory tourism and pre-salt oil exploration, seeking to ensure access, to legalize properties and to provide visibility to traditional life styles.

In this context, since 2009, the Oswaldo Cruz Foundation (Fiocruz) has been developing a set of strategies which started with a study entitled *Sustainable Development and Health Promotion* (see Gallo and Setti 2012). The project became a study and an action plan whose goal was contributing to better living conditions, especially concerning the reduction of inequalities and the promotion of autonomy and sustainability by means of the collective development and implementation of a local strategic agenda—"Sustainable Community"—that is integrated with the agenda of traditional communities and based on community-based tourism and the promotion of a solidarity economy (Gallo and Setti 2012).

Later on, in order to coordinate agendas and promote actions that have been established by an ecology of knowledges and that produce technologies and palpable solutions that promote equity, autonomy and sustainability, the Bocaina Project implemented the Observatory of Sustainable and Healthy Territories of Bocaina (OSHT) to generate information and critical knowledge and, especially, produce collective intelligence. The Observatory of Sustainable and Healthy Territories of Bocaina (OSHT) was created to integrate concurring agendas at the Angra dos Reis, Paraty and Ubatuba Forum of Traditional Communities (FTC), organized by the Oswaldo Cruz Foundation (Fiocruz) and the National Health Foundation, at Bocaina. The goal of the Forum is not only implementing structural and structuring actions linked to environmental health promotion and socio-environmental sustainability, but also developing the notion of "sustainable and healthy territories" based on the identification, articulation with and evaluation of territorialized social agendas, which would allow the creation of methods, technologies and parameters, as well as characterization, analysis, monitoring and evaluation indexes for experiences of healthy areas.

The observatory includes research (generating new knowledge and recovering traditional practices), development (systematization of new technologies), networking and horizontal cooperation (hybridization of knowledges and ensuing networking practices), which constitutes it as a observational network and a repository of the history of communities, assuring their promotion and sustainability.

Methods

Action research was the main method used to implement structural and structuring actions linked to health promotion and the promotion of the socio-environmental sustainability of traditional communities in Mosaico Bocaina and to evaluate effectiveness as a strategy to produce valid, reliable evidence of the impact of the Project, so that it can be improved constantly.

An ecosystemic and communicational approach was used in the strategic/situational planning to facilitate the permanent convergence of actors involved and to create opportunities for dialogue, participation, learning and coordination, so that solutions that promote autonomy and socio-environmental justice are developed.

The literature was evaluated, documentation was analyzed, participant observation techniques were implemented and informal open interviews were carried out in two seminars and 15 constructivist workshops on strategic planning, structuring conversations with methods and tools that facilitate the collective development of the project, preferring collective recording and visualization techniques to produce consensuses:

– Two workshops entitled *Strategic Planning Workshop of the Forum of Traditional Communities (SP FTC)* were carried out in the context of the Angra dos Reis, Paraty and Ubatuba Forum of Traditional Communities (FTC), exclusively with the participation of representatives of the FTC and moderators. The first workshop took place on July 11 and 12, 2013, at the Serra do Mar State Park Training Center, at Ubatuba, São Paulo, and the second on August 8 and 9, 2013, at the same venue;
– Three workshops regarding *Multicenter Validation of theoretical/conceptual and methodological background, methods, technologies, parameters and indicators for the characterization, analysis, monitoring and evaluation of experiences of Sustainable, Healthy Cities/Areas*. The first was carried out on March 27 and 28, 2013, at the Ministry of Health, in Brasília, with the participation of researchers from Fiocruz and the Public Health and Social Development Center of the Pernambuco Federal University and representatives from the Ministry of the Environment and of the Department of Surveillance on Environmental Health and Worker Health, of the Ministry of Health. The second workshop was carried out between June 3 and 7, 2013 at Praia do Sono, Paraty, Rio de Janeiro, with the participation of researchers from Fiocruz and Pernambuco Federal University, representatives from FTC and the community, of the environmental agency of the Brazilian government—the Chico Mendes Institute for Biodiversity Conservation—and of the Rio de Janeiro state government—the State Institute of the Environment. The third workshop took place between October 21 and 25, 2014, in Paraty, with the participation of researchers from Fiocruz, representatives of the FTC and professors of the Center of Functional Ecology of the Coimbra University, the Center for the Study of Migrations and Intercultural Relations of the Open University, Portugal, and the University of Chile;
– Four workshops were carried out in the context of the *Angra dos Reis, Paraty and Ubatuba Center for Regional Integration of Sustainable and Solidary Development (CRI)*. The first took place on October 19, 2013, at Quilombo Campinho da Independência, in Paraty, Rio de Janeiro, with the participation of representatives of the FTC, of OSHT, of the municipal governments of Ubatuba and Angra dos Reis, of the National Indian Foundation and of the Angra dos Reis Municipal Health Council. The second was carried out on December 13 and

14, 2013, also at Quilombo do Campinho, with the participation of representatives of the FTC, of OSHT, of the municipal government of Ubatuba, of the National Health Foundation, of the Ministry of Health and of the Ministry of the Environment. The third took place on February 3, 2014, at Ubatuba's Health Secretariat, with the participation of representatives of the FTC, of OSHT and of the municipal governments of Ubatuba, Angra dos Reis and Paraty. CRI's fourth workshop was organized on June 4, 2014, at Casa da Cultura, in Paraty, Rio de Janeiro, with the participation of representatives of the FTC, OSHT and of the municipal government of Paraty and National Health Foundation;

– Three *Strategic Planning Workshops of the Observatory of Sustainable and Healthy Territories of Bocaina (SP OSHT)*. The first took place on February 11 and 12, 2014, at Quilombo do Campinho, with the participation of representatives of Funasa, Fiocruz, the FTC, the Ministry of the Environment and NGOs Verde Cidadania and Ipema. The second was carried out between June 2 and 7, 2014, at two different moments, one at Quilombo do Campinho and another at Praia do Sono, with the participation of representatives of National Health Foundation, Fiocruz, the FTC and the environmental agency of the Brazilian government, the Chico Mendes Institute for Biodiversity Conservation. The third occurred between July 15 and 29, 2014, at Quilombo do Campinho, with the participation of representatives of Fiocruz and the FTC;
– Three workshops were carried out in the context of the Strategic Direction Center (SDC) of the OSHT. The first took place on August 15, 2014, the second on September 14, 2014, and the third on October 30, 2014, all at Quilombo do Campinho, with the participation of representatives of Fiocruz and the FTC, which are part of OSHT's group of researchers.

Two other seminars in the context of the *Ibero-American Network of Sustainable Territories, Development and Health IAN-STDH* were also organized by a number of institutions and researchers from Bolivia, Brazil, Chile, Colombia, Spain and Portugal, which OSHT participates on through Fiocruz/Brazil. The first was carried out on April 28 through 30, 2014, in the city of Porto, Portugal, and the second on September 9 through 12, 2014, in Rio de Janeiro, Brazil.

The findings were triangulated and analyzed based on the Matrix for the Evaluation of the Effectiveness of Territorialized Sustainable Development Strategies introduced in Setti and Galo (2013). To be taken as evidence, findings were analyzed as to the following aspects: (a) whether they fit the analytical profile; (b) whether they had to do with the impact of CC on the health of traditional communities; and (c) whether they had to do with governance mechanisms to address CC.

Findings and Discussion

As to the reduction of vulnerabilities, the project took local needs into consideration, but in the perspective of traditional communities (indigenous, quilombolas and caiçaras), which consider having rights over and the preservation of the land as priorities for the maintenance of their culture and ways of life, which are directly dependent on natural resources.

> Currently, the community at Quilombo do Campinho (. . .) practice traditional agriculture. They plant manioc, beans, corn, roots and fruit (member of the FTC at the Multicenter Validation Workshop 2014).

> The land is a foundation on top of which connections can be built for the development of the communities (member of the FTC at CRI 2013).

The Constitutional rights of indigenous people, quilombolas communities and other traditional populations in the country are being put at risk in the interest of the greed of economic and political sectors in the country. An example of that is what the rural bloc is doing at the Brazilian Parliament against the rights of traditional communities and in favor of the expansion of agribusiness, whose consequences may be irreparable and cause human and cultural losses, as well as losses in biodiversity (Costa and Oliveira 2011).

The Federal Constitution assures the right to land property to indigenous communities in its art. 231 and to quilombola communities in art. 68 of the Transitional Constitutional Provisions Act (DOU 1988). However, Constitutional norms will not assure rights if the State does not act to enforce laws and amendments.

> Traditional communities have specific characteristics, like the fight for staying in their land. Although there is enough legal background, it seems that policies and laws are not reaching those areas. Traditional peoples are being decimated (member of the FTC at CRI 2013).

In that sense, the FTC adopted the Preserving is Resisting Campaign to claim the rights of traditional peoples to the land, as well as to strengthen them and promoting adhesion to the movement the legalization of property.

> The "Preserving is Resisting" campaign seeks to assure the access to the land, to advance the legalization of property, to give visibility to traditional ways of life and to implement different public policies (excerpt from Multicenter Validation Workshop 2014, p. 14).

The OSHT trained leaders to intervene in environmental agencies and at the judiciary level during conflicts and in the land legalization process, as well as promoting the interinstitutional, intersectoral and interscale coordination established in the Forum of Traditional Communities and the Center for Regional Integration of Sustainable and Solidary Development (CRI).

> To prepare the FCT for managing collectively the recategorization of the Juatinga Ecological Reserve (extracted from CRI 2013, p. 7).

> Expanding the FTC's governability, articulating with other social actors from different levels and different instances and developing an agenda collectively (extracted from SP FTC 2013, p. 17).

Besides the legalization of the land where traditional communities live, there are other land-related issues: real estate speculation because of the region's strong touristic appeal, the construction of marinas and condominiums of various standards for second homes in protected areas, precarious settlements in the periphery of cities, conflicts with the people living in Conservation Units, as well as the precarization of public policies in the fields of housing, education and health.

> The region is socioenviromentally vulnerable due to climate issues, pressures concerning land and real estate speculation and the precarization of public policies in the fields of education, sanitation, health and food sovereignty (extracted from CRI 2013, p. 2).

The above described situations have been described for other social and social contexts (Miranda 2012).

The environmental risks that influence the health of the population are complex and demand holistic approaches that are based on the territory, that includes participation and intersectoral articulations to promote health. In this context, in order to decrease health inequities, the National Integral Healthcare Policy for Rural, Forest and Riverside Populations was established in articulation with the local production of phytotherapeutic drugs at the Itaboraí Palace, in Petrópolis, in the state of Rio de Janeiro (the National Policy for Medicinal and Phytotherapeutic Plants) (DOU 2011).

> Implementing the National Integral Healthcare Policy for Rural, Forest and Riverside Populations in articulation with the local production of phytotherapeutic drugs carried out by Fiocruz at the Itaboraí Palace (extracted from CRI 2013, p. 11).

Moreover: adopting the "valorization of traditional practices and knowledge, promoting people's acknowledgment of the subjective, collective and social dimensions of these practices and the production and dissemination of the knowledge of traditional populations" (DOU 2011).

> Strengthening the way of life of traditional communities, promoting the sustainable use of the land and improving the access of communities to goods and services (extracted from SP FTC 2013, p. 2).

Extreme events produce a greater impact on the sectors that are more heavily influenced by or depend more on the climate, like water, agriculture, health and tourism (UNISDR 2013), all of which have to do with the ways of life of traditional communities, since they rely on family agriculture, artisanal fishing and, more recently, tourism. These activities resisted the pressures of the hegemonic model of development, but were also weakened by legal restrains.

> (. . .) a significant decrease in family agriculture in the region in the last 10 or 20 years because of their difficulty in obtaining environmental permits to plant in Conservation Units (extracted from SDC 2014, p. 27).

Moreover: the promotion of agroecology and the production of organics were established as strategies to assure the access to healthy foods—which is assumed in the idea of food and nutritional safety—to stimulate environmental recovery and to manage agroecosystems sustainably.

> Developing strategies to protect the Atlantic forest based on local production arrangements, on caiçara methods of management (. . .), on agroecology (extracted from SDC 2014, p. 27).

On the other hand, these activities should promote their productive participation in the society, generating income and strengthening the local economy (Alves and Botelho 2014). Therefore, the implementation of the National Policy of Agroecology and Organic Production was articulated in the municipalities of Angra dos Reis, Paraty and Ubatuba, developing a network for the production and distribution of food.

> Consolidating the regional plan for sustainable, solidary development, coordinating the three municipal governments (. . .), focusing on traditional communities (. . .) for the implementation of the National Policy of Agroecology and Organic Production (extracted from CRI 2013, p. 9).

To begin the implementation of the National Policy of Agroecology and Organic Production, experiences in agroecology were collected with the social technologies and traditional knowledge (Alves et al. 2012, 2013; Santos and Meneses 2013) they employed. This Plus, farmers and local leaders in Health and Rural Sustainable Land Development were trained based on the pedagogical method of the ecology of knowledge, concentrating on the major challenges to be faced in the transition for a cooperative, fair, sustainable and healthy model of development.

> Cataloging community knowledge; social technologies and the systematization of their use (extracted from the Multicenter Validation Workshop 2014, p. 22).

> The training of leaders in Health and Rural Sustainable Land Development focusing on the agroecological transition and health promotion (extracted from CRI 2014, p. 9).

Other elements that can also threat food safety are water shortages and worse access to water of good quality, both of which can be aggravated by CC, leading to an increase in cases of diarrhea and worse nutritional conditions, especially of children (IPCC 2014).

More specifically to this study, the precariousness of houses and the absence of a public system (of even at the level of the community) dedicated to supplying and treating water, collecting and treating sewage and properly disposing of garbage contaminated surface water and, in some cases, underground water as well, where water is collected in the region, posing an important risk factor to the health of the population. Many traditional communities can only be accessed by trail or boat, and water is collected directly from rivers with no treatment and sewage runs into cesspits or, less commonly, septic tanks. At the communities of Praia do Sono and the Quilombo Campinho da Independência, at Paraty, the water is contaminated and unfit for human consumption.

> The analysis of water samples (. . .) of the rivers where water is collected at Praia do Sono and at the Quilombo do Campinho accused the presence of fecal coliforms and *E. coli* (extracted from SDC 2014, p. 29).

Water resources are organized by drainage basins throughout Brazil. The Drainage Basins Committees are collegiate bodies created to manage their use in an integrated and decentralized manner, with the participation of the society (Jacobi and Fracalanza 2005). Therefore, to include water safety in the planning of the development of resilience to CC, and, thus, reduce health risks, a few efforts were established to support the FTC to act with the Drainage Basins Committees, such as the creation of the Sanitation and Water Quality Work Group.

> To strengthen the FTC to effectively participate in the Drainage Basins Committee (extracted from CRI 2014, p. 26).

> Sanitation and Water Quality Work Group (. . .) carry out actions to assure the improvement of the quality of the water consumed by traditional populations (extracted from SDC 2014, p. 29).

One of the major challenges for the management of water—and especially of the water supply and sanitation systems—is finding proper solutions that promote balanced adaptations to CC and address the foreseen variability in the availability of water, assuring its many uses and protecting public health.

Recognizing the plurality of knowledges and the need to valorize them (Alves et al. 2012, 2013; Santos and Meneses 2013) so that emancipatory actions can be carried out, technological solutions that take the local context into consideration were adopted, integrating different knowledges (traditional, technical and scientific) and incorporating local practices (composting toilets, septic tanks and root zones) developed by the Caiçara Permaculture Institute.

> Implementing an ecological sanitation system, built by ecosanitary modules (septic tanks, anaerobic filters, filtration ditches and root zones) (extracted from CRI 2013, p. 5).

Instead of the conventional linear systems of sanitation, it was suggested that a close-cycle system was used, returning nutrients, which can be used as fertilizers, and water, as irrigation or back to watercourses, back to the environment.

> A project of ecological sanitation (. . .) using social technologies (. . .) to create a showcase of an integrated perspective on sanitation, with the goal of using waste for composting, for producing manure and using in at the restaurant's vegetable garden, among other initiatives (extracted from CRI 2014, p. 1).

Permaculture seeks to reduce energy waste, rationalizing our impact over the ecosystem and transforming waste—human waste, more specifically—into a resource, using more sustainable and ecologically-aware designs.

> The goal is to use local materials, such as, for instance, a root zone formed by banana trees, based on the principles of permaculture in a process that involves local builders into the discussion of a solution (extracted from Multicenter Validation Workshop 2014, p. 13).

The ecological sanitation project gained scaled after the involvement of the municipal government of Paraty, which wants to implement it at Quilombo do Campinho and Praia do Sono, as well as expand it to municipal public schools until universalization, especially in traditional communities.

> Term of Cooperation between Fiocruz and the Municipal Government of Paraty (. . .) regarding the implementation of ecological sanitation (extracted from SDC 2014, p. 6).

The protagonism of representatives from the FTC and the communities, some social researchers, giving traditional culture and knowledge their proper value in the suggested solutions and in the establishment of mechanisms to support social projects that focus on emancipatory education aiming at a transition to a cooperative, fair, sustainable and healthy model of development.

> Stimulating institutional action in the region and the replication of experiences occurred elsewhere; strengthening the capacity of the FTC to participate in decision-making processes (extracted from the Multicenter Validation Workshop 2014, p. 11).

> (. . .) training and support, as well as persuading projects that are capable of changing their economic and social rationales (extracted from Multicenter Validation Workshop 2014, p. 14).

Considering, especially, territorial intersectoral and interscale factors and their expression in territorialized agendas, whose governance and strategic management—chiefly regarding the evaluation of effectiveness—the following should be highlighted:

> Based on the idea of sustainable, healthy territories to suggest technologies, methods, parameters and indexes of characterization, analyses, monitoring and evaluation in a multicenter validation process uniting researchers from Fiocruz, social researchers and members of other institutions (extracted from Multicenter Validation Workshop 2014, p. 15).

The Project will always be situational, which demands an analysis of the strategic context, of the balance of power over the region and the competencies required for its implementation, that is, the mechanisms for governance and strategic management that reflect (1) the agenda that was agreed on based on a hierarchy of priorities and collectively-established points of greater concern focused on their resolution; (2) the mode of governance established with the FTC and other actors; (3) the cognitive/operational flexibility of the project to include different demands; and (4) the strengthening of the FTC (Setti and Gallo 2014).

> Promoting the integrated action of social actors, expanding the participation of the community and agreeing on a model of sustainable community are considered means of governance (extracted from the Multicenter Validation Workshop 2014, p. 7).

Integrality materializes in the involvement of actors of different instances, scales and areas to establish priorities for intersectoral action, integrating the pillars of sustainable development and producing an impact on all levels of the social determinants of health (Gallo and Setti 2014).

> The Regional Integration Center (CRI) is composed of six representatives of municipal governments and six from the forum of traditional communities. (extracted from CRI 2013, p. 21).

> Articulation with other sectors of Fiocruz; interchange with the Climate and Weather Observatory, as well as with the Center for the Study and Research of Emergencies and Disasters of Fiocruz (extracted from SDC 2014, p. 3).

As to autonomy, the social participation component is evident in all of the project's management phases, especially regarding strategic decision-making, which strengthens the empowerment of individuals and communities, which also materializes in the goal to increase the FTC's management capacity—supporting their strategic management—through strategic planning and monitoring workshops, in the training of leaders and the expansion on the knowledge available on the territory (Gallo and Setti 2014).

> Development of a new knowledge generation rationale, in coordination with the needs of the territory and including the participation of various actors that work in it (extracted from Multicenter Validation Workshop 2014, p. 15).

> The mobilization to demand effective responses from public authorities, especially environmental authorities, to commitments made in the past (extracted from SP FTC 2013, p. 19).

Conclusions

This study makes it evident that the actions promoted by the OSHT do interfere in the governance of and adaptation to CCs (in areas such as the health and well-being of traditional communities, the reduction of vulnerabilities, as well as the mitigation of and adaptation to environmental risks) through its strategies and a territorialized agenda.

Climatic Governance and the Adaptation to CC should be central to the idea, the structure and the dynamics of Sustainable and Health Territories and its components related to the mitigation of impacts, the reduction of vulnerabilities, the problematization of the region's needs in order to attain sustainability and the health and quality of life of traditional communities of the Mosaico Bocaina. As to the latter, "adaptation to CC" (also in the sense of an increase in the frequency and intensity of extreme events) clearly relates to public health and environmental issues.

As to social and environmental practices, the cataloguing of traditional knowledge (also called "ecological knowledge"), including their dissemination and the social recognition and generational reproduction of the knowledge of these traditional populations definitely adds value to the establishment of strategies and good environmental governance practices. The participation in decisions and the collaboration in the processes, in the establishment of policies that will be implemented in the region promote a decrease in inequality, sustainable practices (agroecology, community-based tourism and social technologies) which, not only define standards for adaptation (water stress, sanitation, management of water resources) and climatic governance, but also are sustainable and promote socioeconomic development through the inclusion of traditional communities, as well as through the promotion of their health and sustainability.

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Chapter 20
Observatory of Sustainable and Healthy Territories (OTSS) GIS: Geo-Information for the Sustainability of Traditional Communities in Southeastern Brazil

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Abstract The social practices of traditional communities have low environmental and health impacts. This is important to minimize climate changes and guarantee the health of communitarians. The sustainability of traditional communities has a direct connection with the knowledge about their territories and the constitutive social practices of their territoriality. Building a Spatial Database generates knowledge about their territories and enables carrying out a range of geospatial analyses to support communication and decision making. This paper describes the first step in building a Geodatabase to support the management, planning and communication actions within OTSS, a partnership between FIOCRUZ and the Traditional Communities Forum of the Municipalities of Angra dos Reis, Paraty and Ubatuba in Brazil. Three lines of work were developed: (1) Geodatabase Design—geodata was arranged in different scales, comprising basic and thematic secondary data, as well as primary data relevant for the management and the political action of the communities. The information contained in the system was selected together with representatives from the communities. (2) Geodatabase Analysis and

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This article presents part of these project results: (1) Sustainable Territories, Promoting Equity and Health in Traditional Communities of the Bocaina Mosaic; (2) Sustainable and Healthy Territories: sewage treatment system deployment in the Community Caiçara of Praia do Sono, located in Paraty, Rio de Janeiro, both funded by Notice 2/2012 of the National Health Foundation—Funasa; and (3) Observatory of Sustainable and Healthy Territories of Bocaina, funded by the Cooperation Agreement between Funasa and Oswaldo Cruz Foundation—TC n. 75/2013.

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Management—continuous data input from traditional populations and technical teams was made. Analysis of the geodata provided solutions to spatial questions posed by project members and by communities, especially about territorial disputes. (3) Geo-information Availability—preparation of maps, charts, spatial files and other media to support the management of the project, the traditional communities and the implementation of correlated projects.

Keywords Traditional communities • Geographic information systems • Knowledge ecology • Traditional knowledge • Observatory of sustainable and healthy territories

Introduction

One of the cyclical crises of capitalism began with the Oil Shock of the early 1970s. The Welfare State model developed after World War II was replaced by the neoliberal model, which predominated in the 1980s and 1990s and not only drastically reduced the social protection system, but also promoted economic deregulation.

At the end of the period, after the living conditions of large populations significantly worsened, policies regarding economic-financial regulation and social protection policies were reinstated. Consequently, the international agenda of the first decade of the twenty-first century targeted social policies, health taking the center stage (Belinky 2012; Buss et al. 2012).

Meanwhile, after the 1970s, international environmental policy gained great prominence. "The Limits to Growth," the Club of Rome report that was launched shortly before the United Nations Conference on Human Environment, organized in Stockholm, in 1972, was one of the first documents to place sustainability at the center of the international agenda.

It had a great impact on the discussions, which established the implementation of a global management process for environmental problems, which culminated in the creation of the United Nations Environment Program (UNEP), whose goal, among others, was to redefine the idea of "development."

UNEP created the World Commission on Environment and Development in 1987. One of its earlier works was the report "Our Common Future," which introduced the now classic concept of "sustainable development" as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

In search for human development alternatives, a set of initiatives organized by international organizations consolidated sustainability as a priority in the global agenda. The Earth Summit (1992), the Earth Summit 2002 (the Rio + 10), the United Nations Conference on Sustainable Development 2012 (the Rio + 20) and the United Nations High-Level Panel on Climate Change should be highlighted.

The process culminated in the Post-2015 Development Agenda, which has been establishing a set of sustainable development goals that are to be approved in the General Assembly of the United Nations on September, 2015.

Because of this level of centrality of the sustainability agenda, health is faced with "*the challenge to be incorporated into an inter-sectoral agenda capable of addressing the social determinants of health, which are directly related to sustainable development*" (Gallo and Setti 2014). This requires understanding this agenda as a venue for the confrontation between projects which, therefore, could both produce emancipation or reproduce a structure of domination (Gallo et al. 2012).

If, on the one hand, there is consensus on the central role of sustainability and on the three pillars of sustainable development (economic development, social equity and environmental protection), on the other hand, however, there is great political dispute concerning how to attain sustainable development, which uncovers different—and, often contrasting—worldviews (Drexhage and Murphy 2010; Feola and Bazzani 2002).

Conventional Technologies and Social Technologies

The most important point of contention is the organization of production and consumption. Some groups defend that the capitalist mode of production has to continue, confident that technological development, mainly, will be able to assure the sustainability of development.

Others say that sustainable societies can only exist if production and consumption structures are changed and linked to well-being and values such as happiness, cooperation and solidarity. This dispute materializes in the proposals of the two groups, from their epistemological views to their operations. Green economy, low-carbon production models, high efficiency in the use of resources, human development, carbon markets, rationalization of resources, social integration, protection and strengthening of biodiversity and of the services provided by ecosystems are a few of these strategies.

The centrality of technology—especially regarding science—in the reproduction of the current hegemony has been greatly demonstrated (Adorno and Horkheimer 1985; Habermas 1985). The consequence is that conventional technologies (which are hegemonic today) serve mainly the interests of private companies, especially large corporations, having been very efficient to maximize profits, but not to promote social inclusion and environmental sustainability (Dagnino 2004) (Table 20.1).

Therefore, to be truly emancipatory, the sustainability agenda should prioritize participatory solutions that are not only based on the ecology of knowledge, but also capable of developing innovative policies and technologies dedicated to promote environmental sustainability and social inclusion, which have increasingly been denominated "social technologies." Social technologies are "*replicable products, techniques and/or methodologies developed in integration with communities and representing effective solutions for social transformation*" (www.rts.org.br).

Table 20.1 Characteristics of conventional technologies and the causes and/or consequences that make them unfit for promoting social inclusion and environmental sustainability

Characteristics of conventional technologies	Causes and/or consequences
Save manpower	Reduce the number of people working without reducing productivity; increases profits
Optimal, growing scales of production	More pressure on workers and natural resources
Environmentally unsustainable	Disregard environmental degradation as a cost of production, considering it an externality
Intensive in synthetic products manufactured by large companies	Make it harder for them to be used by communities or small companies
Are preferably driven toward high-yield external markets	Make it impossible for them to be used by communities or small companies
Monopolized by large multinational companies	Make it impossible for them to be used by communities or small companies
Require workers to be coerced	Reduce productivity and creativity
Are segmented	Do not allow producers to control the result of their work
Are alienating	No not make use of the true potential of workers

Based on Dagnino (2004)

Although some authors consider this definition of social technology to be excessively limited (Dagnino 2009), it is possible, however, based on this definition, to build a more encompassing concept, both theoretically and practically speaking, based on a few parameters, as described by Novaes and Dias (2009): "*1) being adapted to small producers and low-income consumers; 2) not promoting a capitalist form of control, hierarchy, segmentation, or domination of workers; 3) being oriented toward meeting human needs (producing use value—"the world is not a product," as we are reminded by the slogan of the World Social Forum); 4) incentivizing the potential and creativity of direct producers and users; 5) making ventures such as popular cooperatives, agrarian reform settlements, family agriculture and small companies economically viable. Finally, social technology has a closer connection to the reality of local societies, and produces solutions that fit specific contexts better*" (Novaes and Dias 2009, p. 19).

Different processes of technological production fit that profile without ignoring one crucial aspect of social technology: making social ventures economically viable (Dagnino 2009).

These technologies tend to be marginalized for being associated to "*popular, lay, plebeian, peasant, indigenous knowledge (...), which are considered irrelevant or incommensurable for being beyond a world of true or false knowledge*" (Santos 2007, p. 3). They are invisible because they derive from forms of knowledge (like that of traditional communities) condemned to invisibility by western thinking (Santos 2007).

The hegemonic scientific discourse tends to consider conventional technologies as the only valuable technologies, which highlights the exclusion of social technologies and the actors that generate them (Dagnino 2009). This poses a theoretical and practical challenge: they need to be proven doable and viable based on concrete experiences, which will demand the implementation, management and evaluation of territorialized agendas (Gallo and Setti 2014).

As said, it is important to legitimize social technologies by making social ventures economically viable. In many cases, this implies that social technologies cannot neglect hegemonic technologies. However, conventionally-produced knowledge and technology should be adapted, whenever necessary, to the social form of knowledge generation, as long as it does not imply subverting the social forms of production related to these technologies.

Social Cartography and Social Technologies

Social technologies have necessarily to do with the territory, which for needs are established and solutions are developed. This living territory materializes the contradiction between the dominant mode of production and new rationalities. Territorialization tools support territory-based actions. Disputes over their reproduction, therefore, take place at their level (Santos 2003; Gallo and Setti 2014).

One of these tools—the Geographic Information System (GIS)—was developed, above all, because of the geopolitical interests of the governments and strategic networks. GIS was, originally, a conventional technology that supported the hegemonic rationality and was often use for war and to maximize profits. However, GISs have been increasingly been used by solidarity networks and social ventures, a method called Social Cartography (Yamamoto and Mcclure 2011).

GISs are based on the use of computers, which allow the input, the management (storage and retrieval), the use, analysis and display of georeferenced data (Aronoff 1989).

These systems can deal with a large volume of very complex data, allowing information to be better manipulated (Menezes and Fernandes 2013).

The capacity of these systems to store, process and disseminate cartographic information facilitate the planning and management of areas, including those that are not the object of territorialized actions, which are more typical of social technologies. Moreover, GISs are very communicative and capable of expanding the knowledge of communities on geographic areas, which would directly improve education and social organization (Coutinho 2011).

Despite its potential, for a long time, GISs were restricted to the territorial planning and management carried out by companies and government and research institutions. Only in the 1990s, researchers started to put forth a theoretical criticism of the hegemonic power relations linked to the GISs. They discussed, among other issues, the antidemocratic nature of the GISs and their ability to promote social surveillance—which strengthened the relationship between knowledge, power, regulation technologies, knowledge engineering and population control (Weiner et al. 2011).

To respond to such criticism, new studies discussed the access, the ethics and the values of GISs, suggesting a new bottom-up model—including the participation of communities—as opposed to the traditional top-down model (Weiner et al. 2011).

In this context, actions were carried out in poor communities in South Africa, aggregating methodologies to the GISs that allowed communities to participate in the planning and management of the territory, which empowered people to participate in political discussions, in analyses, as well as in the development of their own agendas, which were dedicated to their own territories and interests (Cinderby 1999).

Cinderby (1999) managed to establish two fundamental aspects that the development of GISs need to have to actually empower communities. First, they need to be developed from the bottom up and incorporate local interests and knowledge to the spatial database. Second, it should be able to incorporate a top-down model to this foundation of geospatial information, since it strengthens the database and allow errors in information pools to be identified, corrected and updated based on the needs of the communities.

This mode of GIS development strengthens the autonomy of communities, allowing them to better know and represent their territories, expanding their governance and management capacities.

Development of OTSS's GIS

Such conceptual framework is the basis of the GIS of the OTSS. The OTSS is a joint initiative of the Oswaldo Cruz Foundation (Fiocruz) and the Forum of Traditional Communities of the Municipalities of Angra dos Reis, Paraty and Ubatuba (FCT), where around 50 traditional communities live (ethnic groups formed by caiçaras, quilombolas and indigenous populations) (Fig. 20.1). The goal is to strengthen these communities, valorizing their knowledge and the development of territorialized social technologies.

Methods

Both OTSS and this paper are based on action research, assuming a participatory investigation method in which getting closer to the object of study is part of the process. Methodologically speaking, the goal is both to produce knowledge and to establish ways to act upon reality (Ketele and Roegiers 1993; Engel 2000).

Therefore, it assumes the interaction between scientific and popular knowledge, considering the latter fundamental for acting on reality. Popular knowledge cannot be considered merely "intuitive" or "subjective" (that is, of lesser value). This attitude makes territorialized experiences (and their agents) invisible, deterritorializing bodies of knowledge that could have a real impact in reality (Santos 2007).

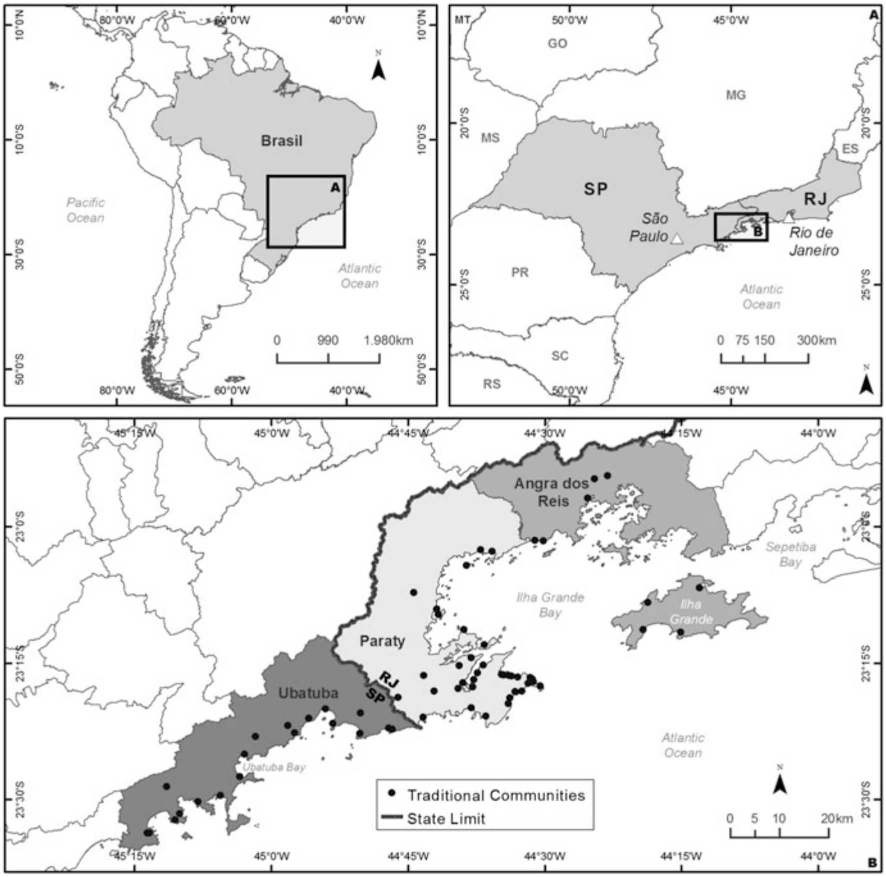

Fig. 20.1 Study area with traditional communities. Source: ArcWorld Supplement, ESRI (country boundaries); Brazilian Continuous Cartographic Base at Scale 1:250,000 (version 1.0), IBGE; Observatório de Territórios Saudáveis e Sustentáveis da Bocaina (traditional communities locations)

Therefore, OTSS's GIS—whose goal is the formation of a Geospatial Database (GSDB) capable of producing quick responses to geographic issues of different levels of complexity—is being developed based on two sets of complementary actions, as recommended by Cinderby (1999).

On the one hand, a complete survey and adaptation of the data produced by public and private institutions in Brazil is to be carried out. The survey is being done through the internet, since these institutions make their data available on their websites.

On the other hand, primary data and analyses on traditional communities are being developed with their participation using a bottom-up model in which their representatives and the researchers establish what they want to be mapped, how they will be represented and the level of access to information on the territory provided to different actors. This form of social cartography assumes that communities want not only to portray the physical space where they reside, but also to reaffirm their life styles and their collective identities (Acselrad 2008).

For such, the process of social cartography is planned and structured with representatives and social organizations of the communities, because they are the ones to establish the goals, the scope and the actual pieces of information that will be included in the mapping. At this moment, the OTSS GIS is working with general information for 53 communities (their locations have been pinpointed) and with specific information about Trindade (a caiçara community).

Every information on localities and practices included on the maps have names and symbols indicated by the communities and respect the categories established by them.

The information produced through these two processes are undergoing cartographic transformation to better adapt it to a unified geodetic system (Universal Transverse Mercator Projection—UTM and SIRGAS2000) that better represents South America.

Based on the GSDB, maps and analytical information are produced to support the activities of traditional communities and represent their territories according to their needs.

Evaluation and monitoring models developed by OTSS are being used to test whether this form of production and representation of information is in line with its goals—that is, whether the development of OTSS's GIS has been adhering to the adopted analytical references (equity, autonomy and sustainability) based on evidences of effectiveness (Gallo and Setti 2014).

Results and Discussion

Although the development of OTSS's GIS is still at an early stage, results have shown it to adhere to the evaluative references.

A large part of the information available on the internet that would be relevant to territorial actions capable of supporting the activities of traditional communities were adapted and gathered.

A GSDB with that information is being developed over a pre-established directory structure (Fig. 20.2). The basic scale interval for the cartographic information is between 1:2000 and 1:250,000 as to include both the information produced in the field with communities and the information made available by institutions.

The Traditional Communities' Representation of the Territory

At the current level of development, OTSS's GIS is already capable of supporting actions in traditional communities, including the delimitation of the boundaries of

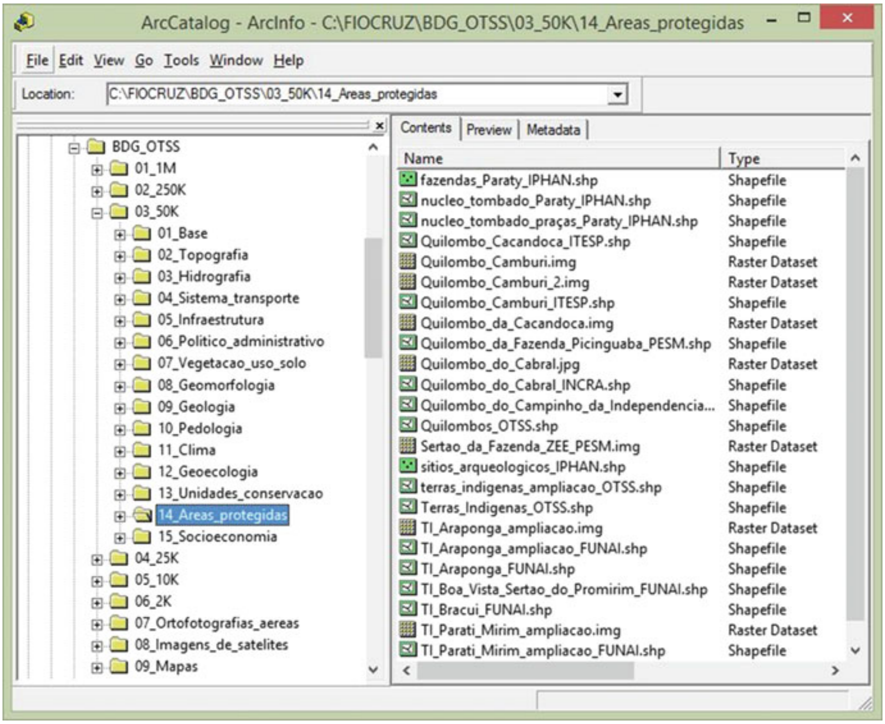

Fig. 20.2 The structure of the Geospatial Database

12 communities that have or are in the process of getting legal title to the land. The mapping can also help other communities get it as well. Such territorial disputes involve caiçaras, quilombolas and indigenous populations that reside in OTSS's working area, and include very important conflicts between communities, government institutions and the private capital (Porto et al. 2013).

In Brazil, unlike the quilombolas and indigenous populations, there is no legal instrument to regulate the drawing of borders for the caiçaras, even though they do have traditional life styles as defined by the National Policy for the Sustainable Development of Traditional Peoples and Communities (Federal Decree 6.040/2007). Therefore, often there are conflicts regarding their demand for land for their traditional activities.

This has been observed in OTSS's working area, where the territories of caiçara communities overlap those of integral protection areas. The law states that no natural resources from these units can be used and that dwelling within them is prohibited. The overlapping of the two areas restricts and often makes the way of life of these caiçara communities impossible. This causes conflicts to emerge, and only the resistance and organization of these communities prevents them from being thrown out of their ancestral land.

Moreover, since there is no boundary delimitation, the caiçara land has been coveted by real estate capital, as the landscape is beautiful with mountains and beaches and is overpriced because of its coastal location between the two major Brazilian cities, Rio de Janeiro e São Paulo.

On the other hand, the five quilombola and seven indigenous communities own the title of their ancestral territories, which are still to be delimited by the government. However, at the region there are also quilombola and indigenous lands overlapped by integral protection areas, which were created without previously consulting these populations, producing the same restrictions and conflicts the caiçaras have been facing.

The drawing of boundaries for these territories not always considers the full physical space used by these populations to carry out their traditional activities. Often, the official demarcation is restricted and makes it difficult for them to maintain their life styles. Their land is also targeted by the private capital.

Therefore, there are serious conflicts involving the land claimed by traditional communities, which generate conflicts between these communities and both the integral protection areas and the real estate capital.

OTSS's GIS is an important tool for supporting these three traditional ethnic groups in the fight for their territories. It provides them with territorial representation in maps that were built based on their knowledge and interests, which can be introduced and discussed at negotiation tables with other actors in the region at a stronger standpoint because they now can show their reality and priorities better.

Moreover, since territorial representation of traditional communities in OTSS's GIS is based on the knowledge of those who actually inhabit the land, this tool allows that the two sides of the border described by Santos as that beyond which reality is invisible for western society (like the knowledge of traditional communities) dialogue to one another (Santos 2007).

Since the invisibility of traditional communities is the reflection of social interests and relations of power, it entails conflicts, which makes this dialogue difficult. Therefore, representing the interests of traditional communities in the territory through maps "forces" this dialogue, but may worsens conflicts.

That happens especially because that form of representation of the territories of traditional communities includes areas in which these communities carry out activities that are fundamental to their ways of life. Therefore, the maps produced based on OTSS's GIS will include social cartography work and introduce the communities' territory of social reproduction. Therefore, it will comprise the places where communities use the social technologies that they developed based on their knowledge.

Since the social technologies derived from traditional knowledge are not considered relevant by the dominant form of thinking, the territorial expression of these technologies in the maps tends to worsen conflicts. However, it makes these communities and social technologies appear in the territory and, thus, empower them, expanding their management capacity and their dialogue with other actors. In the future, OTSS's GIS will also provide tools for two solidarity networks that are currently under development and dedicated to supporting the productive arrangements promoted by OTSS's Incubator of Social Technologies: community-based tourism and agroecological production.

The Trindade Case

One example of this process involved the caiçara community of Trindade, in the municipality of Paraty. The community survives on artisanal fishing, using terrestrial and marine areas and resources, which are important sources of food and income and crucial for the caiçara culture. However, one of their most important areas for artisanal fishing is part of the Serra da Bocaina National Park (PNSB), an integral protection area. Although these communities lived in the region for many generations before the creation of the protection area, the overlapping areas have been causing conflicts between community members and the management of the PNSB, including the application of penalties (Porto et al. 2013).

The fishermen of Trindade placed three of their five fixed trap nets there because the area is protected from the wind and the tides, which allows them to fish there most of the year, including in bad weather. Studies have shown that the fish captured there are just passing by, they are not reproducing or spawning at the sites (Bussolotti 2010).

However, the PNSB insists on considering the artisanal fishing carried out at the Trindade a predatory activity. The argument is that they could only allow it for caiçaras that fish exclusively. However, the essence of the caiçara people is to work on many activities at once. At Trindade, tourism and fishing are the main economic activities. Fishing is important for the food security of families. It is also a source of subsistence, not necessarily a commercial activity.

The Chico Mendes Institute for Biodiversity Conservation (ICMBio), which is responsible for the management of PNSB, has been directly involved in the conflicts with the caiçara community at Trindade.

The Public Prosecutor's Office (*Ministério Público Federal*—MPF—in Portuguese) is the Brazilian institution that protects the collective rights of the society and, in this case, should mediate the conflict between traditional communities and the protected area.

The OTSS has been working on these conflicts, one of the issues discussed at the Socioenvironmental Justice Seminar, organized in April, 2015, by the OTSS in partnership with the MPF and the Mosaico Bocaina (an entity formed by close or juxtaposed protected areas and social organizations to discuss territorial management in the Bocaina Range, which comprises the OTSS study area).

In December, 2013, representatives of Trindade's Association of Boatmen and Fishermen (ABAT), designed a map with the areas associated with artisanal fishing at the Trindade surroundings (Fig. 20.3), including areas that overlap the PNSB. They introduced it in a meeting with the National Park's Consultative Council in hope of demonstrating the importance of the activity and what it represents to local families. As a result, they were able to keep artisanal fishing from being considered a predatory activity at PNSB's Management Plan.

Following that, ABAT and OTSS continued to work on social cartography, linking georeferencing techniques and traditional knowledge, which resulted in a map of artisanal fishing activities carried out at Trindade (which was still being

Fig. 20.3 Map with the areas associated with artisanal fishing at the Trindade surroundings, made by members of Trindade community

made when this paper was written), considering all areas—marine and terrestrial—used. The map was used to support the Trindade caiçaras argument during the Socioenvironmental Justice Seminar, which shows that the community needs to keep working on territorialized actions and to apply related social technologies to them. Moreover, the case also demonstrates that overlapping the PNSB to territories where these practices take place is problematic.

The map, therefore, supported and helped the argument of the Trindade caiçaras and stimulated the community's dialogue with other social actors, breaking from abyssal thinking and going beyond the border that makes these communities invisible.

Other Potentialities

Based on the development of the GSDB and the work carried out by the OTSS, new possibilities are to be explored. The projects currently developed by the OTSS include the characterization of the territories of traditional communities, the support to territorialized productive actions and community-based tourism. OTSS's GIS will support all these projects.

The characterization of the territories of all traditional communities in a similar model to that used for Trindade is a concrete possibility and should be targeted in the next few years. The obvious priority will be the communities with the most important territorial disputes. The action can potentially be expanded to all traditional communities.

Another important potential for OTSS's GIS is providing logistic support to productive actions based on social technologies, inasmuch as it encompasses data provided by official institutions—like roads—and produced through a dialogue with communities—such as areas of production and storage. The use of this information may be relevant, for instance, to establish distribution routes based on local productive arrangements that involve social technologies.

As to community-based tourism, OTSS's GIS has the great potential of supporting the explanation and promotion of tourist sites, including the mapping of attractions, services and products in the involved communities.

Since OTSS's GIS better represents communities on the territory, many other potentialities could also be discussed, expanding both technical and community-based knowledge on the territory and making it easier for communities to dialogue with other actors (Conservation Units, Government Officials, NGOs, etc.) in the Bocaina region.

Conclusion

The development of the GIS has been helping OTSS reach its central goal, that is expanding the traditional communities' capacity of governance and management, supporting counter-hegemonic modes of production and consumption, developing and valorizing their life styles and practices based on the ecology of knowledge and participatory management schemes, as well as producing solutions for the needs of the territory.

Production and consumption patterns of these communities have low environmental impacts and greenhouse gases emissions, so the preservation of their lifestyles is an efficient way to minimize climate change, as well as to guarantee their overall health.

The GIS has the role of strengthening the actions of these communities by representing their spatial knowledge on maps; spatial analyses are capable of supporting the activities carried out. It also gives visibility to these communities and their traditional activities, forcing a dialogue with other actors in the territory, reducing the rigidity of a boundary beyond which the knowledge of these communities are invisible.

For such, this GIS is being developed with the inclusion (in the GSDB) of information produced not only the usual way (by official government institutions), but also based on the knowledge of the communities, a bottom-up model that requires constant dialogue between academia and community members.

This information generation model is consistent with the three analytical dimensions adopted by the OTSS (equity, autonomy and sustainability), as well as with its evaluation parameters (Gallo and Setti 2012, 2014). Sustainability, since it advances toward territorialization, meeting the needs of communities regarding the representation of their territories. Equity, since it supports a reduction in the vulnerabilities of traditional communities using a tool for spatial analysis and representation that strengthens the fight of these communities for the whole of their territories. Autonomy, for reinforcing social participation and empowering communities, since the GIS and its derived products (maps and information) expand their ability to claim their rights, the intensity of their participation and their capacity of formulation and management of their territories.

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Chapter 21
Building Community Resilience and Strengthening Local Capacities for Disaster Risk Reduction and Climate Change Adaptation in Zongoene (Xai-Xai District), Gaza Province

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Abstract The occurrence of extreme climate events in Mozambique constitutes a great barrier to swift sustainable economic development due to associated human and material damages. As a result, the population lives in a situation of threat and instability. The most vulnerable societies in Mozambique are those inhabiting settling areas along coastal or river plains, and those whose economies are strictly related to resources highly sensitive to climate changes. The vulnerability factors of two communities in the lower Limpopo River were analysed using a participative tool, the top mecca. The Zongoene and Mahielene communities in the lower Limpopo River basin lack essential adaptation elements that enable responses to climate change and natural disasters. These elements are required nationwide and include a highly diversified economy and access to new production technologies. In addition and in particular, the Zongoene and Mahielene communities rely directly on the services offered by the coastal ecosystems that have been affected by the impacts of floods, droughts, sea level rise and tropical cyclones. Some activities for climate change adaptation were identified and discussed based on the weaknesses and strengths identified.

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Introduction

Climate change has become the most complicated challenge, given that the impacts are already in place and are affecting a growing number of populations. As stated in the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report, the climate system warming is clearly evident. Global atmospheric concentrations of carbon dioxide, the most important greenhouse gas, for 650,000 years were in the range of 200–300 ppm, but it has increased to about 387 ppm in the past 150 years, mainly because of the burning fossil fuels and, to a lesser extent, agriculture and changes in land use (IPCC 2007). The Sub-Saharan Africa is considered the region where there are the most vulnerable people to the impacts of climate change. The continent is already prone to erratic rainfall, droughts, floods and cyclones, and climate change will only exacerbate these on-going challenges. At the same time, Africa fight against poverty, environmental degradation, uneven land rights, high dependence on natural resources for subsistence, and the HIV & AIDS. These factors limit the ability of people and institutions to adapt to climate change (CARE 2006).

The geographical location of Mozambique is one of the main factors contributing to the country's vulnerability to extreme events, given that most of the tropical cyclones and depressions formed in the Indian Ocean enter Mozambique Channel and affect the Mozambican coastal zone. On the other hand, the country has an extensive coastline where numerous international rivers run towards the Indian Ocean. With the rise in global temperature it is expected that the frequency and severity of droughts within the country, as well as floods in coastal regions will increase (MICOA 2005). In that report, MICOA states that the vulnerability concept in the national context is associated to a variety of factors that contribute to it, where as far as climate change is concerned, the most relevant is on one hand the risk of occurrence of an extreme event such as droughts, floods, and cyclones, and on the other hand, the local capacity of resilience to such extreme events. The concept of vulnerability has been discussed in detail by Soares et al. (2012) who reviewed several literatures on vulnerability and found three definitions, which include a biophysical vulnerability, social vulnerability, and the IPCC definition that combines biophysical and socioeconomic vulnerability. While biophysical vulnerability addresses the degradation of environmental conditions, the social dimension addresses the processes and structures impacting on individuals/groups, be it political, social, historical, or economic.

In Mozambique, the human settlements and the most vulnerable societies are generally those located in riverine and coastal flood plains and those whose economies are closely linked with climate-sensitive resources (Artur and Hilhorst 2014). The poor communities of Zongoene and Mahielene are in the list of highly vulnerable coastal communities in Mozambique. They are located along the flood plain of Limpopo River and in the coastal area. The rising sea level, a result of the global climate change, is a threat itself, but it is also a concern for the Zongoene coastal zone, due to salt intrusion into farming areas since a vast majority of the population finds in agriculture their main source of income (Balidy and Mahumane 2008; INGC et al. 2003). These communities generally have more limited adaptive capacity and are more dependent on climate-sensitive resources, which feature rainfed agriculture, exploitation of forest resources, and fishing activity.

A sound understanding of how livelihoods are managed and sustained is required to assure reduction of current levels of vulnerability and increasing adaptive capacity. By understanding the management of the livelihoods of poor communities, one can infer how people will be affected by the impacts of climate change and how they can respond using the resources available and what additional resources are needed, as well as how can we reflect and consolidate the strategic position to adapt to the effects of climate change successfully (Matavel 2012).

The present study aimed at assessing the vulnerability and the adaptive capacity of the Zongoene District Post to climate change effects using people's perceptions in two neighbouring communities, Zongoene and Mahielene.

Study Site

The Zongoene District Post is located to the south of Xai-Xai District in the Limpopo basin, in the Mozambican Province of Gaza, between Latitudes 25°0′30″ and 25°17′0″ South and Longitudes 33°19′00″ and 33°40′30″ East (Fig. 21.1). It is a village located along the coastal zone and in the vicinity of the Limpopo river estuary, with an area of 505 km^2 and nearly 50 km of coastline. In terms of administrative division, the Zongoene District Post has three localities, namely Zongoene Headquarter, Chilaulene and Novela, with a total of 18 small villages and settlements (Balidy and Mahumane 2008). There are over 30,900 inhabitants in the District Post corresponding to a total of about 5200 households (Matavel 2012).

According to Gove and Boane (2001), Zongoene's climate is tropical humid characterized by two seasons, with a hot and rainy season occurring from November to March, and a cold and dry season from April to October. In the summer, this area is influenced by continental tropical depressions that form in the Southeast and carries heavy rains. The minimum and maximum annual mean temperatures are 20.2 °C and 30.9 °C, respectively. The average annual rainfall varies from 825 to 1145 mm, decreasing very rapidly from the coast to inner lands (MAE 2005).

The economy of Zongoene District Post is primarily agricultural, given that the Limpopo River that crosses the district grants fertilization to its banks and flood plains, making them suitable for production of numerous kinds of commercial crops including rice, wheat, beans, bananas and vegetables (Matavel 2012). The fertile

Fig. 21.1 Localization of Zongoene district post (after Matavel 2012)

soil and good farming conditions make agriculture the main economic activity in this region. Despite the existing potential for the development of agriculture, the people practice subsistence agriculture, using rudimentary technology, with low yields, due to lack of adequate investments. This activity is mainly practiced by adults of both sexes. There are two agricultural seasons, first in the hot and rainy season, between the months of September to March, and the second in the cool and dry season, between April and August. Cultivation takes place mainly in low-lying areas, which are more fertile, yet prone to flooding, but it is also performed in high land but unsuitable soils with high permeability and low nutrients concentrations along the coastal dunes. Maize, cassava, rice, sweet potatoes, beans, peanuts and vegetables are the main crops cultivated in Zongoene (Balidy and Mahumane 2008).

Methods

In order to evaluate the perception, vulnerability, and adaptive capacity of people in Zongoene District Post the TOP MECCA tool was used for two communities in the District Post, namely the Zongoene Headquarter and Mahielene. Data for this study was acquired using participatory semi-structured interviews to community members, being 41 individuals in Mahielene and 38 in Zongoene. These groups were interviewed separately, and each of them comprised men and women, young and elderly people in varying numbers selected randomly from the communities. The TOP MECCA is a set of tools and included CVCA, CRiSTAL, PAVF, and VAP, whose description is given below. Facilitation of the interviews consisted in the exposition and explanation of relevant concepts, followed by stimulation of an open discussion that often resulted in the consent among participants on what was needed at each step. The use of such tools and techniques has some serious limitations, which were dealt with whenever they became evident. That includes the time it took to address each issue and to reach an agreement; the fact that particular groups would eventually not agree with the majority—in which case further explanation had to be provided; and the patience and commitment from everyone involved that not always was present.

CVCA: Climate Vulnerability and Capacity Analysis

The CVCA tool (CARE 2009) provides an opportunity to link community knowledge with scientific information on climate change, which allows interested parts to understand the implications that climate changes have on their livelihood so that they are capable to assess the risks and to plan the adaptation. The tool provides guidelines for facilitating participatory process of vulnerability analysis of communities to climate change effects. The CVCA is designed to stimulate and strengthen planning processes by providing relevant information and specific to the local context, on the impacts of climate change and local vulnerability, where a valuable dialogue is promoted between communities during the process of data collection, as well as the dialogue between communities and stakeholders. The methodology can be used and adapted to collect and assess information aiming at drawing adaptation initiatives to climate change and integrating the issues of adaptation to the effects of climate change on the management of livelihoods and natural resources. CVCA emphasizes the understanding of how climate change will affect people and the livelihoods of target communities. The tool examines the hazards, vulnerability and adaptive capacity in order to create resilience for the future, also examines risks and conditions as well as any interactions between the two.

CRiSTAL: Community-Based Risk Screening Tool: Adaptation and Livelihoods

The CRiSTAL tool (IISD 2012) aims to create the foundations for community development and decision-making based on local projects, so that opportunities for adaptation can be maximized and misleading adaptation can be minimized. In particular, CRiSTAL helps planners and project managers to:

- Realize systematically the links between local livelihoods and climate;
- Evaluate the impacts of local projects on important subsistence resources for adaptation;

- Advise the adjustments that can adequately enhance a project's impact on the resources of the important means of support for adaptation.

PAVF: Participatory Analysis of Vulnerability Factors

The emphasis of the PAVF tool (Somda et al. 2011) is the identification of factors that expose some groups or means of survival to risk. The tool also identifies the factors that cause some community groups or survival resources to be more affected by climate risks, despite being in the same degree of exposure.

VPA: Vision-Action-Partnership

According to Somda et al. (2011) and Beaulieu et al. (2002), this tool enables (1) the drawing of the community vision against a particular impact in the case of project implementation be done successfully; (2) and the identification of actions that can be implemented by the community and partners to achieve the vision; The partners can be either the government institutions, national and international NGOs, private sector, or the civil society, among others.

Results

Livelihood Resources and Climate Hazards

Natural resources occupy a predominant place in the lives of Mozambican rural communities. The success of its main subsistence activities (fishing, agriculture and livestock) and their survival depend directly on the availability, access, control and quality of natural resources such as water, arable land, forests and pastures, (Hahn et al. 2009; UNDP 2009; CDS-ZC 2010; UNEP 2010). The collected data show that the members of the surveyed communities benefit from forest resources for their survival, and they extract from these resources the necessary material to build houses and craft objects, the firewood and fruits for consumption and production of beverages that are marketed locally, making these alternative sources of family income. In turn, the fishing is considered one of the main alternative activities implemented by the community to mitigate the effects of bad harvests observed in Zongoene, as a result of floods and drought.

Through the mapping of sensible resources available in the Zongoene and Mahielene communities performed in a collective manner, as illustrated in plate 21.1, it was possible to identify the resources and assess their degree of

Plate 21.1 Process of mapping the survival resources and climate hazards in the Mahielene community. Community members sat in groups around a flipchart

exposure to climate related hazards. The resources identified are as follows: *natural* which are land, forest, sea; *physic* which include water holes, agriculture implements, fishing boats and nets; *financial which comprises* sale of fish, livestock, and forest products; *human comprising* farmers, cattle breeders, and fishermen; and *social consisting of* church, fisherman association, and woman association. In addition, the hazards that occurred were identified and the regions where they have occurred were equally mapped, based on the information provided by the witnesses. The potential hazards included floods, droughts, and strong winds, as illustrated in Table 21.1.

The degree of exposure of the livelihood resources is summarized in Table 21.1, where three climate hazards are considered. In the villager's perception within the Zongoene Headquarter and Mahielene communities, the degree of exposure of livelihood resources to climate hazards varies a great deal between resources and hazards, with some resources being not exposed at all to a particular hazard, while others are fully exposed to that hazard. In the end, each identified resource is exposed to droughts, floods, or strong winds, and in some cases to more than one hazard.

Adaptation Strategies

Adaptation is a process that enables societies to cope with an uncertain future. Adaptation to climate change involves taking right steps to reduce the negative

Table 21.1 Resources and their degree of exposure

Hazards	Low exposure	High exposure
Droughts	Sea, fishing nets, fishing boats, fish trading, breeding cattle, selling of forest products, fishermen, church, associations	Land, forest, holes, cattle trading, farmers, cattle breeders
Floods	Forest, church, Sea, cattle trading	Land, holes, agricultural implements, fishing nets, fishing boats, farmers, associations
Strong winds	Water holes, agricultural implements, cattle trading, farmers, church and associations	Land, forest, sea, water holes, fishing nets and boats, fish trading, trade of forest products

effects of climate change (or exploit the positive ones) by making appropriate amendments and adjustments (UN-OHRLLS 2009). According to the IPCC (2001) adaptation is seen as an adjustment in natural or human systems in response to actual or expected environmental change, which moderates harm or exploits beneficial opportunities. Adaptation involves dealing with climate change taking steps to reduce the negative effects, or explore the positive, making appropriate adjustments (UNFCCC 2006). For INGC (2009), the adaptability reflects the potential to implement planned adaptation measures, therefore, relates to human deliberate attempts to adapt or cope with the change. Adaptability refers to the combination of all forces, attributes, and resources available to an individual, community, society or organization that can be used to achieve established objectives. This includes the conditions and characteristics that enable society at large to access and use of social resources, economic, psychological, cultural and those related to the way of life, as well as access to information and governance institutions necessary to reduce vulnerability and deal with disaster consequences (IPCC 2012).

There are many options and opportunities to adapt to the impacts of climate change. These range from technological options such as increased coastal defense structures, the individual behaviour change, such as reducing water use in times of drought, use of mosquito nets, early warning systems for extreme events, improved management water, improved risk management, various insurance options and biodiversity conservation.

For each identified climate hazard, members of the Zongoene and Mahielene communities indicated three most severe impacts based on their collective experience, as well as three adaptation measures (Table 21.2) that could be incorporated into a strategy at the District level. Further, an analysis of the way each livelihood resource influences the chosen adaptation measure was performed. All resources have a moderate to strong influence on the various strategies, except those listed in the third column in Table 21.2. The community suggested strategies to cope with the impacts of strong winds are influenced by a vast majority of the resources listed in Table 21.1. These strategies include (1) building of houses using conventional material, as it is currently done, but employing innovative methods and models that assure more stable houses are built; (2) planting trees in areas designated for crop

Table 21.2 Livelihood resources and their degree of exposure to climate hazards in the Zongoene Headquarter and Mahielene communities

Hazards	Impacts	Adaptation strategy	Resources with no influence on strategy
Droughts	1. Destruction of crops 2. Livestock death 3. Water shortage for livestock	1. Small business development 2. Livestock extension 3. Construction of dams	Land, sea, church, animal traction
Floods	1. Destruction of crops 2. Livestock death 3. Emergence of epidemics	1. Dike construction 2. Make small business 3. Organize transport to clinic	Land, sea, fishing boats and nets, farmers, breeders, associations
Strong winds	1. Destruction of homes 2. Destruction of crops 3. Destruction of trees and early fruit drop	1. House building using conventional material 2. Planting trees to serve as windbreak curtains 3. Development of small alternative business	Forest, associations, church

culture as a way to reduce the windstress acting over the crops; (3) and development of alternative business as a mean to generate income after a climate hazard has struck the villagers.

Vulnerability Factors

In the theory on risk and vulnerability due to climate change, the vulnerability must be analysed taking into account three main components: weakness or exposure, susceptibility or sensitivity, and adaptive capacity or resilience. Where the fragility or exposure, is the physical and environmental component of vulnerability, which defines the extent to which a population group is likely to be affected by a dangerous phenomenon depending on their location in the same area of influence, and in the absence of physical resistance to its spread (Braga et al. 2006). For the IPCC (2012) exposure is used to refer to the presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social or cultural assets in places that may be adversely affected by physical events. On the other hand the susceptibility is the socio-economic and demographic component, which makes the predisposition of a population group to suffer damage against a dangerous phenomenon. And resilience is the behavioural component, community and political, which limits the ability of a population group undergone a dangerous phenomenon to absorb the shock and adapt to return to an acceptable level (Braga et al. 2006). According to the IPCC (2012), resilience is defined as the ability of a system and its components to anticipate, to absorb, to accommodate, or to recover from the effects of a potentially hazardous event in a timely and efficient manner.

The vulnerability factors in the Zongoene and Mahielene communities were analysed collectively in terms of the amount of people exposed to a particular climate hazard, and the amount of people whose income activities are sensitive to the impacts of climate change. A summary of the results is presented in Table 21.3. As can be seen, the entire population in the sampled communities is exposed to a number of climatic impacts, including the loss of crops as a consequence of severe droughts and floods, the shortage of water for livestock that persists during prolonged droughts, the epidemics caused by consumption of inappropriate or untreated water and mosquitoes during the seasonal floods, and the destruction of houses that follow each cyclone and strong wind events. Each of the selected climate hazards affects the entire community in one way or another, and this contributes to a greater vulnerability.

The income generation activities practiced by the people in the two communities are in general very sensible to the impacts of climate hazards, meaning that very often the occurrence of either drought, floods of strong winds translates to a major loss of income by the villagers. Alternative sources of income have to activated by then, otherwise the people get into a total catastrophe. The activities or sources of income here refers to the rainfed agriculture practiced by almost everyone in the community, the breeding of cattle that makes use of the low-lying lands prone to both drought and floods, exploitation of forest products that is conditioned during and after strong wind events. Apart from the activities undertaken by the villagers, the methods used in house construction as well as the location where houses are usually built are highly sensible to selected hazards that result in the destruction of infrastructure. The people still build infrastructures in places known to have been affected by past events in order to avoid facing new challenges in newly designated habitation areas.

Based on the identified vulnerability factors, the population in the Zongoene Headquarter and Mahielene communities has put forward the strategic elements displayed in Table 21.4, which includes the vision, proposed action, and potential partners. In terms of vision, the villagers want to see the crop production increased, water for domestic use available year around and in good quality, public heath improved, as well as more stable houses built for their comfort.

Discussion

The Zongoene Headquarter community showed that the region is highly vulnerable to the effects of climate change such as floods, droughts, and strong winds. According to INGC et al. (2003), the lower Limpopo River basin which encompasses the Zongoene District Post, is one of the most vulnerable region to natural disasters within Mozambique. This vulnerability is witnessed through the worldwidely reported floods of 2000 and 2013 that led to dramatic examples of

Table 21.3 People exposed to climatic hazards in the Zongoene and Mahielene communities, and amount of people sensitive to selected impacts of climate change

Hazard	Impact	Exposure	Sensitivity
Droughts	1. Loss of crops	100 %—Entire community is exposed given that everyone practices rainfed agriculture in the low-lying zones	100 %—Entire community is exposed given that everyone practice rainfed agriculture in the low-lying zones
	2. Livestock death due to lack of pasture	30 %—Because it affects only those who own livestock	30 %—Because grazing is made in the low-lying grasslands
	3. Shortage of water for livestock	30 %—Because it affects only those who own livestock	30 %—Because grazing is made in the low-lying grasslands
	4. Shortage of water for domestic use	100 %—Entire community uses water form holes	75 % the majority live in high lands, where water holes are hard to be dug.
Floods	1. Loss of crops	100 %—Entire community because everyone practice agriculture in two regions: the flood plain and transition zone to higher grounds	90 % because the majority of the most fertile soils are in the flood plain, and a smaller amount in the transition zone
	2. Livestock death	55 %—because the majority of villagers own a livestock and feed them in the low-lying zones	55 %—the majority of grazing lands are prone to floods
	3. Emergence of epidemics (cholera, diarrheal diseases, malaria, etc.)	100 %—the majority have access to water from holes, which is taken as potable and appropriate for human consumption	In Zongoene Headquarters, this problem affects only those living in regions without holes (20 %), while in Mahielene it affects the entire community (100 %), given that they all live in the same region
Strong winds	1. Destruction of houses	In Zongoene Headquarters, 20 % of population is exposed as they live in higher grounds, while in Mahielene the entire population (100 %) lives in a zone prone to strong winds and cyclones	10 % of population in Zongoene build houses in vulnerable region, while it is 50 % in Mahielene because half of the houses are located in higher grounds with no sheltering vegetation
	2. Destruction of crops	40 % of people in Zongoene and 90 % in Mahielene cultivate maize and cassava on higher grounds	40 % in Zongoene and 90 % in Mahielene because they all use the same variety of crops sensitive to strong winds

(continued)

Table 21.3 (continued)

Hazard	Impact	Exposure	Sensitivity
	3. Destruction of trees and early fruit drop	45 % of the population, given that it affects only those with access to fruits for consumption, marketing and manufacture of beverages	30 % of the population, those who exploit forest products for a living
	4. Loss of boats	40 % of the population, those who practice fishing for a living	40 % of the population, those who rely on fisheries, and own a boat or canoe

Table 21.4 List of elements of strategic vision, proposed remedial actions, and identified partners for the adaptation of the Zongoene and Mahielene communities in Xai-Xai District

Impacts	Vision elements	Actions	Partners
Crop destruction (drought)	Increase crop production	• Opening and cleaning irrigation channels • Use of short cycle varieties • Use of seeds tolerant to drought • Use of fertilizers and improved seeds	Government (agriculture)
Crop destruction (floods)	Increase crop production	• Construction of drainage channels • Rehabilitation of dikes and placement of gates	Government
Crop destruction (strong winds)	Increase crop production	• Reforestation or building barriers with local vegetation and tree species. • Purchase of seeds, training in nurseries and planting techniques	Government (CDSZC) NGOs
Death of animals (drought)	Increase the number of animals	• Construction of dams • Opening water holes and dam construction	Government
Shortage of water for domestic use	Sufficient and good quality water throughout the year	• Opening water holes	Government (DPOPH)
Emergence of epidemics	Improve public health	• Ensure access to hospital services to the whole community • Ensure drinking water for the whole community	Government
Contamination of water wells	To have sufficient good quality water throughout the year	• Opening water holes	Government (DPOPH)
House destruction (strong winds)	Stable houses and protected from the wind	• Planting trees in coastal areas; • Construction of conventional homes • Nursery and training in nursery establishment and planting technique	Government (CDSZC)

destruction caused by natural disasters in the basin. The region is not only vulnerable to flooding, since most of the basin receives less than 500 mm annually precipitation, but to other hazards as well. Droughts are common in this area and usually last longer than a single season. Despite the Limpopo basin be located outside the tropical cyclone zone, it is affected occasionally by tropical cyclones that carry heavy rains that may result in flooding within the basin. This happened for instance in the year 2000.

The disasters registered along the Zongoene community have had the following main impacts, in the perception of the local villagers: destruction of crops, death of animals, lack of water for domestic use and for the cattle, destruction of houses, destruction of trees, and contamination of water wells, among others.

Villagers in the Zongoene community have indicated the following adaptation strategies to the floods, drought and strong winds that arise from climate change: construction of dikes and drainage ditches, placement of gates, construction of dams and drinkers for cattle, construction of defense barriers to avoid saline water, exploitation of forest products, development of fishing activities, small business development, planting of trees along the coastal zone, creating nurseries, acquisition of small vessels, building houses using conventional material and new models, purchase of motor pumps, and drilling holes for water extraction.

Despite the country's potential for agriculture, in terms of arable land and availability of water resources, adaptation to adverse impacts of climate change will require the adoption of new technologies and improvement of agricultural policies, which includes the rehabilitation and extension of irrigation systems, the promotion of dry tolerant crop varieties, expanding the extension services, and providing financial services in rural areas with subsidized interest rates (World Bank 2010; Bambaige 2007; MICOA 2007). These strategies include some already indicated and well-accepted by the villagers in Zongoene community, as a way to minimize the impacts of climate change in the region, which shows the importance of local community involvement in the design of adaptation projects to climate change.

Concluding Remarks

The participative work undertaken in the Zongoene District Post (Zongoene Headquarter and Mahielene communities) allowed the following conclusion to be drawn:

- The local communities identified as climate hazards the droughts, floods, and strong winds. And these hazards in the perception of the community can effectively cause the destruction of crops, animal death, house destruction, lack of water for various uses, water contamination in the wells, loss of fishing boats and nets, among others.
- The land, which is taken as one of the most important natural resources for the community's survival, is highly affected by droughts and this has severe impacts

because most farmers end up developing crop farming in upper lands that depend solely on rainfall. The rainfall on its turn is currently considered erratic throughout the southern Mozambique. The negative impact associated with the land also come from the fact that land is affected by the floods, and a great deal of villagers practice crop farming in the lower reaches, within the Limpopo River flood plain.

- Strong winds greatly affect fishing activity because the fishermen from Zongoene have little to no access to updated weather forecasts, which cause boats and other fishing materials to get lost during strong winds. Additionally this climate related hazard affects negatively the crop farming and housing in the Zongoene District Post, particularly those houses located in high and unsheltered areas.
- The agricultural implements as well as local knowledge on agriculture play an important role in the construction of dikes and drainage ditches, dams and reconstruction of houses, since these are considered survival resources and are readily available for a large part of villagers with the District Post.
- Regarding the development of small business as a mitigation strategy for the main climate hazards (drought, floods and high winds), the local community in the Zongoene District Post have in place a strategy that includes the sale of agricultural surpluses, sale of domestic animals, fish sale and sale of forest products.

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Part IV
Climate Change and Health Across Regions

Chapter 22
Heat Vulnerability, Poverty and Health Inequalities in Urban Migrant Communities: A Pilot Study from Vienna

Laura Wiesböck, Anna Wanka, Elisabeth Anne-Sophie Mayrhuber, Brigitte Allex, Franz Kolland, Hans Peter Hutter, Peter Wallner, Arne Arnberger, Renate Eder, and Ruth Kutalek

Abstract Climate change is projected to further increase heat waves in number, intensity and duration over most land areas in the twenty-first century. Among the urban population persons with migrant background are particularly considered to be at risk during heat waves due to the intersection of several risk factors: social status (poverty, manual labour), residential area (densely populated, disadvantaged urban areas, heat islands) and health condition. In this chapter we pledge for a differentiated approach in studying heat-related health outcomes and present first descriptive outcomes of two explorative case studies of multi-generation-families in Vienna, comparing a family with Turkish migrant background with a family without migrant background. The data consists of participant observation and in-depth interviews and has been generated in the course of the research project "Vulnerability of and adaption strategies for migrant groups in urban heat environments (EthniCityHeat)" between June and September 2014.

Keywords Urban heat environment • Health inequality • Intersectionality • Migrants • Mixed methods • Vienna

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Introduction

Climate change is increasing the frequency of heat waves and hot weather in many urban environments (White-Newsome et al. 2012; IPCC 2007). According to the definition by Robinson (2001) heatwaves are "extended periods of unusually high-atmospheric related heat-stress, which causes temporary modification in lifestyle and which may have adverse health consequences for a population". High-temperature days can pose a threat to health by triggering acute heat-related illnesses or by exacerbating pre-existing health conditions (Hansen et al. 2013). Urban areas especially suffer from heatwaves because of the urban "heat island" effect that has an impact on health and wellbeing of residents. With future scenarios predicting an increase in the frequency and intensity of heatwaves, there is a substantial need in identifying vulnerable groups and evidence-based adaption and prevention strategies to boost resilience in those at risk (ibid.).

While there are many studies focusing on heat-related illnesses and death of particularly health vulnerable groups like elderly (e.g. Wanka et al. 2014), research addressing the issue of ethnicity remains quite scarce. This is particularly the case for Vienna. The aim of this article is to fill this gap by investigating the underlying reasons for ethnicity being a risk factor for extreme heat. According to Weber (1997: 18) ethnic groups are "human groups that entertain a subjective belief in their commons descent because of similarities of physical type or of customs or both, or because of memories of colonization and migration". We argue that effects of climate change should be framed in multiple ways. The link between heat waves and health inequalities can be understood as a multifaceted process in a changing environment with several major factors influencing it. Urbanization, with its higher density population, potentially enhances people's vulnerability to climate change, especially when residential areas contain heat islands or when settlements are not designed to be 'climate resilient' (Hansen et al. 2013). Further major contributors to health inequalities are e.g. the social and economic conditions that affect people's lives, educational attainment, and the environment in which they live and work (ibid.).

The aim of the research project "Vulnerability of and adaption strategies for migrant groups in urban heat environments (EthniCityHeat)" is to analyze the intersectionality of risk factors cumulating with heat related stress. We seek to draw a comprehensive picture of the potential relation between heat waves and vulnerabilities in health for persons with migrant background. Our main research question is: To what extent are persons with Turkish background living in Vienna exposed to specific heat vulnerabilities? Due to the multifacetedness and interweaving of factors influencing heat vulnerability it is not possible to draw simple causal explanations from the effects of climate change on health. With clear causal pathways linking ethnicity, socio-economic status and health conditions, differences in vulnerability may be attributed to social and economic disparities rather than, or as well as, ethnicity (Hansen et al. 2013). Hence it is crucial to build up on a mixed-method approach in order to be able to discuss various aspects of the consequences of heat waves. Therefore the project draws upon the following data:

1. Two case studies with a consecutive follow-up study of four case studies consisting of participant observation and semi-structured in-depth interviews with a family with Turkish migrant background in comparison with a family with Austrian background,
2. Fifteen qualitative interviews with persons of Turkish background residing in heat-vulnerable environments,
3. Fifteen expert interviews with stakeholders, decision-makers and intermediaries on their awareness, opinions and actions regarding the effects of heat on persons with migrant background,
4. Two standardised face-to-face surveys (each N = 400).

In this chapter we will present first descriptive outcomes of two case studies in order to demonstrate the underlying cumulative inequalities that contribute to heat-related vulnerabilities.

Ethnicity, Poverty and Inequalities in Health in Vienna

Persons with migrant background can be considered particularly at risk during heatwaves (Hansen et al. 2014). This increased vulnerability may be due to several risk factors that intersect among ethnic groups in Vienna that can be subsumed under the residential area (densely populated, disadvantaged urban areas, heat islands), social status (poverty, manual labour) and health condition. The main reason for disadvantaged living conditions can often be found in limited financial resources and social deprivation. Social deprivation can affect heat-stress in various dimensions. First, low income leads to deprivation in living conditions and living space, reduces possibilities to elude heatwaves (e.g. move to the second residence) and financial scope for affording cooling measures (e.g. air condition). Second, persons with a lower educational attainment often do not have sufficient (access to) health information and lead more unhealthy lifestyles than persons with a higher educational attainment (Hurrelmann 2006). They are thus more likely to suffer from adverse health conditions. Third, persons with lower educational attainment are more likely to work in manual labor and under unfavorable working conditions, especially in hot periods (e.g. construction work or cleaning). In Austria, social deprivation is prevalent among persons with migrant background in general and among persons of Turkish origin in particular. The latter show little shares of university graduates and high percentages of persons with compulsory education (Turkish background: 64 %; non-migrants: 12 %). However, the educational situation is improving for the second generation. Still, the migrant pay gap amounts to 20 % and has significantly increased since 2005. 26 % of persons with foreign citizenship are at risk of poverty (Austrian citizenship: 11 %), particularly affecting Turks (44 %). Manifest poverty among foreigners amounts to 16 % (Austrian citizenship: 5 %), again affecting Turks (27 %) in particular. Regarding occupation, nearly half (45 %) persons with migrant background are manual workers (without migrant background: 23 %), with particularly high shares among persons with Turkish origin (63 %). The most important economic branches are production (16 %), trade (15 %), construction (12 %) and tourism (12 %) (Statistik Austria 2013). Particularly in production and construction heat adaption poses problems.

As people of Turkish origin residing in Vienna are considered particularly vulnerable, we decided to focus our research on this group. In Vienna the number of heat days (temperatures above 30 °C) and heat waves has been distinctly on the rise during the last decades. While only 9.6 heat days on average were observed between 1961 and 1990, the number increased to 15.2 per year between 1981 and 2010. 2003 is considered to be a record-breaking year with 40 heat days (ZAMG 2012). Formayer et al. (2007) project, that the number of heat days in Vienna will further rise to approximately 23–60 by 2085. According to the authors, even more than 100 heat days may occur in some years. Therefore it is crucial to get a comprehensive insight into heat vulnerability of specific risk groups residing in Vienna. In the following we present first descriptive results of the case study on a family with Turkish migrant background in comparison with a family with Austrian background conducted during summer 2014.

Methods and Research Instruments

Case Study

A case study is an "intensive study of a single unit for the purpose of understanding a larger class of (similar) units" (Gerring 2004: 342). In our study the aim of the comparison of two cases is not to create generalizable knowledge but rather to "delve into the social world under subject" (Kannonier-Finster 1998: 55). This underlies the methodological principal of case studies, as they are "generalizable to theoretical positions and not to populations or universes" (Yin 2009: 15). Accordingly our research goal is grounded on qualitative and theoretic interests rather than the enumeration of frequencies. The criteria for the selection of the two cases were the following: both families have to be multi-generational, namely three generations have to live in the same apartment or respectively in the same building. In order to be able to picture the potential effects of Urban heat islands, both families have to live in an area that is significantly warmer due to human activities. Furthermore at least one family member has to work from home so that the observation can be conducted.

Participant Observation and Semi-structured In-Depth Interviews

Participant observation is the "process enabling researchers to learn about activities of the people under study in the natural setting through observing and participating in those activities" (Kawulich 2005: 1). Marshall and Rossman (1989: 79) define observation as "systematic description of events, behaviors, and artifacts in the social setting chosen for the study". We have chosen this method in order to gain a better understanding of the context and phenomenon under study. A total of five observations in the Turkish family household and six observations in the Austrian family household were conducted that spanned over 3–5 h. The visits took place on weekdays as well as on weekends at different times of the day. The fieldwork has been carried out by young social researchers, one being a Turkish native, well versed in Kurdish, the native language of the migrant family observed. Observational protocols (OPs) were written by the researchers just after the visit using drafted thematic categories (e.g. intake of fluids, physical activity) but also allowing for descriptions of emerging themes, etc. Special emphasis was laid on the relationship between researchers and the persons under study due to the sensitivity inherent to ethnographic explorations that usually take place in the personal private settings such as the individuals' homes. The observations were complemented by in-depth interviews with one of the household members. The thematic focus of both the participant observation and the interviews was laid on work and working conditions, mobility, social networks, domestic work as well as diet and nutrition, drinking patterns, health condition and health behaviour, heat and provision of information on weather. In this chapter relevant thematic sections are described and discussed below, collected data consist of observational protocols (OPs) and the two interview transcripts. The data was imported to the computer assisting software Atlas.ti. The material was screened through inductive and deductive coding.

Descriptive Results and Discussion

Socio-economic Condition

Within the scope of the ethnographic exploration crucial differences regarding occupational situation, educational background and income conditions were observed between the families. In the Turkish family the mother provides the main steady income to the household, while her husband temporarily found minor employment at his son in laws' take away stand but was dismissed when business went down (OP3_T). The mother works in a school as cleaning staff. She has fixed working hours divided into a morning and an afternoon shift. She describes her health condition as genuinely bad; she suffers from multiple stresses linked to her occupational status, such as frequent exhaustion or fear of losing her job (OP1_T).

> After they have dismissed my husband, I have even more fear of losing my employment. If I manage another three years, I will be able to retire and that is my goal. My [health] problems constrain my daily live but I am forced to continue… (Interview T).

Her step into retirement in the foreseeable future seems equally important to her husband, who explains his worries over his wife's health and the family's income situation (OP2_T). The overall occupational future is experienced as demanding and not promising due to his own bad health status and limited possibilities and difficulties in finding a job (OP2_T, OP3_T). The two adult sons are both not formally employed. One is in early retirement due to his critical health condition and the other one temporarily unemployed and enrolled in a German course (OP1_T, Interview T). The family's meal times depend on the mothers fixed working hours. She typically goes home during her long lunch break and cooks, if she does not feel too tired and exhausted (cf. Interview T). The mother has not finished school and is illiterate, the father and the unemployed son left school after compulsory schooling and the son finished an apprenticeship and now is in early retirement (OP1_T).

In the non-migrant household both adults manage their working hours independently and work partly from home, partly outside home:

> … because I work on a freelance-basis and am involved in various different projects, there is no typical workday (Interview A)

The daily working routine is tailored around the school child's compulsory schedule and meals are prepared according to the students' routine. The father emphasized that he generally prefers to devote less of his time to wage labour and more to other work that actually interests him, such as participating in a self-harvesting group (Interview A). Their lifestyle could be categorized as flexible and alternative and described as a sort of deliberate choice embedded in an ideological conviction:

> I attach particular importance to the things that we produce on our own by now, because it is a certain feeling of satisfaction that we collect this and create home-made food. Self-empowerment, self-sufficient feeling… (Interview A).

Considering the father's educational achievement he left school after compulsory schooling while his child attends secondary school at the time of the participant observation.

Living and Residential Environment

The two case studies differ greatly in terms of the particular housing characteristics as well as the residential environment. The Turkish household is comprised of four adults (parents and two adult children), who share a 75 m^2 apartment located in the

15th district. Migrating to Vienna in 1990, the father applied for asylum and most of his family members followed to Vienna within the next years. The four room apartment is located on the ground floor and classifies as D category (substandard). The living room as well as one bedroom is exposed to a lot of traffic noise (OP1_T). During the participant observation the apartment was not assessed as particularly hot, as it is not exposed to direct sunlight. Within the residential environment small parks can be reached within 500 m.

The mother mentioned she only has little leisure time that she mainly uses for household duties and resting phases whenever she feels too tired (Interview T). Although she explained that on any occasion when she feels exhausted, her husband and children support her, in general she bears all of the household duties (cooking, cleaning, grocery shopping, laundry) (OP1_T, OP4_T, Interview T). Thus, on the one hand her action scope is restricted due to work- and household-related stress and her chronic state of exhaustion and on the other hand her illiteracy as well as her lack of German knowledge skills limit her to a certain degree from engaging in other social activities.

The living environment of the Austrian three-person family differs greatly, firstly in terms of available living space and secondly regarding leisure activities. The family shares a 125 m^2 apartment, located in the 8th district. The apartment is divided into five rooms, all accessible independently. The family's apartment can be described as generous and spacious. In the very same building four extended family members, namely the (grand-)father, siblings and other children reside. The house residents share an elevator and a common garden in the courtyard; additionally each apartment is equipped with a basement store room (OP1_A). The apartment was not perceived as especially hot in summer, nor exposed to particular heat-related or other environmental burdens (OP1_A). The household members generally spend time in surrounding parks frequently; they use outdoor table tennis courts and often visit green areas for harvesting purposes.

In the Austrian family the father works entirely from home and takes care of the household duties:

> It is difficult to say [how much time the preparation of a meal takes] you cut the carrots, put them in and then you go back to the computer, and in 10 minutes you come back and turn it off. Let's say half an hour, forty-five minutes [...] I take care of all of the household duties. (Interview A).

There was no division of any household-related work observed or described and noted that some of these tasks were actually perceived as done by the side, not much burdensome and carried out between other tasks (ibid.)

In terms of indoor temperature data for the two homes has been collected from August 5th 2014 to September 10th 2014 with Opus 10 Climate Monitor. One sensor was placed inside each home with sampling intervals of 10 min. There were no major differences in the range of indoor temperature (apartment in the 8th district: 23.6–28.2 °C; apartment in the 15th district: 24.7–28.0 °C). Concerning the infrastructure, such as public transport connections, both case studies are connected to subway and/or tram and stations located within walking distance.

Household members indicate that they use public transport either as primary mean of transportation (Interview T) or in addition to cycling (OP3_A). Mobility differences between the two case studies were observed in terms of their radius. As for the Turkish family members everyday routes seemed primarily localized around the apartment, the workplace, extended family members' apartments or workplaces (OP3_T) whereas in the Austrian family the mobility radius linked to leisure activities such as self-harvesting, self-cultivation of vegetables or participating in social events (Interview A).

Health Condition and Behaviour

The topic of health condition and behaviour is centred on the self-assessed state of health as well as certain behavioural patterns that are linked to a persons' condition such as nutrition and physical activity. Already in the first participant observation visit the problematic health condition of three of the four family members has been brought up in the Turkish household. The mother appeared generally tired, moved slowly and complained at different occasions about her tiredness and different pains in various parts of her body. Repeatedly she stressed her lack of energy:

> I feel very old and exhausted and have the impression that it gets worse because my pain increases. My foot hurts and I suffer from head and back pain and also I am constantly tired, because I work as a cleaner and that involves a high physical strain. Additionally I cannot sleep well during the night, thus I am not recovering well. I take medicines on a daily basis. (Interview T).

At her workplace there is a nurse she can consult, however, she points out that because of her lack of language skills and her inability to explain herself, she never managed to see her (ibid.). With regards to the question on her overall health seeking behaviour a strong dependency to other family members, especially her daughters, has been observed. This dependency arises through access barriers such as language and uncertainty about how the Austrian health system works.

> I always go to the same doctors, my daughter in law or my daughters accompany me. It occurs that I change doctors if my daughters think it is right or if they get recommendations for a certain doctor. [. . .] I trust them and I let them decide for me. [. . .]Once I was in pain for 2–3 weeks and waited, because I cannot go alone and I am uncomfortable if my children have to come with me every time and I am a burden to them. (Interview T).

Her husband also is in a critical health state. He mentioned that he suffered from a sunstroke last summer when their family was on vacation in Turkey and he feared that he also might have had a heart attack (OP3_T). He self-assessed his situation as very bad various times. He experienced medical services as unsatisfying and articulates his feeling of helplessness and powerlessness. In the non-migrant family the topic of health appeared to be less central. The father explained that he is in a good health condition, dealing with typical problems and vulnerabilities corresponding to his age (Interview A). Generally he emphasises that he prefers to use his own knowledge and home remedies before seeing a doctor and feels well provided and well oriented in terms of (primary) health care in Austria (ibid.).

In both families nutritional habits during summer were similar: more fruits, vegetables and lighter dishes were prepared. Home-made, freshly cooked meals played a central role and ingredients were bought in close-by shops and transported home by walking (OP4_T). In the Turkish household the mother typically prepared traditional Turkish food. The main fluid intake was black tea. It was explained that it is common in many Turkish households to often drink black tea with ample portions of sugar. When visitors come also coffee is served regularly (OP1_T, Field notes T). As for the Austrian case study, the self-sufficiency aspect was very central in their dietary habits. Vegetables, fruits and nuts were self-harvested. For about 4 months of the year they solely subsist on vegetables from their field and only drink self-made juices (Interview A). The self-harvesting process of fruits and vegetables requires not only time but also physical activity by the father who is the main harvester of the family. The open self-harvesting places throughout the city parks and around outskirts areas are reached mainly by bicycle (OP1_A, OP2_A). Being part of a harvesting group, certain fruits such as mulberries, elder and hazelnuts are harvested and processed. Additionally the family rents a self-harvesting field that is cultivated during summer (OP2_A).

Regarding specific adaption measures and behaviour during heat periods, the use of green spaces is in both cases central although utilisation as such varies. Outdoor spaces, especially green areas are visited more often during summer and are source for recreation when it is hot. The Austrian family identifies eating light, drinking more water, ventilating in the morning and during night hours, darkening rooms with blinds and shutters and taking cold showers as helpful during hot times (OP1_A). In the Turkish family the topic of heat periods in Vienna frequently lead to comparisons to heat periods in Turkey that were perceived much more serious and almost not comparable. As for adaption measures within the apartment the curtains are drawn and windows are titled (cf. Interviews T). Green spaces and also bathing places are visited more frequently by the family members, ideally as a day trip with their grandchild (ibid.). They also try to drink more water when it is especially hot. Public swimming bathes were preferred to contrast open public bathing places and big grill pick nicks were mentioned as difficult to reach because they do not have a car (ibid.).

Building up on these first explorative case studies it is shown that the intersectionality of various factors have a crucial impact on heat-related vulnerabilities. In the Austrian family everyday activities are the expression of a specific lifestyle. While cooking is considered to be a duty in the Turkish family, the Austrian family consciously spends a lot of time and energy to be able to accompany the food process from harvesting to preparing meals and drinks. Compared to the Turkish family their physical activity is generally higher due to outdoor activities and choosing the bicycle as main mean of transportation. Furthermore the action scope in the city is bigger and the usage of public space is more strongly part of their everyday life. The case study on the Turkish family demonstrates that the socio-economic condition is linked to various vulnerabilities that can contribute to heat-related stress, like exhausting labour with high physical strain, existential pressure due to insecure job status, disadvantages in living environment or the lack of knowledge when it comes to Austrian health system and individual health behavior etc..

Conclusion

Climate change and associated changing weather patterns are expected to increase the prevalence of a wide range of health risks (Ebi 2011). This chapter deals with investigating the underlying reasons for ethnicity being a risk factor for extreme heat. Like other environmental stressors, severe weather events have differential effects on different subpopulations (Balbus and Malina 2009). Classifying individuals or groups according to ethnicity is problematic on different levels. Therefore we argue that ethnicity has to be seen as a factor that is closely interwoven with many others. Persons with Turkish background in Vienna are at increased risk of heat-related vulnerabilities due to several cumulating factors, like low socio-economic status, occupational exposure, spatial vulnerability and language barriers, more so than ethnicity itself. The link between ethnic status and potential poor health conditions is multidimensional (Hansen et al. 2013).

In order to be able to empirically capture these different aspects of heat-related stress it is essential to adopt a mixed-methods design. The first descriptive results of our qualitative case study provide a contextual understanding of various aspects of the families' everyday lives that would not have been able to cover with a sole quantitative approach. Overall we see incidences for "structural vulnerabilities" (Quesada et al. 2011) in the family with Turkish background. The observed micro unit family reflects larger societal patterns, like for example persistent ethnic segmentation in employment that produces an ongoing gap in occupational status which in turn potentially carries negative health consequences.

In terms of health behavior we see substantial differences between the families. Pierre Bourdieu, in this respect, provides an explanation for the relationship between class, health and lifestyles, forged within the practical logic of everyday life (Bourdieu 1984).

He brings to light the manner in which the very pursuit of health and the cultivation of lifestyles are themselves caught up in various class-related struggles for social recognition or 'distinction' (Barry and Yuill 2008).

The two explorative case studies demonstrate that it is not only objective socio-economic parameters that play an important role in understanding health behavior. For example the institutionalized cultural capital of the father of the Austrian family is comparably low: his highest educational attainment is compulsory school. However he practices a very conscious lifestyle that minimizes health risks. Furthermore in both families the access to economic capital is limited. Yet in one case it is out of hardship (push factor) and in the other case it is out of self-fulfillment (pull factor). Therefore, in the face of projected increase in the number of heat waves, it is essential to deeply investigate heat-related health outcomes not only from an intersectional but also from a differentiated qualitative perspective.

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Chapter 23
Climate Change and Forced Environmental Migration Vulnerability of the Portuguese Coastline

Maria da Conceição Pereira Ramos, Natalia Ramos, and Ana Isabel da Rocha Moreira

Abstract Against the backdrop of Climate Change and the inevitable increase in the negative consequences which arise, there emerges the need to study their economic, socio-demographic and environmental impacts. In this context comes a new threat to human well-being: the "forced environmental migration" of populations due to environmental phenomena resulting from changes in the Earth's climate. There are regions of the World with greater vulnerability to climate change and its consequences than others; countries with extensive coastal areas are included in these regions. As Portugal is a country with a considerably long coastline, it is extremely important to study the problems that such a shoreline faces, particularly those that arise from the increase in the average sea level. These problems resulting from climate variability associated with abusive and inappropriate use of the coastline increases its degradation and the vulnerability of the resident population. In some situations, the best solution involves implementing the planned withdrawal projects through the displacement of the population to an area more climatically stable, which can be considered "forced environmental migration". In Portugal, there are several locations in this situation, as we can see through existing initiatives and interviews with local municipal authorities responsible for environmental issues. In the north of the country, withdrawals are planned in seven

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locations: S. Bartolomeu do Mar, Bonança, Pedrinhas and Cedovém in the municipality of Esposende; Paramos in the municipality of Espinho; Esmoriz and Cortegaça in the municipality of Ovar.

Keywords Climate change • Forced environmental migration • Coastal zones in Portugal • Planned withdrawal projects

Introduction

Environmental issues induce theoretical transformations leading to the development of knowledge in different scientific disciplines, thus demanding a systemic, holistic, and interdisciplinary integration and aggregation of knowledge (Leff 2002).

Climate change is one of the biggest challenges facing the twenty-first century, which not only threatens fundamental aspects of our existence, such as agriculture, access to water, the environment and health, but is also responsible for phenomena such as forced environmental migrations. The Portuguese coast is particularly vulnerable to climate change, which has caused coastal erosion and enforced population displacement, as well as planned population removal, especially along the north Portuguese coast. Such facts are confirmed by published literature and also by interviews with two agents responsible for environmental issues in two of the affected Portuguese municipalities in the north of the country.

The relevant answers must be combined with national, territorial and local strategies for development, as well as with public policies. Sustainable development reduces vulnerability towards environment catastrophes and climatic changes and increases the well-being of populations (Veiga 2005; ILO 2012; Ramos 2012b; Smith-Oliver 2012).

Climate change is beginning to receive considerable attention as regards public, national and European policies and it is vital that the populations and municipalities concerned should be engaged in the strategies of development and adaptation to those policies.

Climate Changes and Associated Impacts

The consequences of climate change have been the subject of considerable debate as a source of particular concern among the world-wide community, as well as international bodies, and they constitute one of the biggest challenges that Humanity currently faces, demanding an urgent effort by all in the resolution of this problem. The main consequences of climate change can be summarized as follows: global warming; an increase in the frequency of extreme climatic phenomena; a rise in the average sea level; loss of ice caps in polar regions; changes in the availability of water resources; changes in ecosystems and loss of biodiversity; desertification; interferences in agriculture; impacts on the health and well-being of populations;

displacements of populations (Goodess 2012; Santos and Miranda 2006; Mcleman and Smit, 2006).

Awareness of climate change as a social problem has been increasing, and there is a need to act upon its triggering factors, its effects (Giddens 2009) and associated problems related to coastal erosion, public health, etc. Vulnerability to climate change depends on a number of variables. There is particular concern in developing countries, where social vulnerability, poverty and inequality intensify [the] existing

Table 23.1 Global impacts of climate change in different areas of the world

Africa	Great vulnerability to climate change Low adaptability as a result of insufficient economic development Increase in average sea level, with an impact on low altitude coastal areas Lower rainfall Rise in temperatures Increase of barren regions Increased food insecurity due to a great dependence on an underdeveloped agriculture Great migration flows towards Europe
Asia	Great vulnerability to climate change, especially in developing countries Ice melting in the Himalayas and resulting floods Rise in sea level, resulting in the displacement of millions of people living in low coastal areas Higher frequency of events such as droughts and floods High water scarcity Low agricultural production
Europe	Considerable adaptability to climate change. Southern, Mediterranean and Arctic areas of Europe are more vulnerable Increase in average sea level Increase in adverse climate events such as floods, extreme precipitation and heat waves Reduction in water availability, especially in southern Europe
Australia and New Zealand	Increase in coastal flooding resulting from the rise in the average sea level Increase in the severity and frequency of extreme climate events such as storms Loss of biodiversity, agriculture and forestry, resulting from droughts, and increases in forest fires. Great adaptability to climate change
South America	Low adaptability to climate change Salinization and desertification of agricultural lands Increased flooding Increased extreme climate events
North America	Increase in floods. Low vulnerability due to great adaptability
Polar regions	Fast melting of polar caps Reduction in the thickness and extension of ice sheets Coastal erosion
Small island states	Floods resulting from rises in sea level Coastal erosion Shrinking water resources

Source: Synthesis based on Chirala (2013), Santos and Miranda (2006) climate issues (Rua 2013). Table 23.1 summarizes the main problems faced by different areas of the planet due to climate changes.

Current Challenges of Forced Environmental Migrations and Climate Refugees

Throughout history population movements have always existed, to a greater or lesser extent, as a response to demographic growth, climate change and economic needs (Castles 2005; Marino 2012; Ramos 2012c). Current migrants and climate refugees pose political, socioeconomic and cultural challenges (Ramos 2012a, b; Fatima et al. 2014). Natural/environmental factors are a strong reason for migration, although on the European continent, a major recipient of migrants, migrations are essentially labour-driven. The number of those obtaining right of asylum is modest, despite the influx of refugees. Natural catastrophes such as earthquakes, floods and volcanic eruptions lead to population displacement and to the abandonment of lands. Myers (1997, 2005) instances desertification, deforestation, water scarcity, salinization of irrigated land and reduction of biodiversity as causes of environmental displacements. These determining factors are linked to the fast population growth in less developed countries, as well as to global climate changes (Castles 2002).

The environmental degradation perceived due to the ecological imbalance and social inequality resulting from the process of socioeconomic development has placed a heavy burden on the world population. The process of climate change and multiple natural catastrophes, such as droughts or floods, and in the long run, desertification or the rise in sea level, force millions of people to move, thus causing important issues of forced migration, or the so-called climate refugees (Brown 2008; Laczko and Aghazarm 2009; Gemene et al. 2011; Piguet et al. 2011; Hassani-Mahmooei and Parris 2012).

There are three ways in which a person may suffer from an extreme climate event (Black et al. 2012, p. 8):

- Long-term displacement for over a year. In this case, one is talking about forced environmental migration;
- Temporary or short-term population displacement, for less than 3 months, usually associated with floods or other temporary events;
- Immobility, with no verifiable population displacement. The population chooses to remain in the same place.

The term “climate refugee”, from the work by El-Hinnawi (1985), has been used since the 1980s. According to the United Nations Environment Programme (UNEP), climate refugees are “those people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption (natural and/or triggered by people) that jeopardized their existence and/or seriously affected the quality of their life". According to the International Organization for Migration (IOM), "forced migration" is about "a migratory movement in which an element of coercion exists, including threats to life and livelihood, whether arising from natural or man-made causes (e.g., movements of refugees and internally displaced persons as well as people displaced by natural or environmental disasters, chemical or nuclear disasters, famine or development projects)" (OIM 2014). Despite the existing definitions, we are far from achieving consensus on this subject. Over the last decade, this issue has been thoroughly discussed and many concepts have been created: "climate induced migrants", "climate refugees", "environmental migrants", among others. We can adopt the following definition proposed by the International Organization for Migration (IOM) and cited by Brown (2008, p. 15): "Environmental migrants are persons or groups of persons, who, for compelling reasons of sudden or progressive changes in the environment that adversely affect their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad".

However, the fact that there is no clear definition implies that the environmental refugees are not certified by the Geneva Convention, and thus have no benefits in terms of rights and protection by international organizations (Biermann and Boas 2010).

Several organizations have estimated the existing number of "environmental refugees". However, this number cannot be accurately determined, since it varies between evaluations and depends on a number of factors (Biermann and Boas 2010; CPR 2010). Up to 2050, about 200 million people may abandon their locations due to climate change, according to data from the United Nations (UN). The United Nations High Commissariat for Refugees (UNHCR) calculates that there are 25 million climate refugees. Since 1970, the risks of the displacement of people due to environmental catastrophes have quadrupled, and tragedies have increased the number of those moving to developed countries. According to a 1994 document drawn up by the World Bank, every year ten million people are forced to move due to large development projects. Among these, four million are driven from their lands and homes to make way for artificially created large dams. Another six million are forced to move due to other large economic projects: urban renewal, the construction of road and rail networks, development of industrial districts, among others. For the World Bank, these processes, which are driven by major economic interests, are a feature of the development of capitalism and take place both in industrialized and developing countries. They are also considered as processes of production and reproduction of poverty and the inequality with which migrations/forced mobilities are almost always associated.

Drawing on our literature review, in the following Table 23.2 we can summarize concrete examples of populations forced to move due to [the] extreme climate events.

Table 23.2 Forced environmental migrations throughout the world

Location	Description of the forced environmental migration	Duration
Tuvalu Islands—An archipelago with very low altitude islands in the Pacific Ocean	Environmental migrations, notably to New Zealand, due to the rise in sea level	Permanent
Carteret Islands—Papua—New Guinea, in the Pacific Ocean	Environmental migrations, notably to Bougainville Island, due to the rise in sea level	Permanent
China	Environmental migrations of millions of people due to strong floods, May 2010	Temporary
Pakistan	Environmental migrations due to strong floods in July–August 2010	Temporary
Indonesia, Sri Lanka, India, Thailand	Environmental migrations of two million people due to the December 2004 tsunami	Temporary/ Permanent
New Orleans, U.S.A.	Internal environmental migrations of 300 thousand people due to the Katrina and Rita hurricanes, 2005	Temporary/ Permanent
Fukushima, Japan	Environmental migrations due to the tsunami that unleashed a severe nuclear issue, March 2011	Permanent

Source: Adapted from Belasen and Polachek (2011), Black et al. (2012), CPR (2010), Warner et al. (2008)

Socio-environmental Impacts of Forced Environmental Migrations

Socio-environmental impacts reorganize space and affect the structures of social classes, health, the quality of life and the mobility of populations in different ways (Ingleby 2005). Coelho (2004) defines *environmental impact* as a process of social and ecological changes caused by disturbances in the environment. It is important to think about the political, economic and social consequences of these processes imposing specific and multidisciplinary challenges on population movements. These issues have not been properly debated, for example with regard to large construction works that primarily benefit businesses such as agribusinesses, petrochemical and mining companies and large manufacturers. In this context, civil society is rarely consulted on the relevance of such works or their modes and effects in terms of climate change. The populations affected are perceived as "collateral and inevitable victims" of the modernization process, one that requires sacrifices especially by vulnerable groups (Hogan 2005). Frequently these populations are forcibly uprooted from territories where they have been living for centuries, and which they did not wish to leave, and they are resettled in areas where there are no conditions for self-development due to the lack of efficient public policies. Moreover, an inevitable social rupture and restlessness is produced, one that destroys interpersonal and family relationships and generates suffering that it is difficult to mitigate simply by offering some form of governmental compensation. Given this picture of violence and violation of rights, such operations cause controversy and disputes between governments, private companies and social movements, who warn against the predatory extraction of natural resources and the violations of human, social and economic rights, which reveal themselves in the destruction of flora, fauna, population displacements with damage and risks for those uprooted (Martinez-Alier 2012; Sevá Filho 2010).

The vulnerability of local communities to the impacts of climate change depends on different factors: geophysical and localization-driven factors; socio-economic factors and factors of social cohesion; population engagement; actions by local authorities, etc. (Laukkonen et al. 2009).

The impact of environmental factors on population displacements must take into account the sociocultural perceptions of the communities affected and the representations of these threats. Climate change is experienced differently depending on the regions and social categories being affected, since [the] vulnerability with respect to the environment is the result of specific socioeconomic, cultural and geographic factors that shape each society. The dynamic and interactive relations point to the constant mutation resulting from the dialectic of the connections between social groups and the "natural" and built [urbanized'] environment, which involves a process of permanent creation that characterizes cultures, in specific times and places (Reigota 1995). The consequences of climate change vary across regions, generations, ages, sexes, social classes, income levels and occupations, mostly affecting the more disadvantaged and vulnerable. Women in particular act as change agents within a community's natural resource management, in innovation, in agriculture, in fishing and in basic health care, and play a key role in [the] adaptation to climate change and sustainable development (Braidotti et al. 1994; OIT 2009; Ramos 2012a, b, c, d). The contributions made by the impacts of gender issues on the environment and of development projects need to be considered.

The twenty-first century brings new challenges to the international and European political agenda: globalization and the explosion of urbanization. The continuous flows of migrants, refugees and other displaced persons lead to the fast growth of cities. It is important to address the issues raised by the vulnerability of urban migrants. Many of these people come from rural areas or small towns and are drawn to large urban centres in search of better living standards. They also migrate due to environmental frailties or to climate change(s). These forced migrants seek the protection and opportunities that cities offer, but may end up being caught up in disadvantaged, overpopulated communities or peripheral neighborhoods lacking basic services and with accessibility constraints. The issue of urbanization and cities has been debated in Europe since 1994—from the first *European Conference on Sustainable Cities and Towns—Aalborg Charter* (Denmark, 27/05/1994). This Charter assumes cities to be entities subject to sustainability, which becomes a creative, local and balanced process. Issues regarding the patterns for the sustainable use of land and EU cities and towns, as well as economic, social and territorial cohesion issues are raised (UNIÃO EUROPEIA 2014).

The management of cultural diversity in urban areas is one of the main concerns in the Council of Europe and the European Commission. In 2008, these institutions launched the "intercultural cities" project in order to transform the city into an open and plural space and a privileged site for intercultural dialogue, presenting challenges to intercultural communication, to planning and urban management and to health and quality of life (Nogueira 2008; Ramos 2008). In view of this, one has to find innovative and sustainable ways to support displaced people and those receiving them. Given the increase in urban population, it is necessary to think about "greener" infrastructures and resolve serious problems that characterize urban centres, such as noise and pollution (Patrício 2012a, b).

Public and European Adaptation Policies Related to Climate Change and the Ecological Crisis

The ecological crisis raises disturbing issues such as climate change, natural hazards, food insecurity, air, water, and soil contamination, loss of biodiversity, risks to public health and loss of quality of life. Citizens view the environment with concern and uncertainty in relation to the future. But there are initiatives and projects involving sufficient determination and creativity to build more sustainable forms of social coexistence. The warnings issued by Stern and Gore have been decisive in causing public policies to be reviewed in the light of the urgency to fight the climate threat. Between 2007 and 2009, the European Union (EU) directed international efforts which led to the December 2009 deal on an international regime, during the United Nations Conference and in the context of the United Nations Convention on Climate Change, and [which also led to] to global strategies and the correction of public policies (Stern 2009; Gore 2009). The belief in a upturn at an EU level, [and] in the context of the fight against climate change, has continued to mobilize efforts (ECF 2010). In the wake of the early 2014 overtopping of coastal defenses by sea water, caused by climate events with an above average intensity, the Portuguese coast acquired greater importance as a beneficiary of public policies. The "Grupo de Trabalho do Litoral" ("Coastline Working Group") was created in March 2014, adding to the existing National Action Plan (APA 2012) and the European guidelines (EEA 2013). In this context, municipalities assumed a fundamental role in prevention, education and information, recognized by the United Nations since the 1992 Earth Summit (CNUAD 1992).

Despite these important environmental advances, many problems, including insufficient implementation of the current environmental laws of the Union, remain. The levels of water quality [and] atmospheric pollution are still problematic and in many parts of Europe citizens are still being exposed to dangerous substances, causing a potential risk to their health and well-being. Urban atmospheric pollution is getting worse (Patrício 2012a) and according to the OECD it will become the first environmental cause of mortality and morbidity throughout the world in 2050.

In order to confront and minimize these problems, the European Union prepared an environment action programme for the period up to 31st of December, 2020: *Environment Action Programme* 2014/2020 entitled *"To live well, within the planet's ecological limits"*. It consists of creating shared goals and objectives and assuring equitable conditions for companies and public authorities. Within its scope, the European Union has assumed some commitments, among which are: to attain levels of air quality that do not generate negative impacts or significant risks for human health and the environment; by 2020, to have minimized the adverse impacts of the use and production of chemical products harmful to human health and the environment. For a more solidary, a greener and safer future, the Environment Action Programme (EAP) is based on three principles—the polluter pays principle; the precautionary principle; the preventing pollution at source principle—and has the following goals:

1. To protect, conserve and enhance the Union's natural capital
2. To turn the Union into a resource-efficient, green, and competitive low-carbon economy
3. To safeguard the Union's citizens from environment-related pressures and risks to health and well-being
4. To maximize the benefits of the Union's environment legislation
5. To improve the knowledge base of the environment policies
6. To ensure investments for the environment and climate policy and to correctly define prices
7. To improve the integration and coherence of environment policies
8. To make the Union's cities more sustainable
9. To help the Union address environment challenges more effectively

Vulnerability of the Portuguese Coastline to Climate Changes and "Forced Environmental Migrations"

The meteorological observations undertaken in mainland Portugal reveal an evolving climate throughout the twentieth century. There has been a significant rise in average maximum and minimum temperatures, as well as frequent heat waves (IPCC 2013). Extreme climate events are expected to increase. In the Portuguese case, the forecast is as follows up to 2100 (APA 2009; CPR 2010; Santos et al. 2001; Santos and Miranda 2006):

- Rise in average sea level by 1 m or a meter and a half by the end of the century;
- Significant increase in the average temperature in all [the] regions of Portugal, especially in inland areas. Gradual temperature increases of between 3 and 7 °C are expected in mainland Portugal;

– Increase in the maximum summer temperature, as well as in the frequency and intensity of heat waves;
– Increase in the number of hot days and nights and decrease in the number of cold days and nights;
– Increase in the number of forest fires, changes in land use and reduction in the availability of water resources;
– Reduction in the precipitation levels all year round, except for winter months.

Portugal is a particularly vulnerable territory as far as climate change and its consequences is concerned, in particular forced population displacements. As a country with a long coastline, the rise in average sea level, associated with erosive coastal events and other issues, exacerbates the problems along the coast, with particular vulnerability for coastal communities. It is therefore on the Portuguese coast, where a large proportion of the population and economic activities are concentrated, that the vulnerability conditions necessary to cause forced population displacements due to environmental factors and the absence of responses to extreme climate events are to be found.

The abusive and inadequate use of the coast increases the predisposition for such risks, thereby demanding intervention, whether planned or in response to a crisis situation, to defend the coast. Hence, the need arises to draw up planning projects in relation to the coast line, where planned removal is assumed as a valid choice in specific situations (Gomes and Oliveira 2013). The capacity to implement concrete measures along the Portuguese coastal area has been clearly too limited compared to the huge problems that local communities face. It is therefore urgent to envisage clear measures and to act, otherwise it will be too late for the sustainability of the Portuguese coast (Gomes 2007).

In this context, several localities in the North of Portugal have been studied and described as coastal areas at risk, whose populations benefit from planned withdrawal projects, the solutions foreseen in the Coastal Development Plans. Thus, the following communities have been studied: Bartolomeu do Mar, Bonança, Pedrinhas and Cedovém in the Esposende municipality; Paramos, in the Espinho municipality, and the fishermen's neighbourhood at Esmoriz Beach and the Cortegaça Beach neighborhood in the municipality of Ovar. For the implementation of this study, two interviews were carried out, in June and August 2014, with local officials responsible for the Environment, namely an Environmental Engineer at the Environment Division, Esposende City Hall, and the Master in Sea and Coastal Area Sciences at the Environment Division, Ovar City Hall.

In the municipality of Esposende, the Planned Withdrawal Projects for the communities of Bonança, Pedrinhas and Cedovém are being reassessed by the relevant authorities (POLIS and the Ministry of the Environment). Still in relation to Esposende, in S. Bartolomeu do Mar the planned withdrawal project is underway and consists of the removal of about 20 homes, all of them seasonal. In relation to the community of Paramos, in the Espinho municipality, the planned withdrawal project is being reassessed, in much the same way as in Ovar, at the Cortegaça Beach. On the other hand, in Esmoriz the project is already underway and consists of the rehousing of 30 families from the fishing community, constantly threatened by the sea. Indeed, in S. Bartolomeu do Mar and Esmoriz there have already been population displacements due to environmental causes. Less exposed areas have been sought; hence this can be considered “forced environmental migration”.

Coastal Erosion in Portuguese Municipalities and Local Development Actions

The policies and tools used by urban planners must promote urban mobility plans, programmes that may specifically address more disadvantaged populations, and environmental aspects related to climate change (Puppim de Oliveira et al. 2013). The improvement of ecosystems and the reduction of environmental impacts increase efficiency in countries and regions and the health and quality of life of their inhabitants. Besides dealing with issues of sustainable environmental management, climate change and the way to tackle it, we must equally consider ethics and social responsibility (Bordeyne et al. 2009; Dias 2011).

What actions have the municipalities been developing to deal with climate change? Even if such change is beginning to cause increasing concern to local governments and municipal officials, it is still not a central issue of municipal planning policies within national borders. Among the measures implemented by local authorities, the areas of environment education and civil defence stand out. Environmental education is a process by which populations become aware of how important the environment is and improve their ability to act individually and collectively and search for solutions to environmental problems.

According to Ramos (2012a, p.35), “environmental education for citizenship must grant an individual and collective perception of how people live in the context of a certain historic and social formation. It must also contribute to solving specific problems affecting the environment, as well as to motivating citizens to take a critical stand towards reality”.

Local knowledge has to be incorporated into scientific studies and political decisions, as is the case with fishing communities, with valuable expertise and experience related to working at sea (Ramos 2012d).

Local authorities and leadership by municipalities are conquering a fundamental space in the implementation of participatory strategies of local development, establishing a basis whereby a decision can be taken by local communities and allowing local agents to participate. There is a need for democratic participation in the local development process. “Local development is thus associated with the improvement of the living conditions in one given territory, but also with the enforcement of a participatory pedagogy among the people who live there, with the exercise of an active citizenship, as a central axis for development processes” (Ramos 2012c, p. 75). Although local authorities must engage with participation and citizenship, one must also demand that populations become more participative and identify their own needs and are better organized. One must also demand a reorganization of institutions, of civil society and the forces promoting development so as to create new relations between the State, the market place and society. Participation refers to taking part not only in decisions but also in citizenship and in responsibility towards decisions being taken, so that local authorities must assume a facilitating role among the social forces in the community. This engagement makes it possible to forestall possible conflicts among the measures implementation process, under a sustainable development frame.

Conclusion

Climate change and related impacts have been the target of concern by the international community, notably in Europe and Portugal. There are natural/environmental factors that cause population displacement and forced environmental migrations, creating the so-called "climate refugees". Their number has been increasing not only in developing countries, but also in industrialized ones. These forced environmental migrations generate important social and environmental impacts on people's space, quality of life and mobility.

The occupation of vulnerable coastal areas and their abusive use, both nationally and internationally, is in fact a serious problem; so tougher legislation and monitoring is vitally important. The coast's great importance forces us to take action concerning its sustainable management so as to ensure a healthier natural asset for succeeding generations. There is therefore an urgent need to undertake specific studies and to implement policies targeted at climate change in Portuguese coastal areas.

One has to create opportunities, both nationally and locally, for the early education of men and women in the realm of climate change and to benefit from their knowledge and management abilities as regards natural resources when policies and adaptation initiatives are drawn up and in terms of reducing the consequences of climate change(s).

There is a need for cross-cutting policies that can facilitate social changes that will have to take into account changing local practices and behaviours and engaging citizens in coping with environmental problems and challenges. Civic participation must be fostered, since populations are often distanced from public information and decision processes, as well as the debate on the social, economic and cultural value of the Portuguese coast being affected by climate change and its consequences.

The repercussions of climate change on local communities (rise in sea level, coastal erosion, forced displacement of populations...), demand greater intervention through public policies and by local/municipal authorities. Municipalities have a fundamental role to play, for they benefit from a unique position of proximity to their populations. This is necessary for the successful implementation of programmes and policies, especially those related to forced environmental migrations and environmental awareness and education.

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Chapter 24
Inequities and Challenges for a Metropolitan Region to Improve Climate Resilience

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Abstract Metropolitan areas require a large flow of environmental services in order to maintain their structures and their population especially considering the challenges associated with climate change. The aim of this chapter is to study inequities among municipalities in the Metropolitan Region of São Paulo—MRSP related to Human Development Index—HDI and the provision and demand for water as an environmental service. Indeed, the growth of metropolitan areas implies pressures for the production of wealth and supply for the population needs resulting in environmental and social pressures as well. This study was conducted by using secondary indicators provided by Brazilian public institutions. In terms of water supply there is a complex and unfair relationship between the municipalities considering their role as providers or receivers of environmental services and so significant inequalities can be observed in the metropolitan area, according to the historic process of urban despoliation characteristic of a developing country. There is a clear distinction between municipalities that have a greater demand for water and those that produce it, since these latter often present worse HDI. In conclusion the diversity of a metropolitan region can be considered necessary in terms of municipalities with different roles. Otherwise, the inequities in the municipalities' providers of environmental services reveal a context of vulnerability, and such asymmetrical scenario must be considered in order to increase the metropolitan resilience towards uncertain climate change scenarios.

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Introduction

The Metropolitan Region of São Paulo—MRSP faces its worst historic water resources crisis[1] endangering the provision of water supply to more than 20 million inhabitants, which are distributed in the 39 municipalities. Considering that one of the more remarkable consequences of climate change is the increase in frequency and intensity of extreme climate events like storms and droughts, these situations can be pointed as challenges in terms of resilience for megacities, mainly in the urban developing world due to the high levels of vulnerability (IPCC 2013). The MRSP is in the Brazilian Southeast, which has suffered a severe drought since the late 2013 and this has been considered as one of the most relevant circumstances of the current water resources crisis.

Actually, as any mega-city in the world, the MRSP is not sustainable in just its territory being necessary the external provision of different resources i.e. water, energy and food. In the case of water supply the MRSP imports water from some river basins out of its territory but there is also a significant domestic production of water in 25 municipalities with watershed protection areas. In this sense environmental services provided by native forest remnants and watershed[2] areas in the metropolitan territory are essential for the sustainability of the urban settlement and its respective population needs. In addition, the conjoining of social and environmental issues can be considered the heart of metropolitan sustainability. Whereas their relation with public health and well-being make a great importance, considering the extent of urban population, especially in developing countries, where mega-cities are characterized by deep inequities in terms of living conditions and the spread of environmental risk and diseases (Smith and Ezatti 2005; McMichael 2000).

The MRSP, like other Brazilian mega-cities, has suffered intense population increase since the 1950s. This very fast urbanization has been marked by a spatial peripherization of poverty conjoining a deeply unequal territory where the public services provision has not gone alongside with the urban sprawl (Santos 2009). In this sense the social iniquities reflect the environmental ones characterizing the peripherization of some relevant areas able to provide essential environmental

[1] This paper was written in May 2015.

[2] In the MRSP, the watershed-protected areas are those with a formal delimitation and a legal restriction for occupation and anthropic activities. The municipalities that accounts substantial parts of their territories under watershed protection have for instance some limitations in order to develop economic activities. The amount of native forest remnants in the metropolitan region are not necessarily included in the watershed-protected areas, but both are important categories in order to provide environmental services.

services as these same areas keep population with worse social and health indicators (Giatti et al. 2013; Cutolo and Giatti 2013).

Kowarick (2000) and Maricato (2003) describe that due to the forces of capital accumulation the urbanization in developing countries carries out a process of urban despoliation. In this context the population impoverishment moves forward alongside with the environmental degradation and lack of urban infrastructure. In the MRSP the urban despoliation proceeds confining the poorest in peripheral areas, mainly overlapping poverty and social exclusion in the territory where prevails the watershed protect areas and also the more remarkable native forest remnants. In the case of the urban occupation of watershed-protected areas, this is regularly informal, even characterizing an urban duality strongly marked by the increase of illegality exacerbating social environmental problems, vulnerability and lowest amounts of social investments (Jacobi 2013).

In a megacity, a diverse territory is alleged to provide environmental services as well as to provide housing, infrastructure and economics. Indeed, diversity is something necessary for sustainability as much as it is also desirable to increase urban resilience (Steiner 2004). But, when a certain territory and its indispensable attributes are suffering the pressure of urban despoliation and illegality, there is worrying scenario of vulnerability considering perspective of climate change consequences (Jacobi 2013; Jacobi et al. 2014; Marandola 2009).

The aim of this chapter is to study inequities among municipalities in the MRSP related to Human Development Index—HDI and the provision and demand for water as an environmental service. In this context, we also expect to discuss relevant aspects that constitute challenges for sustainability and resilience for a metropolitan region, concerning the relation among social environmental vulnerability and the perspective of climate change consequences.

Environmental Services as Water Supply Guarantee: Providers and Receivers

The Millennium Ecosystem Assessment (ONU 2005) states that the mitigation of floods and droughts, as well as the water purification find their providers, primarily, in the preserved vegetation. In practice, the local population can be crucial for the maintenance or degradation of green areas responsible for the continued provision of environmental services.

The dynamics of the society's interrelationship with the ecosystems revealed two kinds of problems. First, ecosystem responses to stress can hinder the choices, the management and sharing of environmental services. Second is that the slow social response to environmental issues tends to cause a suboptimal use and the degradation of environmental services (Scheffer et al. 2000).

The relationship between receivers and providers of environmental services varies according to the range of services provided, the composition of the parties' involved, socioeconomic characteristics, sociocultural context and also involves equity, justice and ethics criteria (Turner and Daily 2008).

The recognition of receivers and providers is critical for the fair distribution of environmental services, aiming at improving the conditions for provision of these services. Environmental service providers may not afford the costs alone, since the preservation of these areas generates costs, if the services are shared, costs must be too. Similarly, the recipient of environmental services should be informed of the characteristics of this provision, where it comes from, how these services are produced and, finally, who is responsible for this provision and what the cost of it all is (Imperio-Favaro and col. 2014).

Thus, it is necessary to identify those who protect green and watershed areas, are responsible for environmental services in MRSP. In this case, the providers (water suppliers) and the receivers (water consumers), bringing information for decision in relation to protection of green areas and water consumption patterns to the urban sustainability. In this chapter, we assume that the municipalities with remarkable amounts of native forest remnants and/or watershed-protected areas are potential providers of the environmental service water.

Methods and Research Instruments

This chapter was developed from bibliographic, documental and secondary data available from public institutions as indicators of social and environmental conditions of the 39 composing municipalities of the MRSP. The conceptual reference to this study is an adaptation of the DPSEEA matrix of indicators (Corvalán et al. 2000) in which a hierarchized analysis of causal nexus was employed. In the original version of the referred matrix of indicators, driving forces from economic and social natures induce pressures over the environment exacerbating risks to human health. In our analysis, we assume HDI as an important social indicator able to contribute to expose the inequalities in the MRSP even considering the process of urban despoliation that characterizes deep asymmetries among the municipalities. The HDI improvement is also understood as a pressure inductor related to the increasing demand for water.

The analysis was applied onto data collected from Governmental Organizations—IBGE, Brazilian Institute of Geography and Statistics; SIFESP, Forest Information System of the São Paulo State; SIGAM, Integrated Environmental Management System; SNIS, National Sanitation Information System and; CETESB, Environmental Sanitation Technology Company.

Indicators of municipal native forest remnants, watershed protected areas, population and water consumption per capita were analyzed to demonstrate the diversity of municipal profiles by ranking the main five providers and the main five receivers (Table 24.1). Water quality index is showed (Table 24.2) as its pertinence to indicate environmental degradation in association with the urban despoliation

Table 24.1 Characterization of the municipalities of the metropolitan region of São Paulo

		Municipality	Rate	% Native Forest Remnants area	Rate	Native Forest Remnants Area (km²) (2)	Rate	% of the total area	Rate	Watershed Protected Areas (km²) (3)	Rate	Population 2010 (1)	Rate	Water consumption per capita (l/inhab/day) (4)
Native forest remnants	% of green area in total area	Juquitiba	1	76.50%	1	399.39	1	100%	26	522.06	6	28,737	37	196.06
		São Lourenço da Serra	2	68.34%	7	127.39	2	100%	9	186.40	1	13,973	34	183.45
		Rio Grande da Serra	3	47.29%	23	17.44	6	100%	18	36.88	8	43,974	12	133.91
		São Bernardo do Campo	4	47.24%	3	193.12	16	53%	7	216.65	37	765,463	30	173.55
		Embu-Guaçu	5	45.90%	12	71.12	3	100%	10	154.95	10	62,769	5	125.02
		São Caetano do Sul	39	0.00%	39	0.00	39	-	39	0.00	20	149,263	39	255.58
		Osasco	38	2.44%	34	1.56	38	-	38	0.00	35	666,740	29	172.48
		Carapicuiba	37	3.29%	37	1.14	37	-	37	0.00	31	369,584	18	144.85
		Barueri	36	8.09%	32	5.35	36	-	36	0.00	27	240,749	38	204.40
		Taboão da Serra	35	9.07%	33	1.84	35	-	35	0.00	28	244,528	21	149.20
	extention of green area	Juquitiba	1	76.50%	1	399.39	1	-	26	0.00	6	28,737	37	196.06
		São Paulo	21	21.09%	2	321.28	20	36%	1	548.38	39	11,253,503	35	188.03
		São Bernardo do Campo	4	47.24%	3	193.12	16	53%	7	216.65	37	765,463	30	173.55
		Mogi das Cruzes	18	23.34%	4	166.50	18	49%	3	349.51	33	387,779	19	147.00
		Cotia	6	45.25%	5	146.22	13	65%	8	210.02	25	201,150	28	172.26
		São Caetano do Sul	39	0.00%	39	0.00	39	-	39	0.00	20	149,263	39	255.58
		Poá	35	5.33%	38	0.91	25	6%	24	1.02	15	106,013	15	141.60
		Carapicuiba	37	3.29%	37	1.14	37	-	37	0.00	31	369,584	18	144.85
		Jandira	34	7.46%	36	1.32	6	-		0.00	16	108,344	4	123.52
		Diadema	36	4.99%	35	1.54	21	22%	23	6.79	34	417,064	23	150.78
Watershed Protected	% and extention of watershed protected	São Lourenço da Serra	2	68.34%	7	127.39	1	100%	9	186.40	1	13,973	34	183.45
		Embu-Guaçu	5	45.90%	12	71.12	2	100%	10	154.95	10	62,769	5	125.02
		Itapecerica da Serra	7	40.25%	14	60.50	3	100%	11	150.30	21	152,614	10	128.85
		Ribeirão Pires	12	33.22%	17	32.80	4	100%	13	98.75	18	113,068	20	148.54
		Rio Grande da Serra	3	47.29%	23	17.44	5	100%	18	36.88	8	43,974	12	133.91
		São Caetano do Sul	39	0.00%	39	0.00	39	-	39	0.00	20	149,263	39	255.58
		Osasco	38	2.44%	34	1.56	38	-	38	0.00	35	666,740	29	172.48
		Carapicuiba	37	3.29%	37	1.14	37	-	37	0.00	31	369,584	18	144.85
		Barueri	36	8.09%	32	5.35	36	-	36	0.00	27	240,749	38	204.40
		Taboão da Serra	35	9.07%	33	1.84	35	-	35	0.00	28	244,528	21	149.20
Population		São Lourenço da Serra	2	68.34%	7	127.39	1	100%	9	186.40	1	13,973	34	183.45
		Salesópolis	11	34.02%	6	144.58	7	98%	2	416.47	2	15,635	8	127.96
		Pirapora do Bom Jesus	14	26.59%	19	28.92	27	-	27	0.00	3	15,733	17	142.64
		Guararema	28	14.35%	16	38.83	32	-	32	0.00	4	25,844	33	179.17
		Biritiba-Mirim	10	35.37%	9	112.17	8	89%	5	282.27	5	28,575	14	137.49
		São Paulo	21	21.09%	2	321.28	19	36%	1	548.38	39	11,253,503	35	188.03
		Guarulhos	13	30.91%	10	98.67	20	30%	14	95.76	38	1,221,979	32	178.19
		São Bernardo do Campo	4	47.24%	3	193.12	15	53%	7	216.65	37	765,463	30	173.55
		Santo André	9	37.02%	13	64.77	14	54%	15	94.47	36	676,407	31	176.52
		Osasco	38	2.44%	34	1.56	38	-	38	0.00	35	666,740	29	172.48
Water consumption per capita (l/inhab/day)		Mairiporã	8	37.78%	8	121.25	10	80%	6	256.744	13	80,956	1	104.12
		Itaquaquecetuba	31	9.51%	27	7.89	34	-	34	0.00	30	321,770	2	116.93
		Mauá	30	11.91%	29	7.3	23	19%	22	11.65	32	386,089	3	120.03
		Itapevi	17	23.91%	22	19.87	29	-	29	0.00	24	200,769	4	123.22
		Embú-Guaçú	5	45.90%	12	71.12	2	100%	10	154.95	10	62,769	5	125.02
		São Caetano do Sul	39	0.00%	39	0.00	39	-	39	0.00	20	149,263	39	255.58
		Barueri	36	8.09%	32	5.35	36	-	36	0.00	27	240,749	38	204.4
		Juquitiba	1	76.50%	1	399.39	26	-	26	0.00	6	28,737	37	196.06
		Santa de Parnaiba	16	24.13%	15	43.38	28	-	28	0.00	16	108,813	36	204.40
		São Paulo	21	21.09%	2	321.28	19	36%	1	548.38	39	11,253,503	35	188.03
Providers	Native forest remnants	Juquitiba	1	76.50%	1	399.39	1	100%	2	522.06	6	28,737	37	196.06
		São Paulo	21	21.09%	2	321.28	19	36%	1	548.38	39	11,253,503	35	188.03
		São Bernardo do Campo	4	47.24%	3	193.12	15	53%	8	216.65	37	765,463	30	173.55
		Mogi das Cruzes	18	23.34%	4	166.50	17	49%	4	349.51	33	387,779	19	147.00
		Cotia	6	45.25%	5	146.22	12	65%	9	210.02	25	201,150	28	172.26
	Watershed-Protected	Juquitiba	1	76.50%	1	399.39	1	100%	2	522.06	6	28,737	37	196.06
		São Lourenço da Serra	2	68.34%	7	127.39	2	100%	10	186.40	1	13,973	34	183.45
		Embu-Guaçu	5	45.90%	12	71.12	3	100%	11	154.95	10	62,769	5	125.02
		Itapecerica da Serra	7	40.25%	14	60.50	4	100%	12	150.30	21	152,614	10	128.85
		Ribeirão Pires	12	33.22%	17	32.80	5	100%	14	98.75	18	113,068	20	148.54
Receivers	Population	São Paulo	21	21.09%	2	321.28	19	36%	1	548.38	39	11,253,503	35	188.03
		Guarulhos	13	30.91%	10	98.67	20	30%	15	95.76	38	1,221,979	32	178.19
		São Bernardo do Campo	4	47.24%	3	193.12	15	53%	8	216.65	37	765,463	30	173.55
		Santo André	9	37.02%	13	64.77	14	54%	16	94.47	36	676,407	31	176.52
		Osasco	38	2.44%	34	1.56	38	-	38	0.00	35	666,740	29	172.48
	Water consumption per capita (l/inhab/day)	São Caetano do Sul	39	0.00%	39	0.00	39	-	39	0.00	20	149,263	39	255.58
		Barueri	36	8.09%	32	5.35	36	-	36	0.00	27	240,749	38	204.4
		Juquitiba	1	76.50%	1	399.39	26	100%	2	522.06	6	28,737	37	196.06
		Santa de Parnaiba	16	24.13%	15	43.38	28	-	28	0.00	16	108,813	36	204.40
		São Paulo	21	21.09%	2	321.28	19	36%	1	548.38	39	11,253,503	35	188.03

Source: (1) IBGE Cidades (2011); (2) SIFESP (2009); (3) SIGAM undated; (4) SNIS (2013)
Note: Elaborated by the authors

Table 24.2 Water quality index of the municipalities of the metropolitan region of São Paulo, 2013

Municipality	Water Quality Index - WQI (1)			
	River/Reservoir	Best	River/Reservoir	Worst
São Lourenço da Serra				
Embu-Guaçu	Capivari-Monos	68	Ribeirão do Cipó	43
Itapecerica da Serra				
Ribeirão Pires	Rio Grande Reservoir	72	Ribeirão Pires	36
Rio Grande da Serra	Rio Grande	58		
Cotia	Graças Reservoir	79	Ribeirão das Pedras	31
Santo André	No data available			
São Bernardo do Campo	Billings Reservoir	81	Billings Reservoir	74
Mogi das Cruzes	Jundiaí River Reservoir	86	Tietê River	66
Guarulhos	Cabuçu Reservoir	85	Tietê River	19
Juquitiba	Juquiá River	72		
Santana de Parnaíba			Edgard de Souza Reservoir	17
Barueri			São João do Barueri Stream	21
Osasco	No data available			
São Caetano do Sul			Tamanduateí River	19
São Paulo	Braço do Taquacetuba	77	Córrego do Ipiranga	14
			Cabuçu River	16
			Aricanduva River	17
			Córrego Jaguaré	18
			Ribeirão Itaquera	18
			Ribeirão dos Meninos	17
			Córrego Pirajuçara	19
			Córrego Água Espraiada	16
			Embú-Mirim River	35
	Guarapiranga Reservoir	79	Guarapiranga Reservoir	44
	Billings Reservoir	58	Billings Reservoir	42
	Pinheiros River	43	Pinheiros River	17
	Tamanduateí River	16	Tamanduateí River	15
	Tietê River	19	Tietê River	15

WQI
Harmful
Bad
Regular
Good
Great

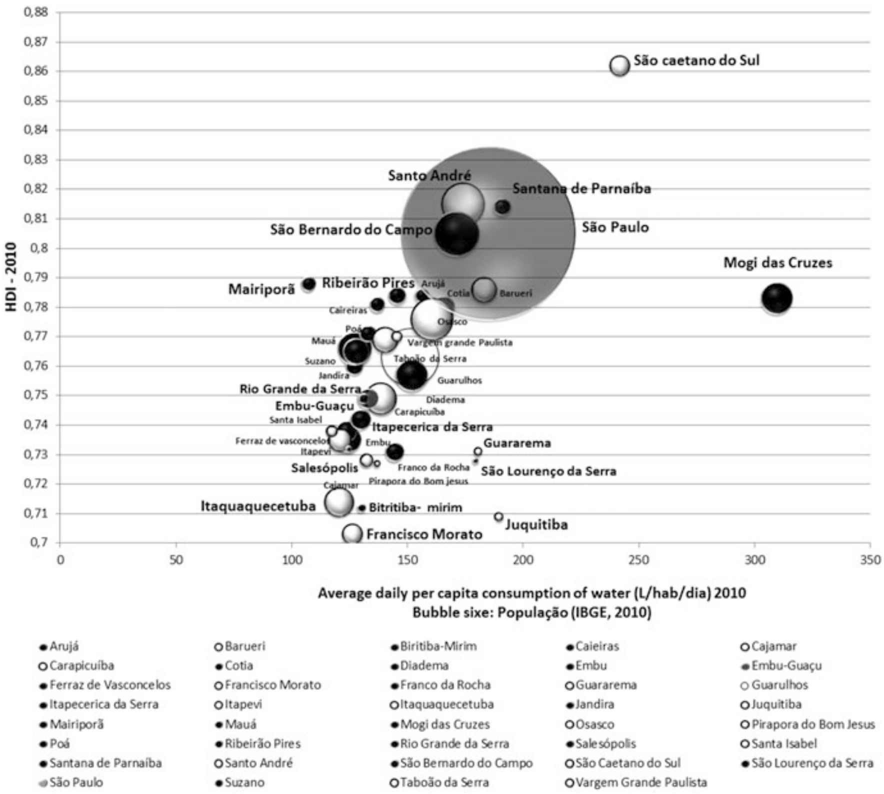
Source: CETESB (2013)
Note: Elaborated by the authors

process. On the other hand, better quality must be seen as an opportunity to increase the resilience to periods of severe water scarcity.

The MRSP is Brazil's biggest urban center with a population of 19.6 million inhabitants (IBGE 2011) distributed in 7.9 thousand km^2 (EMPLASA 2011). This metropolitan area encompasses the most important national and international financial center of Brazil having its economy mainly associated to the services sector in the areas of leisure, tourism, finances, health and education. Industrialization was the main leading force of São Paulo's urbanization. Nowadays, the industry is still important in the economy; however, it is not the prevailing activity. São Paulo is the biggest municipality of the metropolitan area with 11.2 million inhabitants (IBGE 2011) exerting a central role in terms of the historic process of urban sprawl and conurbation.

Results and Discussion

The distribution of HDI and water consumption per capita of the 39 municipalities of the MRSP (Graphic 24.1) denote a linear relation of growing consumption associated to social inclusion. In a timely short perspective from 2000 to 2010, although the population growth of the MRSP was not so dynamic (increase of 10.0 %), total demand for water supply grew faster (14.2 % in the period). Considering that in the last three decades the growing water demand for this metropolis induced a constant search for solutions and water availability (Gaviolli 2013), and this process was constantly threatened by the geographical scarcity of water resources, the expected economic ascent of Brazilian society reflects an unsustainable future for this mega-city in terms of water supply. The current crisis



Graphic 24.1 Distribution of municipalities by Human Development Index (IBGE 2011) and average daily per capita consumption of water (SNIS 2010), with the bubble size representing the population (IBGE 2011) and the presence of protected watershed areas in a darker tone (SIGAM undated) [*Source*: IBGE (2011) ref 2010, SNIS (2010). *Note* 1: elaborated by the authors. *Note* 2: although São Paulo has a significant watershed-protected area it is represented in gray tone considering its huge demand for water due to its amount of population in comparison to the others]

of severe drought is exacerbating the historic scenario of scarcity and constant growing demand for water in this metropolitan area.

An important issue related to environmental services, and specifically the service of water supply, is that all municipalities depend on this resource without worrying about the origin of the final product, in this case, “fresh water supply”. This product has a cost, not only financial, but also environmental and social for “producing municipalities”, in other words, the municipalities responsible for the favorable conditions for the maintenance of this environmental service. The regulating laws of the watershed-protected areas impose, on municipalities with part or all of their territory located in these areas, several restrictions of land use in order to guarantee this resource. However, the municipalities that provide this service, with legal obligation, do not have any subsidies for this protection.

The consumption and the production of this environmental service are not always related, meaning that the municipalities with the highest water consumption per capita are not necessarily the water providers.

To analyze the inequalities concerning access to water as an environmental service, municipalities were divided into blocks according to their characteristics: providers or receivers, or even both. As providers, were considered those with the largest areas of native forest remnants (able to protect springs and rivers), as well as those with 100 % of its territory in watershed protected areas. As receivers, those with the smaller areas of native forest remnants, as well as those municipalities that are not in watershed protected areas.

Table 24.1 shows the results of a ranking: Providers and receivers of water as an environmental service are grouped into blocks. Those that are the main providers are ranked by the higher potential for water production—marked in light gray. Those that are the main potential receivers, are ranked by an inverse relation considering how big their populations are and how high their water consumption per capita rates are—marked in dark gray.

Juquitiba, São Paulo, São Bernardo do Campo, Mogi das Cruzes and Cotia, for preserving native forest remnants, and São Lourenço da Serra, Embú-Guaçú, Itapecerica da Serra, Ribeirão Pires and Rio Grande da Serra, for keeping watershed-protected areas, are considered potential providers of water supply.[3] These municipalities are required, by law, to preserve these areas and cannot dispose of them for other purposes than preservation without any payment. Among these municipalities, Juquitiba (0.709), São Lourenço da Serra (0.728), Embú-Guaçú (0.749), Itapecerica da Serra (0.742), Ribeirão Pires (0.718) and Rio Grande da Serra (0.749), have the HDI[4] below the average for MRSP (0.757).

[3] Mairiporã is a very important municipality in terms of the total amount of water supply for the MRSP, once it receives water from other river basins from outside of the metropolitan territory. However, as the criteria applied in this study was to discuss about the internal metropolitan capacity of providing environmental services, Mairiporã was not classified as one of the main potential providers considering the amount of native forest remnants or watershed protected area.

[4] HDI—IBGE 2011.

Similarly, half of these provider municipalities (Mogi das Cruzes, Embu-Guaçu, Itapecerica da Serra, Ribeirão Pires and Rio Grande da Serra) have water consumption per capita below the median (149.99 l/inhab/day). While among the five largest consumers of liters of water per capita, four (São Caetano do Sul, Barueri, Juquitiba and Santa de Parnaíba) did not have watershed-protected areas. Four (São Caetano do Sul, Barueri, Santa de Parnaíba and São Paulo) of these five largest consumers of water per capita have the HDI above the average for the region (0.862, 0.786, 0.814 and 0.805, respectively).

When it comes to the demand for water, the cities with the five largest populations are placed as high receivers of this environmental service in MRSP. São Paulo, Guarulhos, São Bernardo do Campo, Santo André and Osasco comprise 14.6 million inhabitants, 74 % of the whole metropolitan population.

Not only quantity does matter when the issue is fresh water supply. Quality is also an important factor, since the necessary treatment and respective costs will depend on the water quality of the water bodies. In this sense, Table 24.2 presents the average of the water quality index acquired in different sampling points in 2013. Overall, the water bodies used for captation in the municipalities' providers of water are showed in the left column demonstrating the level of water quality index varying from good to great. Nevertheless, a great part of other important water bodies show water quality index in regular, bad or even harmful condition. In a territory of historic scarcity of water, the whole amount of water bodies that have showed worse conditions and have not been adopted, as sources should be an opportunity to increase the metropolitan water supply, mainly for industrial use. In other words a remarkable amount of water that have been polluted could help to mitigate the context of scarcity, but the degradation of natural resources in the metropolitan region is a consequence of the historic urban development also leading to a scenario of unsustainability (Jacobi 2013).

Similarities and differences among the municipalities require an integrative planning in the metropolitan range because these characteristics are related to determinant aspects of sustainability, which must be viewed as multi-dimensional. Ignoring the heterogeneity can undermine the defeat of public policies when these are focused on cities as isolated unities (SMVMA 2008).

Discussing aspects of urban human ecology Steiner (2004) brings primary concepts that can be relevant for the ability that cities must maintain to respond to change and positively adjust actions in order to improve their resilience. Among these concepts we identified five with meaningful worth significance in the case of the provision of the ecosystem service water for the MRSP:

(1) Structure, functions and change—the interrelationships in social systems can be considered as a product of connectivity and so, interactive processes provide a '*glue that holds the parts together in a system*' (Steiner 2004, p. 186). In the MRSP the interrelationship among receivers and providers of ecosystem services constitute an intrinsic element essential for the sustainability of the whole metropolitan system. On the other hand, the asymmetries in terms of the

unequal relation of provision of water conjoined with worse HDI and lower access per capita to water seem to be a fact that leads to a structural imbalance;

(2) Edges, boundaries and ecotones—Administrative divisions as the border of composing municipalities of the metropolis are not correspondent to the distribution of the ecosystem characteristics and their transitional zones, the ecotones. Sometimes a river and its riverbanks can be the border for two different municipalities; sometimes the same river goes across another municipality. The management of the ecosystem river then must occur considering the relation with the administrative and political arrangements present in its domain. The watershed protected areas although being considered as part of the municipalities should be understood as a vital component of the whole metropolitan system, and its conservation so should be a target of a metropolitan integrative management;

(3) Diversity—diverse ecosystems generally are rich, healthy and able to be resilient. Overlapping this concept to a metropolitan system the diversity among component municipalities can be considered relevant. On one hand it seem to be natural to identify municipalities with more important roles as providers of ecosystem services meanwhile others are more concentrated in terms of receiving such services and being also denser with population and economics. On the other hand, the inequalities among them can be viewed as unacceptable. In face of this, a search for equity is a necessary guideline of treating differently those, which are different. The peripheral municipalities should not have the worse HDI index; actually, they have to be the target of a process of sustainable development considered as fundamental parts of the metropolitan system;

(4) Adaptation—the ability of a system to answer to changes or disturbances in order to maintain its integrity. Adaptation can be related to the complexity of certain system in which there is a variety of possibilities to cope with external conditions and changes. In the current crisis of water provision posed to the MRSP several alternatives have been considered to cope with the severe drought, but there is a need for an integrative answer considering that 39 distinguishable municipalities compose the metropolis. Repairing the historic circumstances that carry out the process of severe pollution of water bodies can be considered relevant as an adaptive measure;

(5) Holism—A concept derived from the system theory that coined the term ‘holon’ as something that can be considered at the same time as a part and a whole. Holism is very useful to understand contexts of interactions and among different organization levels, i.e. cells, tissue, organism, population (Kay et al. 1999; Waltner-Toews 2001). Considering such a background, municipalities can be seen as a whole, having indeed their autonomy, but cannot be considered alone, but being part of a whole in a high level, the metropolis. One important thing in this sense is the perspective of interaction across municipalities and among the municipalities and the metropolitan areas. Under this perspective, the sustainability of the MRSP must be considered with the interdependence among the component municipality also considering that there is property of a loose hierarchical structure (Kay et al. 1999). For

example, an emergent crisis in an important peripheral municipality provider of water can represent a possibility of a system failure for the whole metropolitan area.

Conclusion

Analyzing the relationship of municipalities' providers and receivers of the environmental service water it is possible to understand that there is a necessary diversity to support the metropolitan demands. Otherwise, an unfair process of peripherization that also leads to the environmental degradation and worse social indicators leads to a growing vulnerability and a severe imbalance. In summary, diversity in terms of roles for municipalities can be something important for sustainability, but, when the municipalities responsible for providing environmental services suffer with an urban despoliation characterizing deep inequities this asymmetrical circumstance leads to an unsustainable scenario.

Another relevant aspect to consider is that certain similarities are not concentrated in specific areas conjoining homogenous groups of municipalities. Therefore, aspects inherent to the environment and essential to sustainability of the metropolitan whole can be in part concentrated and in part dispersed throughout the component municipalities. This characteristic alongside with the need for an understanding of the wholeness of the metropolitan system reveals that it is not possible do adopt single and isolated interventions to cope with the complexity of a metropolitan system when dealing with the necessary resilience to pose uncertain scenarios of climate variability.

The overlapping of the social precariousness is not necessarily compatible with the environmental aspects so the municipalities with worse social indicators considered as peripheral can be, on the other hand, centralities in terms of the provision of environmental services. That is what can be realized analyzing the asymmetries in the MRSP and so this characteristic of heterogeneity and inequity can be viewed as fundamental to the understanding, planning and acting in order to improve resilience.

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Chapter 25
Water Supply, Climate Change and Health Risk Factors: Example Case of São Paulo—Brazil

Sofia Lizarralde Oliver and Helena Ribeiro

Abstract Studies indicate the potential carcinogenic and other harmful effects on health of *Microcystis aeruginosa* (cyanobacteria) in drinking water. Cyanobacteria blooms are becoming an increasingly common phenomenon worldwide, especially in urban lakes and reservoirs. The aim of this chapter is to demonstrate the potential relationship between cyanobacteria in the drinking water from the Guarapiranga Reservoir and climate change in the Metropolitan Region of São Paulo, as well as health risks factors associated. Methods used: literature review and analysis of data on water quality and climate parameters. Results: The Guarapiranga Reservoir in São Paulo-Brazil, accountable for supplying water to 3.8 million inhabitants of this city, has shown frequent cyanobacterial blooms when the temperature rises and in rainy weather (summer). Climate change in the city of São Paulo can worsen these problems related to drinking water once the ideal climatic conditions for the proliferation of cyanobacteria are increasing in frequency. Especially in the last 20 years, the maximum temperatures are higher and episodes of heavy rain are more frequent. This scenario can magnify a public health problem related to cyanobacteria in São Paulo and around the world. Climate change may increase public health risks related to drinking water quality as associated with land use.

Keywords Drinking water • Climate change • Megacities • Public health • Environmental health

Introduction

Overall, 54 % of the world population lived in urban areas in 2014 (United Nations 2014). In 1950, 30 % of that population was urban and, in 2050, 66 % of the world population is expected to be living in urban environments. The world's urban population has increased rapidly since 1950, from 746 to 3900 million in 2014.

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In 2014, the World Urbanization Prospects recorded 28 megacities in the world, home to 453 million people, or about 12 % of the world population. Sixteen of them are located in Asia, four in Latin America, three in Africa and Europe and two in North America. Most megacities and large cities are located in the global South. The fastest growing cities are located in Asia and Africa, in developing countries. Most of them lack sanitary infrastructure such as sewage collection and treatment that is efficient and sufficient for the entire population.

The continual environmental degradation in water basins with intense human occupation has significantly altered the quality of water bodies predominantly used for public supply. The artificial enrichment of aquatic ecosystems—the eutrophication—is due to nutrients, such as nitrogen and phosphorus from industrial effluent and domestic sewage discharge without proper treatment, destruction of riparian vegetation around water sources, high urbanization rate, poor sanitation, air pollution, and use of fertilizers in agriculture (Esteves and Meirelles-Pereira 2011). According to Vidotti and Rollemberg (2004), algae are directly affected by chemical or household effluents that have nitrogen (N) and phosphorus (P) as macronutrients. In addition to the concentration of nutrients, favorable conditions of temperature, pH, and stability of the water column, there is the rapid algae population growth—a phenomenon known as blooms—a condition that indicates deterioration of the water quality. In accordance with seasonality, there is a greater or lesser proliferation of cyanobacteria, also known as blue algae.

According to WHO (1999), that year, 28 % of lakes in Africa were eutrophic; 41 % in South America; 48 % in North America; and in East Asia the eutrophic lakes amounted to 54 %.

Climate change, characterized by the intensification of natural phenomena—such as periods of intense rainfall or extended periods of drought—may result in ideal environments for blooms of cyanobacteria, when associated with other environmental factors. Although eutrophication can occur naturally, in most cases, it is linked to discharges of untreated or inadequately treated sewage in water bodies. The weather elements are also predispositors.

Following WHO (2011), whenever the conditions of temperature, light and nutritional status are favorable, the surface of fresh or seawater may host an increase in the amount of cyanobacteria. However, there are major differences in cyanobacterial blooms in temperate and in tropical waters.

There is a characteristic pattern of seasonality in algal blooms and cyanobacterial communities. In temperate countries, in eutrophic and hypertrophic waters, cyanobacteria often dominate the environment in the summer period. As winter approaches, the increased turbulence and absence of light lead to their replacement by diatoms. In the tropics, however, the seasonal differences in environmental factors are often not large enough to induce the replacement of cyanobacteria by other species of phytoplankton. Thus, cyanobacteria may be present or even dominant for the most part of the year, bringing practical problems associated with high biomass of cyanobacteria and potential health hazards by increasing toxin (WHO 1999).

According to Fonseca et al. (2010), the cyanobacterial proliferation in eutrophic environments occurs in the months when the water temperature is around 22 °C. Water at an average temperature above 25 °C was sufficient to trigger the flowering of cyanobacteria. In freshwater environments with basic pH, temperatures ranging from 15 to 30 °C and high concentrations of nitrogen and phosphorus, this microorganism has its growth accelerated. They have identified the increase in cyanobacteria density during the rainy season. They argue that this behavior is directly related to increased availability of nutrients in the period. Esteves and Suzuki (2011) state that the availability of nutrients is controlled not only by the artificial addition of compounds and also chemical and organic elements, but by external ecosystem factors as well, such as wind, rainfall and incident radiation.

For Esteves and Meirelles-Pereira (2011), the climate changes in recent decades are potential causes of variations in the hydrological cycle. Designed models of the changes to which the planet is submitted show the increase in global average temperature. Besides, Esteves and Suzuki (2011) claim that long-term studies have also allowed to observe, in addition to seasonal variations, interannual variations related to the phenomena La Niña and El Niño Southern Oscillation (ENSO), noting, in periods of influence of La Niña the massive dominance of cyanobacteria and, under the influence of El Niño, besides cyanobacteria, diatoms and cryptomonads. Although the blooms are not exclusive of low latitude countries, that is where cyanobacteria meet the best conditions to proliferate. By 2030, 41 megacities with 10 million inhabitants or more are projected. According to the United Nations (2014), China and India will contribute more than one third of the increase in the urban population between 2014 and 2050.

In large cities, it is common to import water from other river basins for local supply. This water, which comes through the supply network, goes out the sewer, reaching the rivers and causing increased runoff volume (Ribeiro et al. 2010). The increase in heat causes a movement tendency of the wind, from the periphery to the central region of the urban area with the formation of one or more convection cells, causing more cloud formation and bringing up the total rainfall. Moreover, it can favor the creation of vectors of waterborne diseases. The additional rainfall may increase the larval habitat and the vector population as it creates a new habitat, so as the lack of rain can have more mosquitoes breeding in containers as it forces water storage (Patz 2010).

Thus, the variation in the intensity of rainfall patterns may pose risks to the population health. In after-torrential rain periods, waterborne diseases are more spread.

The waters that reach urban river basins after torrential rains come heavily contaminated with garbage and dirt from the streets of the runoff loads. Furthermore, they often mix with the sanitation and sewage system due to the large volume of water passing through the channels in a short span of time, which causes the drainage system to be insufficient.

Primavesi et al. (2007) state that the environmental impacts and interference on the urban water cycle cause delay in the rainy seasons, more frequent and more intense dry spells during the rainy seasons (less durable frontal rainfalls as a result

Table 25.1 Deterioration of the quality of surface water and groundwater

State of	Source[a]	Consequences[a]
Eutrophication	Raw sewage waste water, industrial and agricultural effluents	Excessive algae blooms which may contain toxic strains, high levels of total suspended solids
Contamination	By heavy metals and organic substances as hydrocarbons, pesticides e herbicides	Excessive algae blooms, soil and fresh-water acidification
High levels of total suspended solids	Excessive algae blooms, storm water runoff	Visibility or clarity decreases, surface water temperature increase
Acidification	Disposal of industrial and agricultural waste	The contamination of the air, soil and surface and groundwater
Increase of waterborne and vector-borne disease	Surface and underground waters quality deterioration	Increased incidence and spread of waterborne and vector-borne diseases

[a]Examples
Data Source: Adapted from Tundisi (2008)

of shorter cold fronts), more intense tropical (convective) rains caused by warmer air masses saturated with water which results in greater water flow, more flooding and more erosive power of rainfall, although the annual rainfall volume may remain unchanged, reduction in the water replacement to groundwater tables, major droughts and intensification of sedimentation processes, of contamination of water bodies and of water eutrophication increased risk of appearance of phytoplankton, such as cyanobacteria. Table 25.1 illustrates the various aspects of deterioration in the quality of surface waters.

In developing countries, urban planning, when it occurs, is held in cities occupied by the population of middle and high income. According to Tucci (2008), what is left for the low-income population are the invasion and occupation of areas at risk of flooding and landslide, with frequent losses—both material and human—especially during the rainy seasons, which is the case of Brazilian cities in the states of Rio de Janeiro and São Paulo. A major part of the population tends to live in some kind of substandard housing. Tucci (2008) argues that there is a formal city and an informal city, and that urban management usually only reaches the first of them.

The larger the share of "informal city" the greater the proportion of untreated sewage being added to the water bodies fit to help form the nearest reservoir. Although the "informal city" share may be subject to more negative consequences related to climate dynamics, such as floods and landslides, the entire population of the city supplied with water from a contaminated reservoir, whether belonging to the formal or informal city, is subject to variations in the quality and healthiness of this well.

Urban settings of megacities generate intrinsically potential risks to the water supply of the population.

The "contamination and the increase in toxic substances in water and in vectors of waterborne diseases are closely related to sanitation and improper treatment conditions of water contaminated by various processes" (Tundisi 2008). According to the author, one of the most serious problems nowadays is the deterioration of water quality—usually for lack of wastewater treatment—which is worrying, “the toxicity of aquatic environments and water bodies and also the countless organic substances dissolved in water, which cause multiple direct or indirect impacts on human health” (Tundisi 2008).

The occurrence of cyanobacterial blooms in eutrophic reservoirs has been regarded as a worldwide problem (Fonseca et al. 2010). According to the World Health Organization (WHO), the eutrophication process has admittedly become a pollution problem in many lakes and reservoirs in Europe and North America since the mid-twentieth century. Since then, the eutrophication of surface waters has become increasingly frequent, causing deterioration of aquatic environments and serious problems for the use of water, especially in the treatment of drinking water (WHO 1999).

In 1995, the American Water Works Association Guide (AWWA), “Cyanobacterial Blue-Green Algae”, compiled 94 cases of poisoning of domestic animals, rural animals and wildlife by cyanotoxins in countries such as Australia, United States, Canada, Finland, Russia, South Africa, Bermuda, New Zealand, England, Argentina, France, Scotland and Germany. The poisoning of human populations by the ingestion of contaminated water with cyanotoxins has been described in several countries, such as Australia, England, China and South Africa.

Human Intoxication and Public Health

Cyanobacteria are widely known for their potential to produce cyanotoxins. Depending on the type of toxin, a slower poisoning may occur, such as those caused by microcystin, nodularins and cylindrospermopsins (hepatotoxins), which are the most common and can cause the death of the animals within a few hours or a few days, due to liver hemorrhage and hypovolemic shock. However, there is also the poisoning by anatoxin, anatoxin-a(s) and saxitoxins (neurotoxins), which cause rapid death of animals by respiratory arrest (Esteves and Suzuki 2011). The effects on human health can range from liver, gastrointestinal disorders, neuromuscular dysfunction, allergic reactions, cancer and death.

The cyanotoxins entail problems to human and environmental health because they are water-soluble and pass through the conventional treatment system, being even resistant to boiling. Therefore, the monitoring of toxic cyanobacteria and cyanotoxins in water sources for public supply is essential to map the locations with potential risk.

Cases of poisoning have been recorded in countries located in several continents and latitudes; however, there has been a predominance of reports concerning the Northern Hemisphere. This may be related to the earlier industrialization process that took place in that region while the peripheral regions are subsequent, with their urban agglomerations and related issues.

In the literature in this regard some cases are emblematic, as reported by Falconer (2001) in Australia. Falconer (2001) describes the constant cyanobacterial blooms in Australian history, characterized as a common issue, especially for agriculture and for human water supply; but that the first case of poisoning by water in that country was described in 1878, and the environmental disaster is still reflected in the names of streams that cross the country; for example, in the designation of "Poison Creek Waterhole".

And the case among the most serious ones of poisoning by cyanotoxins became known as the Caruaru syndrome, for the death of 52 patients with symptoms of acute hepatotoxicosis caused by microcystins in Caruaru, in the state of Pernambuco, Brazil, after the use of contaminated water in hemodialysis (Carmichael et al. 2001). Thus, toxic events are not uncommon, as well as blooms in different types of weather.

The aim of this chapter is to demonstrate the potential relationship between cyanobacteria in the drinking water from the Guarapiranga Reservoir and climate change in the Metropolitan Region of São Paulo, as well as health risks factors associated.

Studies report the bloom of potentially toxic cyanobacteria in surface waters in many cities in Brazil. In São Paulo, blooms in Guarapiranga were studied and, in them, toxic strains found in the most endangered reservoir region (Rodrigues et al. 2010; Oliver and Ribeiro 2014). Along with the Billings reservoir, the Guarapiranga reservoir feeds the second largest supply system of the metropolitan region, which produces 14,000 l of water per second and supplies 3.7 million people in the South and Southwest zones of the Capital, according to the Basic Sanitation Company of the State of São Paulo; which is equivalent to about 18 % of the population of the Metropolitan Area of São Paulo.

Study Area

The city of São Paulo—in the State of São Paulo—Brazil, is bisected by the Tropic of Capricorn and located in the range between 23°20′ and 24°00′ S latitude and 46°20′ and 46°50′ longitude W, 760 m above sea level. With these features, it sets up a climatic reality of transition between the humid tropical climates of altitude, with dry period defined, and the permanently humid subtropical climates, typical of Southern Brazil. Due to its location in this transition zone, the Metropolitan region of São Paulo is distinguished by the alternation between the two types of climate, outlining a hot and humid season in summer, and a cold and dry one in winter. According to the Köppen-Geiger classification, the climate in São Paulo is Subtropical Cwa.

To the South, the city is limited by the Serra do Mar mountains. To the West, North and East it is surrounded by the 39 municipalities that make up the metropolitan region of São Paulo, in a 7497.3 km^2 conurbation. Of the 20.820.093 inhabitants of the region, more than half live in the city of São Paulo, with its 11,376,685 inhabitants, according to the 2010 Brazilian census.

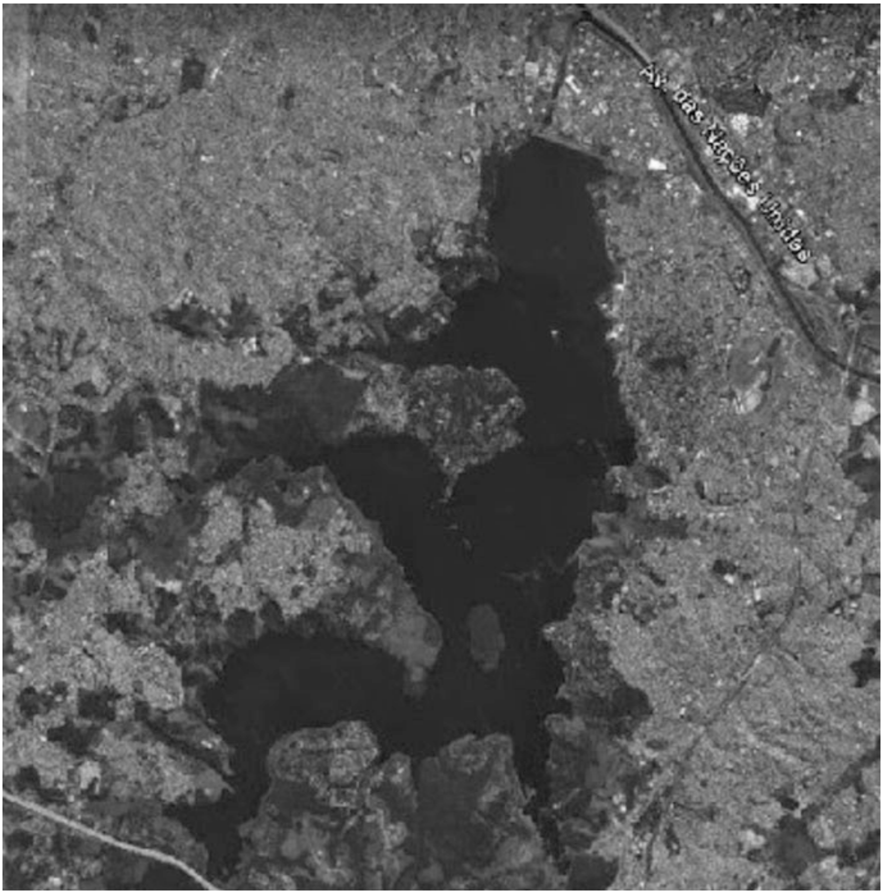

Fig. 25.1 Satellite image showing human occupation around the Guarapiranga reservoir (*Source*: Image 2013, DigitalGlobe 2013 accessed Google Earth in 23/05/2013. Image date: 13/07/2012, altitude of eye point 28.30 km)

The Metropolitan Region of São Paulo is the main economic hub in the country and one of the most densely populated regions of the world. Such characteristics favor the occurrence of serious environmental problems such as contamination of drinking water supply sources (Richter et al. 2007). According to Whately and Cunha (2006), in 2006, the areas of protected water supply already housed more than 10 % of the urbanized area and 18 % of substandard housing areas in the entire metropolitan area, totaling a population of over 1.6 million people. The urban setting and the way the urban area have expanded toward the springs compromise the water quality, leading to problems both in its raw condition as in the water already treated, especially overlapping problems of anthropogenic pollution to climate change in the region, as is common in densely populated locations (Fig. 25.1).

Methods

Literature Review

A search of relevant literature to the topic addressed in the research was conducted. Search tools in databases and virtual libraries were used (LILACS; PubMed; SciELO; SIBiUSP and Web of Science), as well as visits to the physical libraries of the University of São Paulo.

In this search, the following keywords were used, either alone or in combinations: cyanobacteria (Portuguese), cyanobacteria (English), cyanobacterial proliferation, cyanobacteria blooms, water supply systems, water supply, urban water supply, urban water supply systems, urban water sources, water sources, climate change, climate variability, climatic variations, climate and the Metropolitan Region of São Paulo.

Papers have been chosen for combining at least two of the defined keywords (cyanobacteria, water for public supply and climate). Of these, the reading of the abstracts has caused the exclusion of those not addressing the research focus. Papers cited in the references of the studies researched have also been consulted, as well as some appointed by professors and researchers in the area.

Data and information from electronic sites of Brazilian, São Paulo State and São Paulo City government agencies were also accessed, as well as non-governmental organizations.

Analyses

Meteorological data were provided by the meteorological station of the Astronomy, Geophysics and Atmospheric Sciences Institute, University of São Paulo (EM-IAG/USP)[1,2]. The EM-IAG/USP is located within the Ipiranga Water sources State Park (PEFI) at 23°39′ S latitude and 46°37′ W longitude in the Agua Funda district, in the southern area of the municipality, 799.2 m above sea level. It is registered with the World Meteorological Organization under nr. 83.004. The meteorological variables used were atmospheric temperature daily average, daily maximum and minimum temperatures (T°C); Rainfall (PMM) in rain millimeters accumulated per day.

All graphs were generated with Microsoft®Excel15.0 software (Office 2013).

[1] EM-IAG/USP = Weather Station from the Institute of Astronomy, Geophysics and Atmospheric Sciences of the University of São Paulo (Estação Meteorológica do Instituto de Astronomia, Geofísica e Ciências Atmosféricas/Universidade de São Paulo)

[2] SABESP = Basic Sanitary Company of São Paulo State, SABESP (in portuguese (Companhia de Saneamento Básico do Estado de São Paulo)

Meteorological Variables Adopted

- Atmospheric temperature (T°C) in Celsius degrees
- Rainfall (Pmm) in millimeters of rain

Debate and Outcomes

Blooms in reservoirs of the Metropolitan Region of São Paulo have been reported (Rodrigues et al. 2010) highlighting the Guarapiranga Reservoir, where toxic strains were found. The study conducted by Oliver and Ribeiro (2014) relating the cyanobacteria with the climate of São Paulo had as results evidence that cyanobacteria are sensitive to climatic change in the Metropolitan Region of São Paulo. The study mentioned has concluded that the hot and rainy periods may enhance the proliferation of cyanobacteria in the Guarapiranga reservoir, especially at higher maximum temperatures such as those seen in the summer.

The study has relied on data from the years 2010, 2011 and 2012 of rainfall and water quality of the Guarapiranga Reservoir. Figures 25.2 and 25.3 show the accumulated rainfall per month, adding the values for the corresponding months of each year. Therefore, the totals sum January precipitation of 2010, January 2011 and January 2012, and so on for each month of the 3 years. The same has been done with the monthly totals of gross values of cyanobacteria density in two different collection points of Guarapiranga Reservoir, the GU 101 in the middle of the reservoir and the GU 104 in the water capture to the treatment plant.

Figure 25.2 shows the typical pace of annual rainfall in São Paulo. In a way, cyanobacteria values at GU 104 collection point follow the rainfall variation, albeit

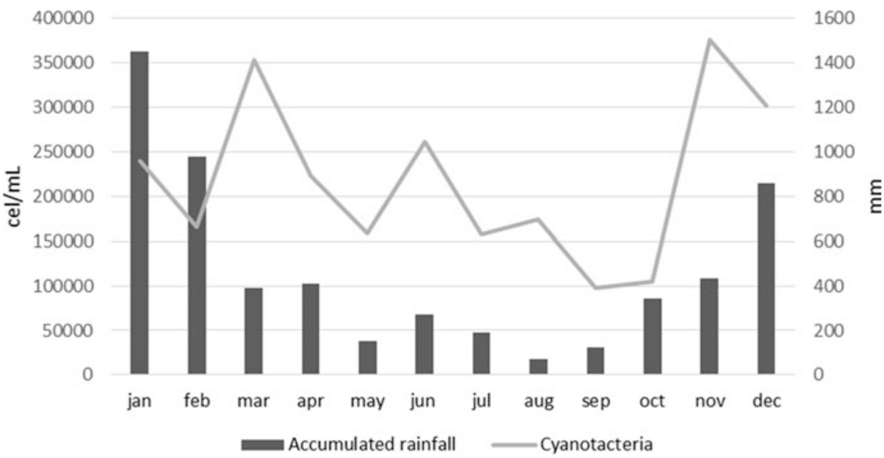

Fig. 25.2 Monthly totals of rainfall and cyanobacteria density per month (2010–2012) at GU 104 (*Data Source*: EM-IAG/USP (2013), SABESP (2013))

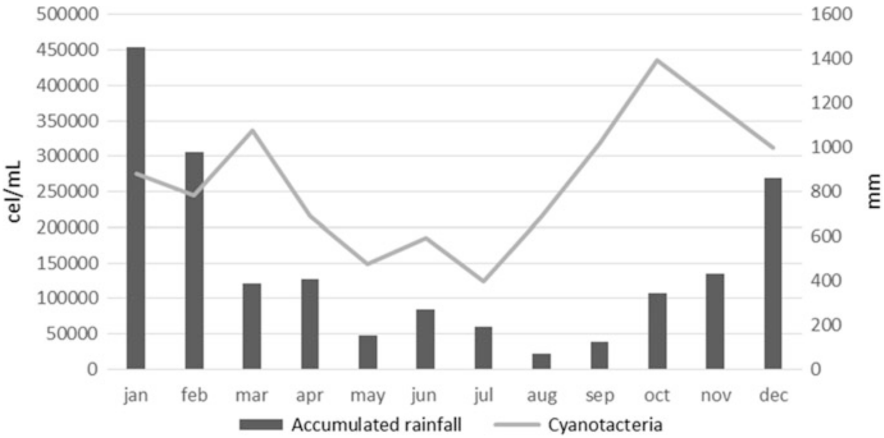

Fig. 25.3 Total monthly values of rainfall and cyanobacterial density accumulated per month (2010–2012) at GU 101 (*Data Source*: EM-IAG/USP (2013), SABESP (2013))

in a milder way. It is clear, however, that the onset of the rains after the dry season, in October and November, contributes to the cyanobacteria proliferation. This phenomenon can be explained by the increased supply of nutrients due to both the natural process and the wash made by the rain with runoff water in the metropolitan area, carrying debris deposited on the reservoir banks. In addition, the increase in nutrients converges from tributaries of the reservoir that are connected to the sewer galleries and sluice gates of the metropolitan region. This cyanobacteria density remains high during the hot rainy season, but decreases slightly during the cold and dry season.

In Fig. 25.3, the relation between cyanobacteria density and rainfall becomes more clear: the same phenomenon of increasing proliferation at the start of the rainy season is observed in the early spring (October), maintained at a high level until the decrease of rainfall and temperature in April.

It is necessary to point out that the difference in results between a collection point and another is due to the fact that one of them is in the middle of the dam (GU 104) while the other is in the capturing inlet (GU 101) of the Guarapiranga Reservoir System, a dam characterized by lentic system. Thus, the movement of organic matter present in the water body is limited, except in episodes of rain. There is a difference in the distribution of organic matter as a result of the water column depth and the proximity of the shore.

Figure 25.4, with data of absolute maximum annual temperatures shows a raise in a series of 44 years.

Figure 25.5 demonstrates the increase in maximum temperatures and their frequency in the last two decades. A change in the pattern starting from 1988 is noticeable, but from 1993 on, the increase in the frequency of maximum temperatures is evidenced.

Analysis of data in the figures indicates that the temperature has risen by an average of 0.27 °C per decade in the Metropolitan Region of São Paulo. In

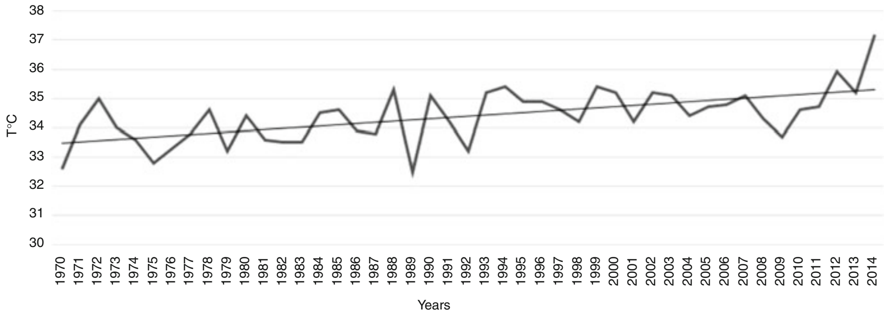

Fig. 25.4 Absolute maximum annual temperatures (1970–2014) (*Source*: EM-IAG/USP (2015))

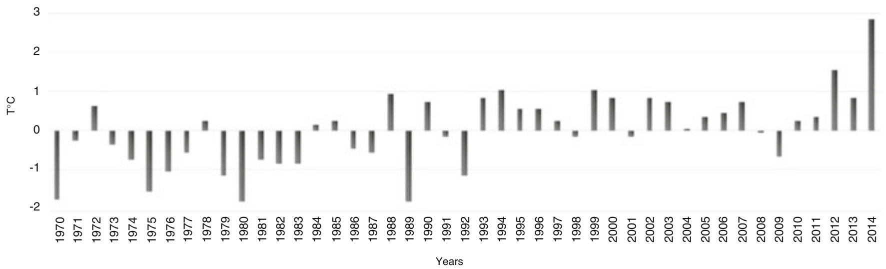

Fig. 25.5 Deviation of maximum annual temperatures as compared to the average of maximum temperatures (°C) from 1970 to 2014 (*Data Source*: EM-IAG/USP (2015))

Fig. 25.5, deviations from the maximum annual temperature between 1970 and 2014 may be compared to the climatological average in the same period. Looks like from the year 1991 only 6 years have had maximum temperatures lower than the average 34.35 °C, while the opposite is true for the previous series, 1970–1990, in which only 6 out of 20 years have had absolute maximum temperatures above the period average. It is still possible to see that the 10 years with the highest maximum temperatures have happened after 1988.

Figure 25.6 shows the time series of annual rainfall from 1970 to 2014 in São Paulo. During this period, rainfall has increased, as shown in the trend line. There has been an average increase of 121.7 mm per decade between 1970 and 2014.

Figure 25.7 portrays the rainy days each year from 1970 to 2014. Year after year, the reduction in the number of days with rainfall can be observed.

Using the month of January as a reference, since it is the wettest month of the year, the trend in Fig. 25.8 suggests an increase of rainfall even more pronounced than the trend of accumulated rainfall per year. Adding to the information that the number of days when there is rainfall per year has been decreasing since 1970 (Fig. 25.7) a scenario unfolds in which, in addition to the increasing rainfall in the city of São Paulo, the days when it occurs are decreasing and more focused on episodes of more intense rainfall that overload the city's drainage system causing more frequent floods, as well as the diffuse charge density that is added to rivers and reservoirs in the region.

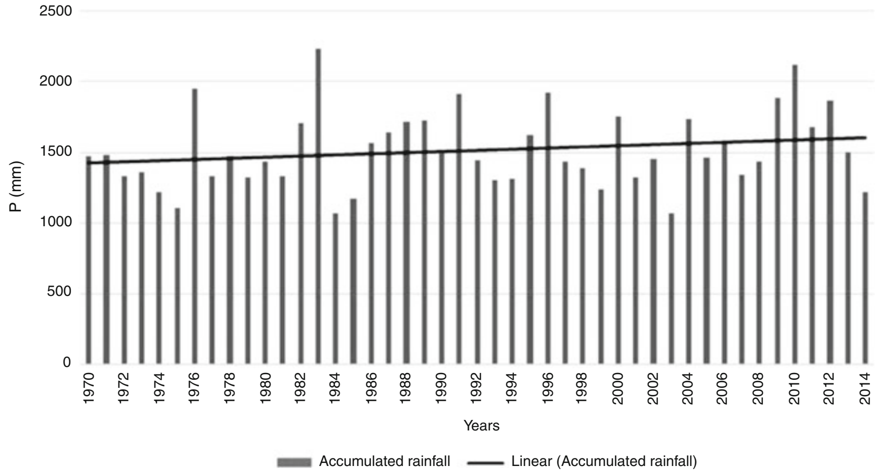

Fig. 25.6 Yearly accumulated rainfall 1970–2014 (*Data Source*: EM-IAG/USP (2015))

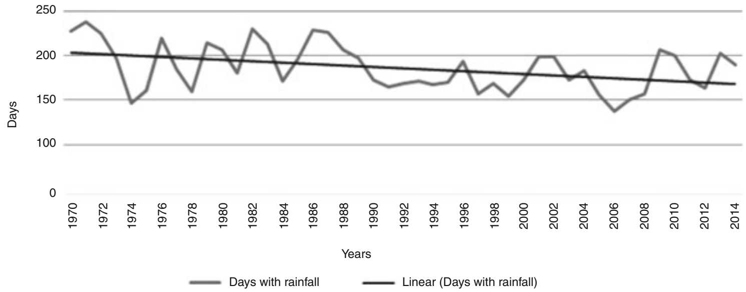

Fig. 25.7 Days with rainfall in São Paulo per year (1970–2014) (*Data Source*: EM-IAG/USP (2015))

Besides this addition of nutrients through the diffuse load from runoff, sparse rainfall episodes can find a more polluted atmosphere when they occur, causing the precipitated water to reach the surface already loaded with nutrients, once it is a major natural source of phosphate (inorganic version of phosphorus) and nitrogen. The rainfall is more important as a source of nutrients in regions of intense air pollution, and industrial regions may have higher average values of phosphate. Reservoirs near highways may receive additional intake of phosphate and nitrogen due to vehicle traffic, especially during the rainy season (Esteves and Meirelles-Pereira 2011).

Results found confirm the studies (Pereira-Filho et al. 2007; Nobre et al. 2010; Marengo et al. 2013) and indicate the strong climate variability over the last two decades.

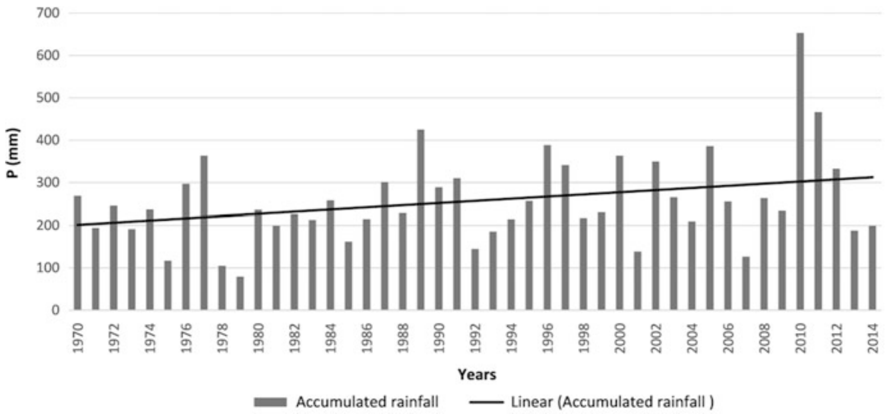

Fig. 25.8 Rainfall accumulated for the months of January each year (1970–2014) (*Data Source*: EM-IAG/USP (2015))

Conclusion

According to the findings of this study, the ideal climatic conditions for the proliferation of cyanobacteria in the Guarapiranga Reservoir have been accentuated in the last four decades and more so in the last 20 years. According to the climatological trends presented, this is a scenario to worsen.

One can infer, therefore, that the frequency and intensity of cyanobacterial blooms in the Guarapiranga Reservoir and the resulting risks to human health can increase while the foregoing conditions are accentuated.

The growth of megacities is noted as producing an environment more often featuring reservoir eutrophication. This study has showed an example of a megacity with all urban problems common to most of the megacities in developing countries, especially those located in low latitude tropical and subtropical climates. This is the case of the city of São Paulo, where a problem that already occurs and deserves attention regarding prophylaxis in public health can be further aggravated when found in the scenario of climate change with increasing temperature in these regions and their influence on rainfall and air and soil pollution, closing a cycle of influence in the hydrological cycle.

Therefore, attention to adaptations to climate change in megacities is needed, especially with respect to infrastructure and urban planning to minimize impacts to the environment, safety and public health. These are adaptations that also apply to solve other usual public health problems of megacities in tropical and subtropical climates, as they derive from climate impacts such as water shortage, floods, waterborne disease epidemics, vector increase seasonality, among others.

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Chapter 26
Introducing Hydro-Climatic Extremes and Human Impacts in Bolivia, Paraguay and Uruguay

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Abstract Climate change and ENSO events are increasing hydro-climatic risks and health impacts in Bolivia, Paraguay and Uruguay, as well as social inequalities in Bolivia and Paraguay. Climate scenarios project increase in average temperature in the whole region, a slight decrease in precipitation and modified rainy patterns in the Andean region and Paraguay for 2040. More hydro-climatic extremes are also expected, which will likely worsen health vulnerability without further adaptation

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measures. A Vulnerability, Impact and Adaptation Network conducted research on excessive rainfall, floods and land-slides from 2007 to 2014 in Bolivia, Paraguay and Uruguay. Herein, a case study of the vulnerability and human impacts of an extreme rainfall and land-slide in Callapa, La Paz, Bolivia in 2011 is presented. As result of early warning system (EWS) and emergency systems human life losses were not recorded. A comparison between two districts (with and without land-slide) was made modifying Urban HEART equity instrument. Its goal was to better inform the adaptation and community resilience measurements design. The health outcomes included dehydration, diarrhea, acute respiratory infections, and mental health issues. Inter-sectoral policies and strategies were developed to improve climate adaptation measures. Despite strong differences in socio-economic and health status the three studied countries are vulnerable to hydro-climatic extremes. EWS and preparedness based on climate and socio-economic assessments and monitoring are crucial to increase resilience to extreme events.

Keywords Climate scenarios • Capacity building • Climate inequality • Disasters • Early warning • ENSO • Floods • Landslide • Waterborne diseases

Introduction

> Climate change may bring some localized positive effects in health, but, the overall health effects of climate change are likely to be severely negative. Between 2030 and 2050, climate change is expected to cause approximately 250,000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress. http://www.who.int/mediacentre/factsheets/fs266/en/

Climate and Human Impact Network: Bolivia, Paraguay and Uruguay

> Emphasis must be put on building capacity to develop a community of experts in Climate Science Management and the co-production of knowledge with the aim of increasing public awareness and trust, through a participatory and informed process (Coronel et al. 2015)

This chapter is the first of two written by the "Climate Vulnerability, Impact and Adaptation Network" (CliVIA-N). This interdisciplinary Education and Research Programme is jointly developed by the three following academic groups from Bolivia, Paraguay and Uruguay:

- Climate Change and Environmental Health Unit (UCCLIMAS), Universidad Mayor de San Andrés (UMSA), La Paz, Bolivia;
- Master's degree Program in global change and climate risks of the National University of Asuncion, Paraguay (FP-UNA);
- Graduate Programs in Environmental Sciences, School of Sciences, University of the Republic (FC-UdelaR), Montevideo, Uruguay, respectively.

Both education and research outcomes include the use of climate and environmental scenarios, vulnerability, impacts and adaptation (VIA) and community participatory assessments, stakeholders' analysis, eco-health and risk-management approaches to developing climate adaptation policies and resilience strategies. Emphasis is put on the "adaptation deficit" to current climate variability and observed changes or a failure to keep pace with development (Burton 2004) which captures the notion that countries are underprepared for current climate conditions, much less for future climate change. The shortfall is not the result of low levels of development but of less than optimal allocations of limited resources (EACC 2012). CliVIA-N focuses on current hydro-climatic variability and extremes (droughts, floods and land-slides), VIA assessments, and the potential impacts associated with plausible future climate change scenarios. The two chapters of CliVIA-N are as follows:

1. "Introducing hydro-climatic extremes and human Impacts in Bolivia, Paraguay and Uruguay" (Aparicio-Effen et al.). This chapter introduces the overall socio-economic and health status, climate scenarios and risks, focusing on the only recent extreme land-slide in the studied countries, the Callapa mega land-slide occurred at La Paz associated with excess rainfall during El Niño event 2006–2007.
2. "Impacts on well-being and health by excessive rainfall and floods in Paraguay, Uruguay and Bolivia" (Nagy et al. 2016). This chapter focuses on the human and health impacts of excessive rainfall and floods associated with El Niño events. Three case studies on floods are presented.

Climate Change and Variability: Human Impacts and Health Inequality

Global climate change has become one of the most visible environmental problems of the twenty-first century. However, to date, most research has focused on the environmental effects and rarely in health effects. There is no doubt that climate change affects public health through countless environmental consequences, such as changes in precipitation, floods, droughts, heat waves and others (Campbell-Lendrum et al. 2009; OMS 2014).

These changes and extreme events could enhance the spread of climate sensitive diseases. Increases in the frequency or severity of extreme weather events such as rainfall, storms, high winds, hailstorm, could increase the risk of flooding, land-slide and produce direct damages to people and property. Since the early twentieth century, new infectious agents have emerged. Also, other preexisting agents who were considered controlled reemerged (Londoño et al. 2011).

A WHO report estimates the future global burden of disease as a result of climate change. For example, it estimates a 10 % increase in diarrheal disease than without climate change in 2030 (Shuman 2010). Despite a limited knowledge primarily focused on vector-borne pathogens (Lafferty 2009; Epstein 2010), climate change is commonly predicted to impact the transmission of infectious diseases and their geographical distribution (McMichael et al. 2006; Senior 2008).

According to The Royal Society (2015) "The direct and indirect physical and mental impacts of climate change on health and well-being are considerable. Extreme weather events can cause injury and death while infrastructure losses, mental stress and trauma can have long-term effects. Future changes in temperature and rainfall regimes could alter the distribution and transmission of vector-, food- and water-borne diseases. More frequent extreme weather events will also place a greater and growing demand on public health and emergency services".

Countries in Latin American and the Caribbean (LAC) are significantly affected by adverse consequences from climate variability and extremes, particularly the El Niño Southern Oscillation (ENSO) events (McCarthy et al. 2001). Central and South America has multiple anthropogenic stressors on natural and human systems exacerbated by climate variability and change. Decadal variability and changes in extremes have been affecting large sectors of population, especially those more vulnerable and exposed to climate hazards (Magrin et al. 2014).

El Niño Southern Oscillation (ENSO) events are the cause of many flooded, drought and land-slides areas that are prone to the transmission of Hantavirus, E. Coli, Hepatitis A, Malaria, Dengue, Leptospirosis, Leishmanias in Latin America (Nagy et al. 2006; Magrin et al. 2007). During extreme droughts, floodings and land-slides there is an increase in the number of diarrhea due to the lack of potable water or its contamination by flooding waters.

According to Watson et al. (2007) "the relationship between natural disasters and communicable diseases is frequently misconstrued. The risk for outbreaks is often presumed to be very high in the chaos that follows natural disasters, a fear likely derived from a perceived association between dead bodies and epidemics. However, the risk factors for outbreaks after disasters are associated primarily with population displacement. The availability of safe water and sanitation facilities, the degree of crowding, the underlying health status of the population, and the availability of healthcare services all interact within the context of the local disease ecology to influence the risk for communicable diseases and death in the affected population".

In this chapter the health and socio-economic status as well as the availability of safe water, sanitation and healthcare services are considered as key factors, especially when there is no massive population displacement.

Latin America (LA) is a highly urbanised region; almost 80 % of its population lives in cities, 14 % of who live in megacities (UN-Habitat 2012). The epidemiological profile in LA is marked by diseases of poverty and current socio-economic inequalities. The diarrhea and respiratory infections in children still constitute a serious problem in some regions. Climate change is producing ecosystem changes with vector-borne transmissible diseases increase. Chagas, Leishmaniasis and Malaria are amplifying their geographic and altitudinal distribution. In Andean countries, glacial retreat is reducing the quality and availability of drinking water, and also threatens hydroelectricity supply. In Bolivia, 80 % of glaciers are retreating; the Chacaltaya glacier shrank from 0.22 km^2 of surface ice in 1940 to only 0.01 km^2 in 2005 (Aparicio-Effen 2010).

There are the risks of an increase in the occurrence of Dengue, and the resurgence and spread of others as viral encephalitis, Yellow fever and Leptospirosis (Haines 2008).

Climate change also has an indirect impact on health through reduced water supply. These factors operate in a framework of inequality, compounded by failures in urban planning, illegal settlements, constraints on basic services and pollution of different environmental systems (Aparicio-Effen 2010).

The aim of this article was to discuss hydro-climatic extreme events in the countries of Bolivia, Paraguay and Uruguay (Fig. 26.1) focusing on socio-economic and health status, and regional climate scenarios. A case study of a severe rainfall and land-slide at Callapa, La Paz, Bolivia is presented. The impact of extreme rainfall and floods is found in Nagy et al. (2016).

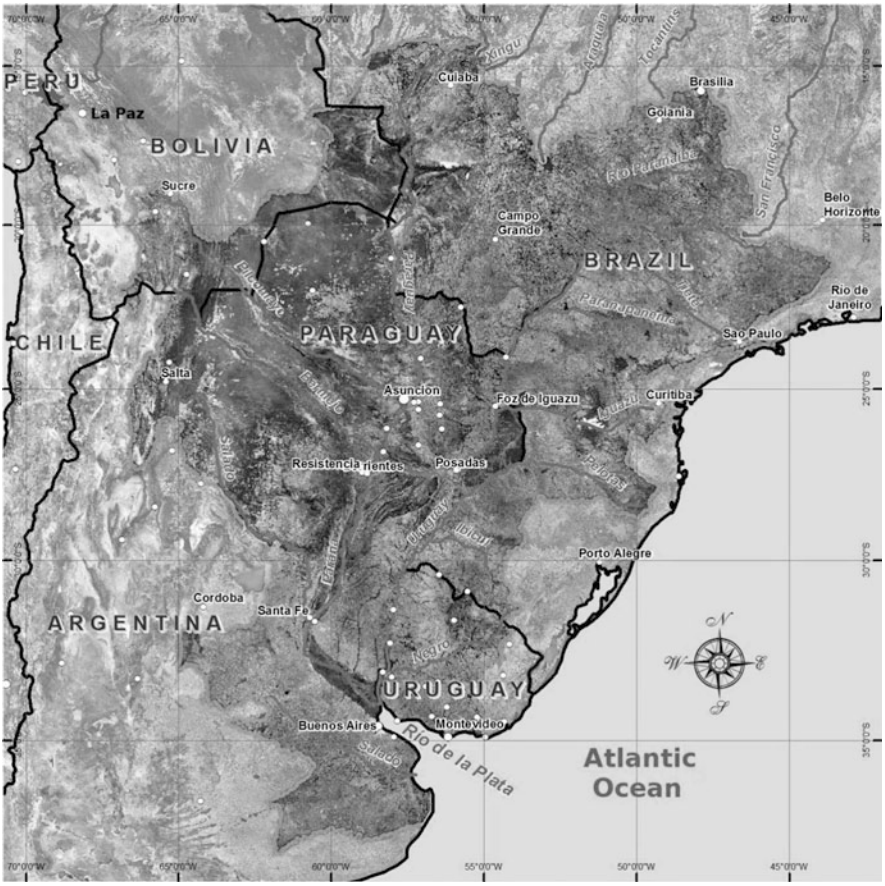

Fig. 26.1 Map of la Plata Basin (five countries) including Bolivia, Paraguay and Uruguay

Extreme Events and Disasters

The frequency and severity of extremes which inflict exceptionally high economic and social costs have been linked to climate change. There is growing scientific evidence that human action is responsible for warming the atmosphere and oceans, rising sea levels and some climate extremes (IPCC 2012). Global warming increases the likelihood of severe, pervasive and irreversible impacts (IPCC 2013). Climate change and environmental degradation are major threats to human development. Action to reduce these vulnerabilities, including a global agreement on climate change negotiations, will be fundamental to securing and sustaining human development IPCC (2014).

More frequent and intense environmental disasters are destroying lives, livelihoods, physical infrastructure and fragile ecosystems. They can impair human capabilities and threaten human development in all countries, especially in the poorest and most vulnerable (UNDP 2014).

Extreme events can also indirectly threaten human health in a number of ways (CCSP 2008; EPA 2010) such as:

- Reducing the availability of fresh food and water.
- Interrupting communication, utility, and health care services.
- Contributing to carbon monoxide poisoning from portable electric generators used during and after storms.
- Increasing stomach and intestinal illness among evacuees.
- Contributing to mental health impacts such as depression and post-traumatic stress disorder.

Natural disasters are increasing in frequency and intensity. Between 2003 and 2012 there were more than 4,000 worldwide; particularly worrying is the much greater incidence of hydrological and meteorological disasters, with a significant increase in hydrological ones. A hydrological disaster is an event caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up, i.e., a flood. Although fatalities from natural disasters appear to be declining, the number of people affected is increasing (Guha-Sapir et al. 2014).

Vulnerability to extreme weather events is a function of exposure to a weather event; the sensitivity of the population to such impacts; and our ability to reduce those impacts through adaptation. The magnitude of future health impacts will depend on the progress of mitigation activities to reduce greenhouse gas emissions as well as adaptation strategies that reduce the exposure and sensitivity of populations (The Royal Society 2015).

The statistics of natural disasters (ProVention 2013) shows differences between Bolivia, Paraguay and Uruguay. The three of them are subjected to frequent hydro-climatic extreme events, many of them coincident with ENSO events. Land-slides are the most common extreme in the city of La Paz, Bolivia (Fig. 26.2) in the

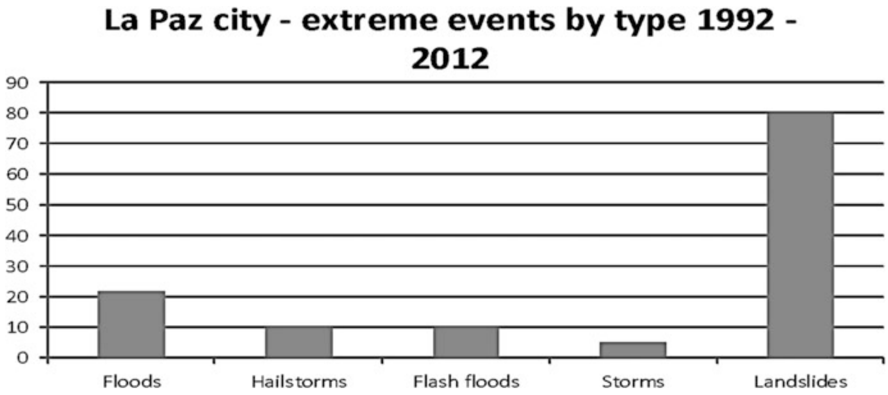

Fig. 26.2 Number of extreme events per type in La Paz, 1992–2012. Elaborated by the authors

Table 26.1 Natural Disasters in Bolivia, Paraguay and Uruguay (1980–2010), normalised by surface ($N/km^2/1000$) and total population-TP (N/100,000 people), and of affected people at the most severe flood by TP in Bolivia, Paraguay and Uruguay from 1980 to 2010

Country	Disaster		
	Number of natural disasters	Most frequent disasters	Number of disasters normalised by surface and population
Bolivia	61	Floods; landslides; drought; epidemic; extreme storms; hailstorms	0.055/0.61
Paraguay	30	Floods; epidemic; drought; extreme storms; extreme temperature; wildfire	0.073/0.44
Uruguay	22	Floods; extreme temperature; extreme storms; droughts	0.12/0.65

Elaborated by the authors based on data from ProVention (2011)

Andean Cordillera followed by floods (Disasters 2007). Floods and epidemics are also frequent, mainly in the lowlands. Climate-related disasters in Bolivia are frequent, severe, and manifold (Seiler et al. 2013). Paraguay and Uruguay suffer frequent floods, being epidemics usual in Paraguay, i.e., Dengue, and wind storms in Uruguay.

The number of natural disasters (Table 26.1) shows that Bolivia suffers more disasters and Uruguay less. However, if these numbers are normalised by surface area and total population, Uruguay becomes the most exposed and Bolivia and Paraguay the less ones for surface and total population respectively. Beyond the different nature of hydro-climatic stresses, the quantity of exposed people and human impacts are mostly a function of the adaptive and management capacities, some proxies of which are GDP, social and health expenditures, poverty and inequality (Tables 26.2 and 26.3).

Table 26.2 Socioeconomic status of the studied countries and Latin America and the Caribbean

Selected countries from LAC	GDP per capita (IMF 2013; WB 2013)		HDI (UNDP 2014)	Social expenditure (CEPAL 2014a)	Per capita (US$ current and parity purchase power-PPP) Total health and public health expenditure (WHO 2014)			
	Current US$	PPP US$		% of the GDP 2011–2012	Current US$	PPP US$	Current US$	PPP US$
LAC			0.74	19.2				
Mexico	10,500		0.76	7.9		1,048		
Chile	15,750		0.82	10.2	1,103	1,606	536	780
Brazil	11,200	15,000	0.74		1,057	1,109	490	515
Bolivia	2,868	6,106	0.67	11.5–15	149	305	107	219
Paraguay	4,400	8,075	0.68	8.9–11	392	633	165	266
Uruguay	16,400	19,600	0.79	23–24	1,318	1,438	895	976

Table 26.3 Poverty, indigence and inequality indicators, affiliation to health-care systems and access to safe water and sanitation in the studied countries and Latin America and the Caribbean (LAC) in 2012 (CEPAL 2014b; ECLAC 2013) and the Notre Dame Index of readiness (1: the best) and vulnerability (1: the worst) to climate change (ND-Gain 2012)

Countries	Poverty and extreme poverty (%)	Inequality (QV/QI)[b]	Health-care systems (%)	Access to safe water and sewage (%)[c]	ND-Gain index[c]	
					Read	Vuln
LAC[a]	28/11		66	94/82		
Bolivia[d]	42/22	16	44	81/26	0.33	0.36
Paraguay	49/28	21	40	86/<50 %	0.38	0.33
Uruguay	6/1	7	99	100/99	0.57	0.32

[a]Expressed as the median of LAC countries
[b]Inequality measured as the ratio average per capita income 20 % richest/20 % poorest (similar to GINI Index)
[c]The Notre Dame Index (ND-Gain Index) of readiness (the greater is better) vulnerability (the lower is better) to climate change is shown
[d]MMA (2013)

Heavy Rains and Floods in Southern South America

Over the last few years several extreme hydro-meteorological events have impacted the Southern South America (Disasters 2007; Bidegain et al. 2014; PAHO 2015; INUMET 2015; Bidegain et al. 2015), which might be linked to ENSO events (Nagy et al. 2016):

- Flood, freezing, and hail in Bolivia in January–March 2007 with 50 deaths and 103,595 families affected (Disasters 2007)
- Flood in central Uruguay in May 2007.
- Drought in Eastern Argentina and Uruguay in 2008–2009.

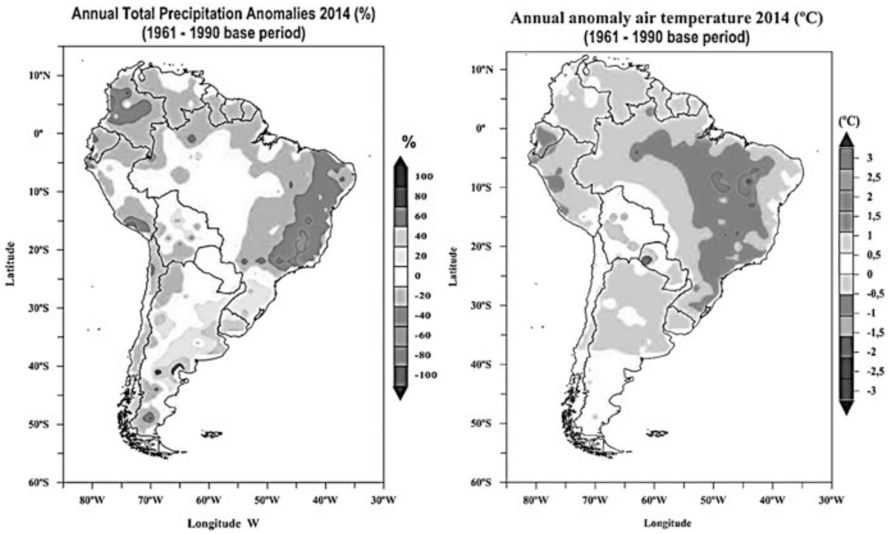

Fig. 26.3 Annual total precipitation and air temperature anomalies in South America for the year 2014. Source: Bidegain et al. (2015)

- Anomalous yearly positive anomalies of rainfall and temperature in 2014 in Eastern Argentina and Uruguay: the second rainiest since 2002 and the second warmest ever.
- Floods in the Parana and Paraguay Rivers in Argentina and Paraguay with 231,360 affected people in Paraguay (as of July 2014), and in the Uruguay River (July 2014).
- Heavy rains that caused overflowing of rivers flooding in several countries in South America (Argentina, Bolivia, Paraguay and Uruguay), have also caused various emergency situations that have exacted a heavy toll in people and infrastructure (PAHO 2015).

The annual total precipitation and temperature anomalies in South America during 2014 are shown in Fig. 26.3.

In regards to extreme rainfalls the Pan American Health Organization (PAHO 2015) recommends taking preventive measures regarding the consumption of safe water. It is also important to keep spaces clean to avoid the collapse of the drainage systems, and prevent the accumulation of water in order to stop the proliferation of mosquito breeding sites. Particular attention should be paid to acute diarrheal disease cases, acute respiratory infections and communicable diseases.

Socioeconomic and Health Status and Vulnerability

The social determinants of health are the circumstances in which people are born, grow, live, work and age, including the health system. These circumstances are the result of the distribution of money, power and resources at global, national and local levels, which in turn depends on the policies adopted. These determinants explain the majority of health inequities, i.e., the unfair and avoidable differences in and between countries with regard to health status (Corvalán 2012).

Climate change and variability, global population growth, poor planning of human settlements and persistent problems of access to health and education are increasing human-made pressure on natural resources through wastage and pollution. In Bolivia, many villages and rural communities are declining and tending to disappear, whereas urban centres are experiencing rapid and uncontrolled population growth, consisting of informal settlements and slums located on the slopes of the mountains on unstable soils. These problems are compounded by issues of poor governance, lack of infrastructure and health inequity which cause high levels of human vulnerability triggered by climate impacts (Aparicio-Effen 2010).

Socio-economic Indicators in Relation to Human Impacts and Health

Income and Social Expenditure in Health

Higher income and socioeconomic status are associated with greater ability to absorb losses and higher resilience (Guha-Sapir et al. 2014).

Economic growth and poverty reduction has been sustained in the region and well-being has improved over the last decade (ECLAC 2013; CEPAL 2014a). Notwithstanding, in regards to human impacts, the intensification of climate threats is posing a severe challenge to the adaptation and risk-management programmes and, despite their fostering, an adaptation deficit exists were the current climate scenarios to worsen. Thus, climate change and extreme events contribute to increase social inequalities (climate inequalities) in Bolivia and Paraguay, imposing new costs to the already high social budget in Uruguay.

According to the Economic Commission for Latin America and the Caribbean-ECLAC (CEPAL 2014a) poverty and indigence have decreased in LAC from the historical peak of 48 and 23 % in 1990 to 28 and 11 % respectively in 2013 (Table 26.2), and continue decreasing despite the Gross Domestic Product (GDP) growth in LAC slows down since 2012 (IMF 2014). However, Bolivia and Paraguay still grew more than 5 % and Uruguay about 4 % since 2012 (IMF 2014; WB 2014a, b; CEPAL 2014b).

With regard to extreme poverty, Bolivia is only two points short of meeting the Millennium Development Goal (MDG) target of cutting its 1990 level in half. Although inequality is decreasing it remains high in rural areas, where the indigenous population is predominant and remains the most vulnerable group. From the studied countries only Uruguay has achieved the MDG goals (MDG 2014).

Overall Vulnerability: Inequality, Water and Sanitation, and the Health System

> Areas with weak health infrastructure—mostly in developing countries—will be the least able to cope without assistance to prepare and respond (WHO 2014)

Table 26.2 shows poverty, inequality and social expenditure indicators relevant to climate adaptation, human impacts and health in relation to hydro-climatic extremes in the studied countries. Bolivia and Paraguay, two highly vulnerable countries to climate change and variability (Nagy et al. 2006; Magrin et al. 2007, 2014) still have poor numbers when compared to the average of Latin America and the Caribbean (LAC), whereas Uruguay, one of the less vulnerable LAC countries to climate change together with Chile and Argentina (ND-Gain 2012), has very good numbers for the region. Despite this diversity, the three countries are highly vulnerable to extreme hydro-climatic extremes, e.g., heavy rains and landslides in Bolivia, droughts and floods in the three of them (Table 26.1).

The Notre Dame Index of Readiness and Vulnerability (ND-Gain 2012) shows slight differences in overall vulnerability (not specific for health) among the three countries which are not among the five less vulnerable in LAC, whereas in regards to readiness, Uruguay is very well ranked.

The access to safe drinking water and sanitation is a key factor for achieving good levels of public and environmental health. LAC has already achieved the safe drinking MDG goal 94 % as of 2014 (MDG 2015 = 92.5 %; MDG 2014) (Table 26.3). Nevertheless, there are disparities between rural and urban areas and between different regions, as well as between groups with different income levels. Overall, an estimated 46 % of LAC countries have already met the target and an additional 31 % are on schedule, but 23 % are unlikely to meet the target by 2015 (CEPAL 2014b; MDG 2014). Because of these differences, poverty and inequality indices are that important to have an overall picture of vulnerability and adaptation to climate stressors.

Near-Future Climate Scenarios (2011–2040)

Future (2011–2040) temperature and rainfall RCP 4.5 CO_2 emission scenarios over Southeastern South America (SESA) developed by Ferraz-Mourão (2014) are presented in order to have a climatic reference to support discussion on plausible future well-being and health risks [see also Nagy et al. (2016)].

The big picture of temperature increase projections made with RCP 4.5 shows relatively good agreement with previous projections made with IPCC SRES scenarios (Bidegain et al. 2011; Pasten and Giménez 2012; Seiler et al. 2013; Ramallo 2013). Part of the expected increase was actually registered. For instance in southern Uruguay an increase of 0.8 °C already occurred from 1961 to 2008 (Bidegain et al. 2011; Nagy et al. 2014a, b) which accounts for nearly half of the

Table 26.4 Projected temperature and rainfall in Uruguay, Paraguay and Bolivia for 2011–2040 (baseline: 1961–1990)

Season	Temperature (°C)		
	Uruguay	Paraguay	Bolivia
Summer (D-J-F)	+1 (Southern Uruguay)	+2 to +3.0	
Autumn (M-A-M)	+1.5 to +2.0	+2.0 to 2.5	
Winter (J-J-A)	+1 to +2		
Spring (S-O-N)	Somewhere in between winter and fall projection		
	Rainfall (mm/day)		
	Uruguay	Paraguay	Bolivia
Summer	No change	−0.5 to −1	−0.5 to −2.0
Autumn	+0.5	−0.5 to +0.5	−0.5 to +0.5 Southeast −0.5 to −2 Andean Foothills
Winter	No changes		−0.5 Andean Foothills
Spring	+0.5	−0.5 to +0.5	

Based on Ferraz Mourao (2014), Bidegain et al. (2011), Pastén and Giménez (2012)

projected increase for 2011–2040, and less for northern Uruguay, Paraguay and Bolivia.

For rainfall the big picture of RCP4.5 projections shows differences of about −1 mm/day with previous SRES scenarios, which projected a slight increase at most regions. Thus, whereas slight rainfall increases are projected for Northeastern Argentina, Uruguay and Eastern Paraguay, projections are slightly negative for most Paraguay and Bolivia.

Projected seasonal changes for temperature and rainfall for the region are detailed in Table 26.4.

Notwithstanding, available future scenarios do not give a clear picture of hydro-climatic well-being and health risks due to the uncertainty of rainfall patterns. A plausible slight decrease in fall and winter rainfall length and/or duration does not necessary imply less intensity or less occurrence of floods.

Case Study: Mega-landslide at Callapa, La Paz, Bolivia

Introduction

Climate change is placing a series of additional demands on human settlements: a recurring lack of water availability and water quality, exacerbated by the retreat of glaciers, and increased frequency of extreme events and disturbances in rainfall patterns (Aparicio-Effen 2010).

The case study “The Callapa mega-landslide” caused by a historical excessive rainfall event in February 2011 is presented herein. The Callapa district located in

Fig. 26.4 Map of Bolivia showing La Paz City

the Eastern slope in the North of the city of La Paz has been declared a risk-area due to the increase of settlements (GAMLP 2011).

La Paz city (Fig. 26.4) lies in a mountain ecosystem between 3600 and 4000 m above sea level. The high vulnerability of the city to land-slides and subsequent outbreaks of vector-borne diseases and other diseases classified as new, emerging or re-emerging is attributable to the following factors (Aparicio-Effen 2010; GAMLP 2011; Aparicio-Effen et al. in press):

- Meteorological instability,
- Steep slopes,
- Unstable soils,

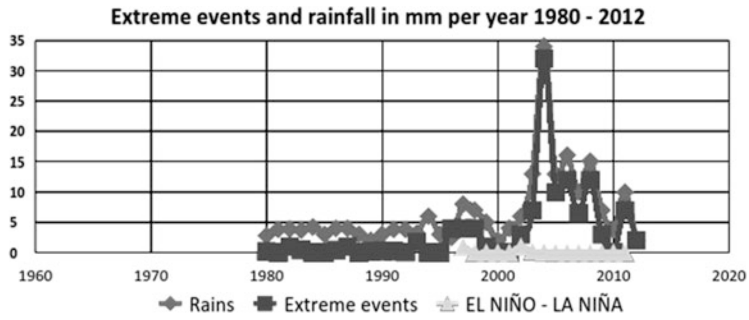

Fig. 26.5 Relationship between the NOAA ENSO multivariate index (El Niño/La Niña), extreme events and rainfall in mm per year, La Paz from 1980 to 2012. Elaborated by the authors from data of PNCC (2007), NOAA (2014) and Laikakota-weather station, Servicio Nacional de Meterología e Hidrología (SENAMHI)

- Uncontrolled sanitary discharges, groundwater outflows, and septic tanks in some neighbourhoods.

The vulnerability to excessive rainfalls is also explained by a dry climate characterised by the occurrence of 57 % dry years and 28 % rainy years from 1919 to 2011 and an average annual precipitation of 575 mm/year from 1981 to 1999 (Vuille et al. 2000; Seiler et al. 2013; Ramallo 2013).

Extreme events in La Paz are related to its geographical features, its subtropical location and the presence of the Andean cordillera, which are responsible for land-slides (the commonest events), hailstorms (which may cause land-slides), flooding and extreme temperatures (Fig. 26.2, section "Extreme Events and Disasters").

The "El Niño Southern Oscillation" (ENSO) multi-variate index shows that recent events have been moderate although their impact in La Paz have nevertheless been severe. The comparison between ENSO index and the number of extreme events that occurred in La Paz from 1980 to 2012 (Fig. 26.5) showed a weak correlation after 1997 (NOAA 2014), while the correlation with global warming was stronger. This changing pattern might be linked not only to climate change but also to the occurrence of El Niño Modoki events (see also Nagy et al. 2016) and or the Pacific Decadal Oscillation (PDO) as found for the Rio de la Plata lower basin (Nagy et al. 2014c).

"Callapa" Mega-landslide

The Landslide

Callapa is located in the basin of the Callapa-Irpavi River in La Paz (Fig. 26.6). The valley runs from 4,000 m above sea level at the watershed headwaters, to 2,600 m near the La Paz River (Lorini 1991).

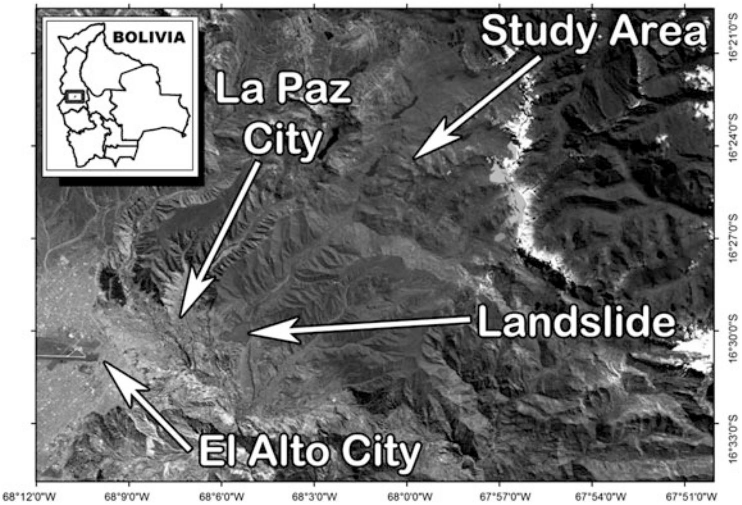

Fig. 26.6 Study area outlined by the limits of the basin. The landslide *arrow* shows the impacted area (*dark gray*). Elaborated by the authors

The first sign of the land-slide was the crack of streets and ground observed on 24 February (Fig. 26.7) preceding the "mega-landslide of Callapa" on 26 February. These warning signs led to the evacuation of the inhabitants of those districts and prevented the loss of human life.

The mega-landslide affected three of the city's macro-districts: San Antonio, Sur and Hampaturi, which represents 26.4 % of the city (532 km^2), 84 % of which at Hampaturi.

The month of February 2011 was the sixth rainiest and the one with most rainy days (25) from 1919 to 2011. A strong precipitation (33 mm) occurred a day before land-slide, which in addition to non-controlled sewage emissions and the upwelling of subterranean water and soil saturation could all have been the cause of the land-slide.

Health Impacts of the Mega-landslide

The mega-landslide developed slowly enabling the La Paz Early Warning Systems (EWS) to prevent deaths. The health services registered cases of dehydration, with greater prevalence among children and adolescents, diarrhea in children under 2 years old, myositis, muscles pain due to efforts to carry belongings, mental health problems (depression, stress, and anxiety), acute respiratory infections, minor injuries, ectoparasites (fleas) in the camp "Flor de Irpavi" due to overcrowding.

The persons affected reported that they had suffered from respiratory diseases (49 %), followed by digestive and dermatological diseases and bruises while 33 % of the victims said that they had not suffered any health problems.

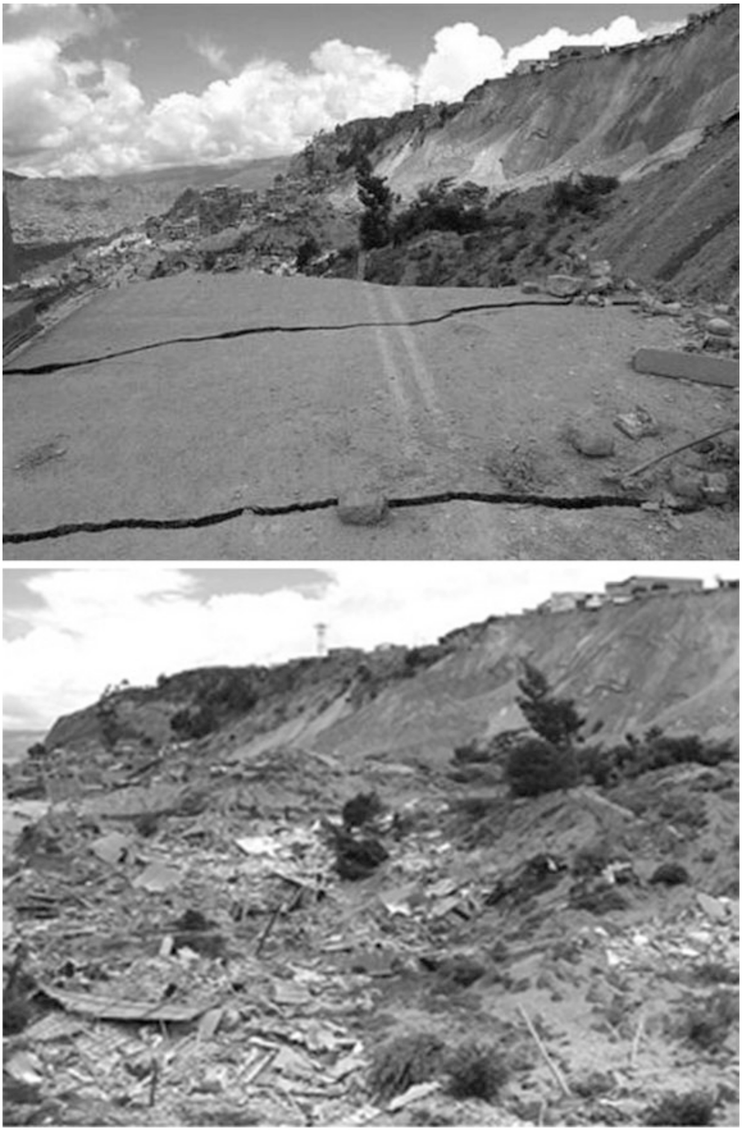

Fig. 26.7 Cracks that preceded the landslide (*above*) and scale of the mega-landslide (*below*). From GAMLP (2011)

Equity Assessment in the Area of the Mega-landslide and in Its Control Area

The Urban Health Equity Assessment and Response Tool "Urban HEART" (WHO/PAHO 2010) methodology was applied to assess equity, adjusted to climate impacts and land-slides. Knowledge, Attitudes and Practices (KAP) surveys (Handicap International 2009) were carried out among 200 affected families and among are representative number of families in the control area Alto Irpavi. These surveys required to work on the identification of indicators for social and environmental determinants of health that may have contributed or not to the mega-landslide. An equity assessment was carried out for the area of Callapa (nine districts) which was compared to the opposite slope, in the Alto Irpavi district. Both areas are located in the same basin and were exposed to the same extreme precipitation, but with different impacts.

San Antonio and Sur macro-districts have a smaller territorial extension and they concentrate a larger number of inhabitants. Hampaturi has a larger territorial extension and lower rate of population growth (1882 inhabitants/year). More than 40 % of the persons interviewed were in the 20–40 age group (average 36 and mode 25), affecting the productively active group. Forty per cent of the affected families were made up of 5–6 persons, which meant that more than 4,000 persons were affected, probably up to 7,000, 73 % of which were female.

About 50 % of the houses were built with bricks (mostly in the Sur macro-district) whereas "adobe" and "adobe with brick" were typical in the other two macro-districts, San Antonio and Hampaturi, explaining their fragility and their unsuitability. About 50 % of houses had 3–5 rooms (including bathroom and kitchen) and only 34 % had more than 6 rooms.

Regarding the education levels of the persons interviewed, 6 % were professionals, 78 % were at the primary/secondary education level, 10 % were university students and about 6 % were illiterate. In terms of family income levels, 54 % received the minimum national salary (US$115), and 34 % received US$145 which is insufficient in the case of five or six family members. In the control area the incomes were higher and the number of family members was lower.

Table 26.5 shows the results of the assessment of both districts according to Urban HEART method, modified by authors including climate and weather indicators, as well as the urban ecosystem to assess and compare the districts from the perspective of climate vulnerability.

These results show that the districts where the mega-land-slide occurred were in an inequitable situation compared to the control area, due to the higher quantity of black results (high vulnerability, lack of services, and/or poor quality) requiring improvement.

Discussion

Climate change is showing its effects over mountain ecosystems, affecting human population (Aparicio-Effen et al. in press). The increase of settlements in the highly vulnerable Callapa area is evidence of a bad practice which increased the exposition of people, housing and soils to extreme rainfalls.

To cope with high vulnerability in Bolivia a "National Adaptation to Climate Change Mechanism" (MNACC) was developed (PNCC 2007) which considers five

Table 26.5 Equity comparison of vulnerability at Callapa and Alto Irpavi

POLICY AREA	INDICATORS	DISTRICT	
		Callapa	Irpavi
Physical environment and infrastructure	Healthy housing		
	Access to safe water		
	Access to sanitation		
	Solid waste management system		
	Climate and weather		
	Urban ecosystem		
	Soil stability		
Human and social development	Access to health services		
	Better practices in personal life		
Economic	Poverty		
Governance	Government spending on health		

Elaborated by the authors from KAP surveys, expert opinions, and GAMLP (2011). Highly vulnerable, poor conditions or lack of (*black*) and low vulnerable, good conditions or availability (*white*). Intermediate conditions or vulnerability (*light gray*)

priority sectors including human health. Some of the programmatic areas for human health adaptation are as follows:

- Mainstreaming of climate change policies and health programmes in national and sub-national institutions.
- Identifying current and future vulnerability.
- Building capacities.
- Encouraging a pro-active attitude on the part of national health system and social participation.

The main measures to reduce disaster risk exacerbated by the change in the intensity of rainfall in the urban area of La Paz city were:

- The development and improvement of EWS which resulted in the rapid evacuation of vulnerable populations.
- The evacuation of the population at risk.
- Temporary shelters for displaced people who lost their homes were established.

Conclusions and Recommendations

The rainfall over the period November–March 2011 was very high (33 mm a day before land-slide). The number of rainy days (25) was the maximum ever recorded (since 1919). This event coincided with a La Niña year (2010–2011).

The districts affected by the land-slide were poorly served by sanitation facilities which were in any case sub-standard for want of maintenance, so uncontrolled sanitary discharges and groundwater outflows might have contributed to the land-slide. Despite the nature and scale of the mega-landslide, there were no deaths or wounded persons, but only minor health consequences.

The experience of Callapa highlights the interconnection between development and climate stressors. Based on this experience, a series of inter-sectoral policies and strategies were developed in order to improve adaptation measures to climate change and variability and to reduce the population's vulnerability to extreme weather events. These included to:

- Draw up a municipal adaptation plan for climate change to reduce the impact of global warming on human welfare and other sectors.
- Generate investments to protect sources of water and establish offsetting mechanisms to protect basin headwaters as part of efforts to manage natural resources, and promote recovery of ecosystems, wetlands and basin headwaters.
- Strengthen the current Municipal Early Warning System (EWS) and carry out hydro-climatic modeling.
- Develop community education and environmental programmes to prevent extreme events and human impacts on the city, and strengthen compliance with building regulations in the city and particularly in areas of high and very high risk modelling.

Overall Discussion, Summary and Conclusion

The adaptation to climate change (CCA) is part of the early incorporation of effective measures to prevent acute and chronic impacts on the development process. These actions are systematic, dynamic in face to expect anomalous behaviour due to climate change. In many places the damage is increasing giving evidence of an adaptation deficit, meaning that practices to manage climate hazards are falling short of what can be done (Burton 2004).

Bolivia, Paraguay and Uruguay are being increasingly impacted by hydro-meteorological and climatic disasters associated with excessive ENSO-linked rainfall over the last few decades, mainly land-slides in Bolivia and Floods in Paraguay and Uruguay. Climate change would also be important but it is somewhat masked by current variability and extremes impacts. Future scenarios for 2030–2040 suggest that warming and rainfall changes could seriously affect the sub-region without further improvements in pro-active adaptation measures such as EWS and forecasting, preventive displacement and evacuation of people, and better demographic, socio-economic, and equity conditions.

There are strong differences in socio-economic, vulnerability and health status conditions, and exposition to extremes in the three countries, i.e., Asunción is exposed to floods and La Paz to landslides, which determines different human and health impacts of extreme events.

Despite these socio-economic and health status differences, the three studied countries are highly vulnerable to hydro-climatic stressors. Resilience relies on these intrinsic statuses whereas adaptive capacity also depends on management.

Evidence is that most of the vulnerabilities are associated with poor pro-active measures and national and sub-national level planning. The adaptation deficit seems to be more related to increased exposition and poor adaptation than to increasing climate stressors. Where relatively good socio-economic conditions and/or risk-management practices prevails impacts are reduced.

The low human and health impact during the Callapa mega land-slide demonstrate the importance of EWS and evacuation plans to reduce impacts.

Equity comparison of Callapa and Alto Irpavi at La Paz shows how two areas similarly exposed to climate and weather conditions, and with similar government expenditure in health, have different vulnerability due to socio-economic and demographic factors.

In the studied countries the adaptation to climate variability (CVA) and its changing patterns in extremes is a key climate management goal. Despite an increasing adaptation it remains insufficient (Coronel et al. 2015; Nagy et al. 2016). For instance, there is a strong adaptation deficit to the high concentrations of rainfall on short-time in urban areas with poor access to basic services as sewage and drainage system. In many cases old systems cannot cope with the increase in rainfall intensities and exposure to weather extremes runoff. To reduce the impact of these new rainfall patterns new approaches in engineering works and municipal regulations are required.

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Chapter 27
Impacts on Well-Being and Health by Excessive Rainfall and Floods in Paraguay, Uruguay and Bolivia

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Abstract Hydro-climatic anomalies are impacting the well-being of populations and increasing vector-, rodent- and water-borne diseases (H-ID) in Bolivia, Paraguay and Uruguay where extreme ENSO-linked floods have been frequent since 2007. In Paraguay and Uruguay H-ID have increased over the last decade associated with yearly rainfall variability. The extreme floods of Paraguay River in Asuncion (Paraguay) in 2014 were the most devastating ever recorded in terms of

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affected people due to the increase in exposed population and duration of the event. The extreme flood of 2007 in the Beni region, Bolivian Amazonia, is discussed focusing on the nature of the link with ENSO events. Both well-being and health impacts are discussed as well as the development of adaptation plans after disasters. The evolution of Hepatitis A in Uruguay which was endemic and correlated with droughts where a sewage deficit existed is also discussed because mandatory vaccination strongly reduced the number of cases since 2007. Future climate scenarios show increases in average temperature and modified rainfall patterns, with increases in Uruguay and decreases in Bolivia and Paraguay for 2011–2040. There is high uncertainty with regard to river flow, floods and health impacts, and more hydro-climatic extremes are expected. There is evidence of both an adaptation deficit to cope with current climate and a risk-management learning process, the balance of which remains to be established.

Keywords Adaptation • Climate change • Climate scenario • Disasters • Hydro-climatic extremes • El Niño Modoki • Vector-borne and water-borne diseases

Introduction

Climate Change, Extreme Events, Human Impacts and Health

> Changes in weather and climatic patterns are negatively affecting human health in Central and South America, either by increasing morbidity, mortality, and disabilities (high confidence), and through the emergence of diseases in previously non-endemic areas (high confidence). With very high confidence climate-related drivers are associated with respiratory and cardiovascular diseases, vector- and water-borne diseases (Malaria, Dengue, Yellow fever, Leishmaniasis, Cholera, and other diarrheal diseases), Hantaviruses and Rotaviruses, chronic kidney diseases, and psychological trauma. International Panel on Climate Change-IPCC Fifth Report-AR-5, CSA (Magrin et al. 2014)

Climate variability may affect outbreaks of infectious diseases and the increase in the transmission of different vector-borne diseases such as visceral Leishmaniasis, Dengue and Malaria which have been linked to the El Niño Southern

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Oscillation (ENSO) driven climate anomalies such as excessive rainfall and flooding (Hales et al. 1999; Gagnon et al. 2001; Franke et al. 2002; Auld et al. 2004). Extreme weather conditions can easily affect water purification systems and the collection of rainwater and wastewater, as well as to contaminate wells and springs, rivers, estuaries and coastal waters (Hunter 2003; Patz et al. 2003).

Among the most ubiquitous and common viral agents in the Americas are those transmitted by wild and urban rodents (Rojas and Scribano 2010), i.e., Hantavirus, a zoonotic disease which causes human lung syndrome. Excessive rainfall, floods, and even warm winter and spring have been associated with Hantavirus outbreaks worldwide (Hjelle and Glass 2000; Tersagoa et al. 2009; Londoño et al. 2011; Morand et al. 2013).

Outbreaks of Hantavirus pulmonary syndrome have been reported for Argentina, Bolivia, Brazil Chile, Panama and Paraguay, and after prolonged droughts, probably due to the intense rainfall and flooding following the droughts. Some models project changes in the dispersion of the cutaneous Leishmaniasis vector in several countries in South America (Magrin et al. 2007) including Bolivia, Paraguay and Uruguay (from now on UruPaBol).

Outbreaks of re-emerging Leptospirosis triggered by excessive rainfall and flood, global warming and urbanisation (socio-economic deprived areas) have been reported worldwide, especially in subtropical humid regions (Pappas et al. 2008; Hartskeerl et al. 2011; Miyazato et al. 2013; Guimarães et al. 2014; Weinberger et al. 2014).

Bolivia and Paraguay are among the most vulnerable countries with regard to human development and health effects. It is expected that climate change will exacerbate the vulnerability of people and pose new threats such as availability of fresh water supplies and distribution and seasonal transmission of vector-borne infectious diseases, i.e., Dengue and Leishmaniasis. El Niño Southern Oscillation (ENSO) events are the cause of many flooded, drought and landslides areas that are prone to the transmission of Hantavirus, *E. coli*, Hepatitis A, Malaria, Dengue, Leptospirosis, Leishmaniasis. Economic development has triggered the suitable environmental conditions for the appearance of ENSO-related cyanobacteriae blooms in the lower Rio de la Plata basin, Argentina-Uruguay (Nagy et al. 2006).

The aim of this chapter was to discuss:

- The trends of some infectious diseases (ID) which might be triggered by yearly rainfall anomalies and/or extremes, mainly floods, i.e., acute diarrheal disease (ADD), Hepatitis A, Hantavirus, Leptospirosis and visceral Leishmaniasis in UruPaBol (Fig. 27.1) and,
- Case studies of the impacts on well-being of the populations and health in these three countries of recent El Niño-linked floods.

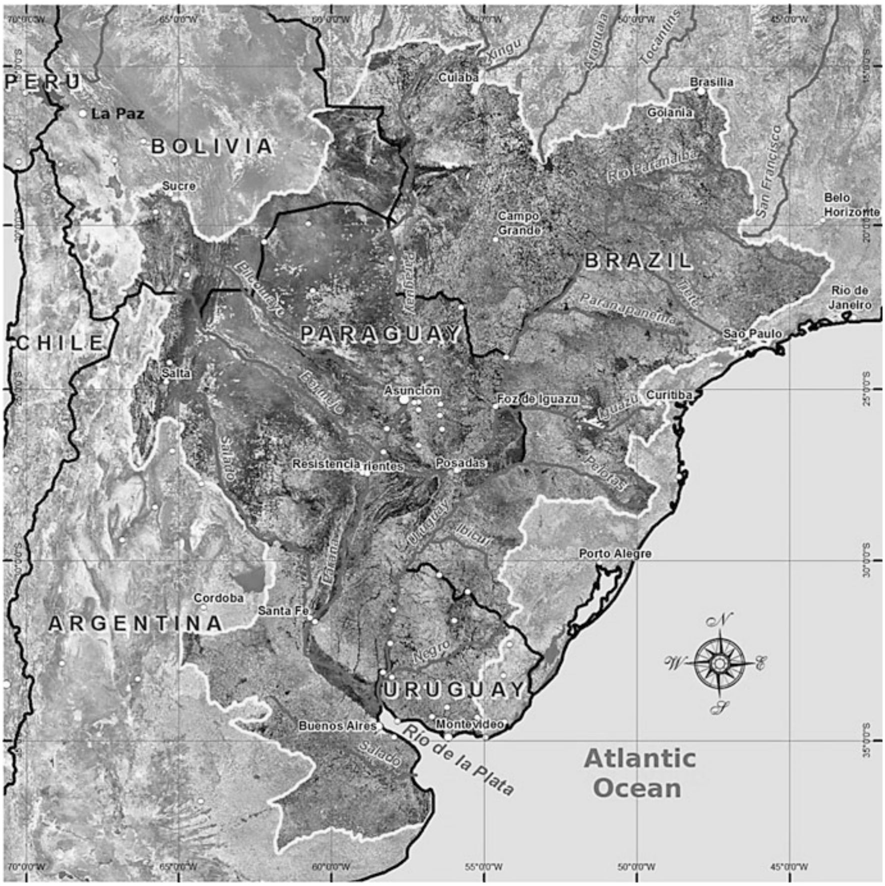

Fig. 27.1 Map of la Plata Basin (five countries) and main rivers

Hydrometeorological Disasters

> A disaster is a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering. Guha-Sapir et al. (2014)

Natural disasters are increasing in frequency and intensity. Between 2003 and 2012 there were more than 4,000 worldwide; particularly worrying is the much greater incidence of hydrological and meteorological disasters, with a significant increase in hydrological ones. A hydrological disaster is an event caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up, i.e., a flood. Although fatalities from natural disasters appear to be declining, the number of people affected is increasing (Guha-Sapir et al. 2014).

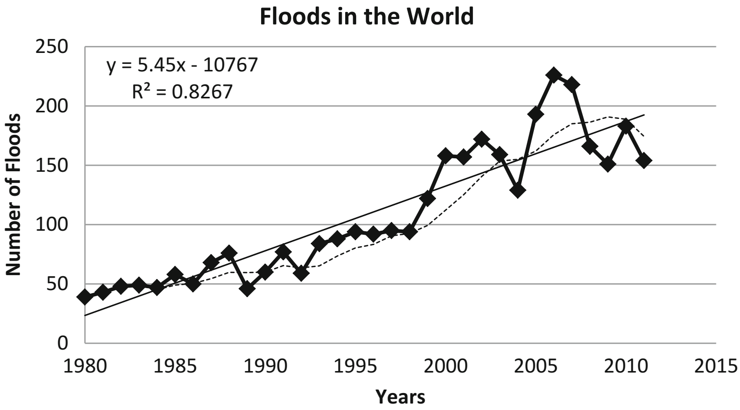

Fig. 27.2 Time-series of the number of floods in the world (1980–2011). Elaborated by the authors from data of the UNIDSR (www.unisdr.org). Linear trend: *black line*; moving average (5 years): *points*

The frequency and severity of extremes inflicting exceptionally high economic and social costs have been linked to climate change. Moreover, there is growing scientific evidence that human action is responsible for warming the atmosphere and oceans, rising sea levels and some climate extremes (IPCC 2012). Global warming increases the likelihood of severe, pervasive and irreversible impacts (IPCC 2013). Climate change and environmental degradation are major threats to human development. Action to reduce these vulnerabilities, including a global agreement on climate change negotiations, is fundamental to securing and sustaining human development IPCC (2014).

Some of the most important hydro-meteorological events in South Eastern South America (SESA) over the last few years have been (Disasters 2007; UNICEF 2007; Bidegain et al. 2014, 2015; INUMET 2015):

- Flood in central Uruguay in May 2007: the worst since 1959.
- Flood, freezing, and hail in Bolivia in January–March 2007 with 50 deaths and 103,595 families affected (Disasters 2007)
- Drought 2008–2009: the most important one in Argentina and Uruguay over the last five decades.
- Yearly mean temperature in 2014: the second warmest ever in Argentina and Uruguay.
- Anomalous yearly rainfall in 2014: the second rainiest since 2002 in Argentina and Uruguay, with a high number of displaced people in the Uruguay River in Argentina, Brazil and Uruguay.
- Floods in the Parana and Paraguay Rivers in Argentina and Paraguay with 231,360 affected people only in Paraguay (as of July 2014).

According to the data presented by UNISDR (2013) the number of floods worldwide increased by about four times since 1980. Since 1994 floods exceed storms reaching a peak between 2005 and 2007 (Fig. 27.2).

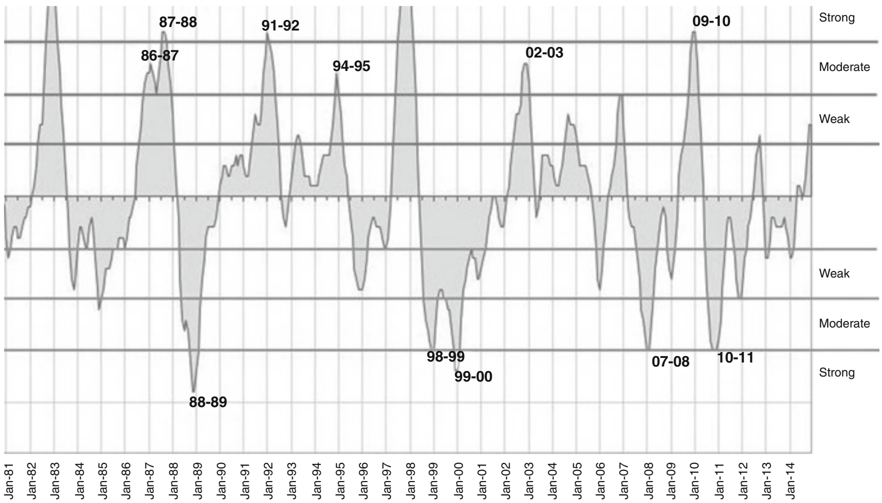

Fig. 27.3 Oceanic Niño Index (ONI) Jan-1981–Jan 2015. │0–0.5│ °C: Weak; │0.5–1.0│ °C: Moderate; │1.0–1.5│ °C: strong; >│1.5│ °C: very strong (1982–1983; 1997–1998). Source: NOAA (2015)

Although El Niño 2014–2015 only developed as a weak event from September–November 2014 (NOAA 2015, Fig. 27.3), excessive rainfall was typical of a strong event which was observed in the whole region. As of the quarter December 2014–February 2015 Oceanic Niño Index (0NI) is +0.7 °C (weak El Niño).

El Niño 2014–2015 is a "Modoki El Niño" (from the Japanese for "similar but different") which is dissipating by April 2015 (IndyWx.com 2015; Sierra 2015). During Modoki El Niños Sea Surface Temperature (SST) anomaly is concentrated in the Central Pacific (CP mode) region. CP mode El Niños have occurred more frequently in recent decades and dominated 2000–2010 at a time when ENSO forecast skill decreased (McPhaden 2013). The CP mode is less intense and more erratic than the classical El Niño (Canonical or Eastern Pacific-EP El Niño). It is characterised by relatively low temperature anomaly at the Central region of the Pacific Ocean with climatic teleconnections in the Southern Hemisphere (Ashok et al. 2009; Zubiaurre and Calvo 2012; Xie et al. 2014).

Prevailing hydro-climatic 2014–2015 conditions have been characterised by strong rainfall and high temperatures in regions of Bolivia, Paraguay, Argentina, Uruguay and Southern Brazil (Sierra 2015).

Some recent analog years of 2014–2015 have been 2004–2005, 2006–2007, and 2009–2010 which give us similar patterns of years past to help formulate an idea of what may lie ahead (IndyWx.com 2015).

Near-Future Climate Scenarios (2011–2040)

Future (2011–2040) temperature and rainfall RCP 4.5 CO_2 emission scenarios over Southeastern South America (SESA) developed by Ferraz Mourão (2014) are presented in order to have a climatic reference to support discussion on plausible future well-being and health risks. Additional information on regional scenarios is presented in Aparicio-Effen et al. (2016).

The big picture of temperature increase projections made with RCP 4.5 shows good agreement with previous projections made with IPCC SRES scenarios (Bidegain et al. 2011; Pastén and Giménez 2012). Part of the expected increase was actually registered. For instance in southern Uruguay an increase of 0.8 °C already occurred from 1961 to 2008 (Bidegain et al. 2011; Nagy et al. 2014a, b) which accounts for nearly half of the projected increase for 2011–2040, and less for Northern Uruguay, Paraguay and Bolivia. "For rainfall the big picture of RCP 4.5 projections shows differences of about −1 mm/day with previous SRES scenarios, which projected a slight increase at most regions. Thus, whereas slight rainfall increases might be expected for North-Eastern Argentina, Uruguay and Eastern Paraguay, projections are slightly negative for most Western Paraguay and Bolivia. Projected seasonal changes for temperature and rainfall for the region are detailed in Table 27.1".

Future combination of temperature and precipitation scenarios should increase evapotranspiration likely affecting the hydrological cycle, decreasing river flows and increasing and extending the risk of temperature dependent water and vector-borne diseases. Notwithstanding, available future scenarios do not give a clear picture of hydro-climatic well-being and health risks due to the uncertainty of rainfall patterns. A plausible slight decrease in fall and winter rainfall length and/or duration does not necessary imply less intensity or less occurrence of floods.

Table 27.1 Projected temperature and rainfall in Uruguay, Paraguay and Bolivia for 2011–2040 (baseline: 1961–1990)

<table>
<tr><th>Temperature (°C)</th><th>Uruguay</th><th>Paraguay</th><th>Bolivia</th></tr>
<tr><td>Summer (D-J-F)</td><td>+1 °C (Southern Uruguay)</td><td colspan="2">+2 to +3.0 °C</td></tr>
<tr><td>Autumn (M-A-M)</td><td>+1.5 to +2.0 °C</td><td colspan="2">+2.0 to 2.5 °C</td></tr>
<tr><td>Winter (J-J-A)</td><td colspan="3">+1 to +2 °C</td></tr>
<tr><td>Spring (S-O-N)</td><td colspan="3">Somewhere in between winter and fall projection</td></tr>
<tr><th>Rainfall (mm/day)</th><th>Uruguay</th><th>Paraguay</th><th>Bolivia</th></tr>
<tr><td>Summer</td><td>No change</td><td>−0.5 to −1</td><td>−0.5 to 2.0</td></tr>
<tr><td>Autumn</td><td>+0.5</td><td>−0.5 to +0.5</td><td>−0.5 to +0.5 Southeast
−0.5 to −2 Andean Foothills</td></tr>
<tr><td>Winter</td><td colspan="2">No changes</td><td>−0.5 Andean Foothills</td></tr>
<tr><td>Spring</td><td>+0.5</td><td colspan="2">−0.5 to +0.5</td></tr>
</table>

Based on Ferraz Mourão (2014); Bidegain et al. (2011); Pastén and Giménez (2012)

Results and Discussion

Natural Disasters

The studied countries of Bolivia, Paraguay and Uruguay (UruPaBol) have specific geographic, health, socio-economic, and vulnerability profiles to climate extremes (Table 27.2). Paraguay, most of Uruguay and South-Eastern Bolivia are within the Rio de la Plata Basin (La Plata River basin), whereas Bolivia is divided in high-altitude Andean Cordillera and lowlands, including the Amazon basin in Eastern Bolivia. El Niño events are associated with excessive rainfall and floods in La Plata River basin and South-Eastern Bolivia, and less rainfall in Bolivian highlands.

The most important natural disasters in terms of human impacts and health in UruPaBol from 1980 to 2010 were floods (ProVention 2011), whereas droughts were the main cause of negative economic impact (Nagy et al. 2006; ProVention 2011). While Bolivia and Paraguay suffer epidemics, i.e., Dengue, Uruguay is epidemics-free. In Andean Bolivia the prevailing disaster are landslides (Aparicio-Effen et al. 2016).

The number of natural disasters (N) and particularly of floods (Table 27.3) suggest that Bolivia is the more exposed country (N = 25) with more affected people, and Paraguay and Uruguay are less affected (N = 11). However, if these numbers are normalised by surface area or population, Uruguay becomes the most exposed, not the most affected in terms of well-being of the population. Beyond the different nature of hydro-climatic stresses, the quantity of exposed people and the adaptive capacity (mostly socio-economic) and risk-management capacity (policy-driven) are key factors.

Only Asuncion (Paraguay) is exposed to extreme floods (from the Paraguay River) among the most populated cities of the region. Montevideo (Uruguay) is exposed to strong storms and coastal floods and La Paz (Bolivia), to landslides.

Table 27.2 Socio-economic and health status of the studied countries

Indicator	Bolivia	Paraguay	Uruguay
GDP Per capita; IMF Current/PPP (USS)	2,800/6,100	4,400/8,075	16,400/19,600
Income Classification (WB 2014a)	Lower-middle-income	Lower-middle-income	High income
HDI	0.67	0.68	0.79
Social Expenditure (as % of Public Expenditure) over the last few years	11.5–15	8.9–11	23–24
Per capita Public Health Expenditure Current/Parity Purchase Power—PPP (USS)	107/219	165/266	895/976
Poverty/Extreme Poverty (%)	42/22	49/28	6/1
Inequality (QV/QI)*	16	21	7

Modified from Aparicio-Effen et al. (2016). Data from World Bank WB (2014a, b); CEPAL (2014); IMF (2014); United Nations Development Programme (UNDP 2014); World Health Organization (WHO 2014)

* Inequality measured as the ratio average per capita income 20 % richest/20 % poorest (similar to GINI Index)

Table 27.3 Natural disasters, floods in particular, normalised by surface (N/km^2 × 1,000) and total population-TP (N/thousands × 1,000), and of affected people at the most severe flood in Bolivia, Paraguay and Uruguay from 1980 to 2010

Country/ Disaster	Number of natural disasters; floods	Number of floods normalised by surface and population, and affected people of the most severe flood normalised by total population	Main floods by affected people (× 1000)	Second and third natural disaster (N)
Bolivia	61;25	0.023; 0.0025; 0.048	2007: 485; 2001: 357; 2007: 339; 1980: 310; 2010: 227	Drought; Epidemic (9)
Paraguay	30;11	0.027; 0.0016; 0.034	1995: 225; 1983: 100; 1982: 85; 1997: 75; 1992: 66; 1995: 50	Epidemic (6); Drought (5)
Uruguay	22; 11	0.061; 0.0032; 0.035	2007: 119; 2009: 22; 1986: 18; 1988; 9; 2000; 2001; 1992: 5	Storms (4); Extreme Temperature (3)

Elaborated by the authors based on data from ProVention (2011)

Paraguay

Paraguay River and Its Basin

Paraguay (406 × 10^3 km^2 and 6.9 million inhabitants, DGEEC 2014) is located within the La Plata River Basin (LRPB: 3.1 × 10^6 km^2) (Fig. 27.1). The country is divided by the Paraguay River into two major regions: Western (Chaco) and Eastern regions (Báez et al. 2014).

The rainiest seasons are summer (DJF) and spring (NOD) and the winter (JA) the driest. Paraguay River's flow is maximum during austral winter and minimum in September and January. Typical river flow at Asuncion is about 3000–4000 m^3/s (with extremes of 800–12,000 m^3/s and 1–9 m water level respectively). Cyclic floods affect the population, i.e., more than 100,000 people in 1983 (Báez et al. 2014).

Most floods occur between May and July in phase with the winter maximum annual flow cycle, which had been mainly related to El Niño (Barros et al. 2004).

Excess Rainfall and Floods in 2014

Yearly rainfall at Asuncion in 2014 (Fig. 27.4) was the second highest (2,325 mm) recorded from 1967 to 2014 (average: 1,404; maximum: 2,330 mm). The rainiest years (2000 mm/year: 1973, 1986, 2014) and floods (1983, 1992, 1997, and 2014) have coincided with El Niño events (only 2014 was CP mode).

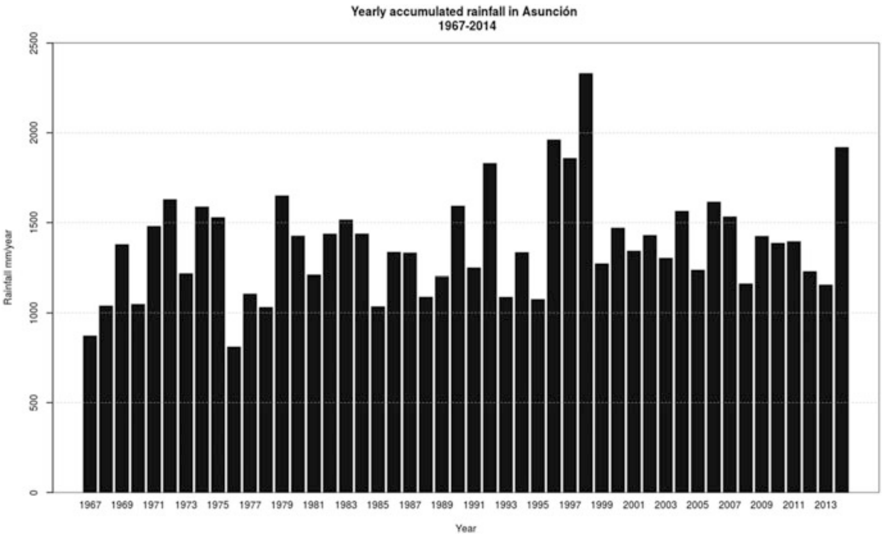

Fig. 27.4 Accumulated yearly rainfall time-series at Asuncion from 1967 to 2014. Data from DMH

The increasing trend of the rainfall time-series could pose a big threat if this trend were to continue. Thus, the occurrence and seasonal distribution of these outliers is a key factor because mainly due to the coincidence of floods with the coolest months which increases human impacts and health risks.

Rainfall at Asuncion in 2014 showed increases of 50–100 % compared with the climatic reference (1967–2013, Fig. 27.5) with a similar pattern than the one observed during strong El Niño Years 1983 and 1997. However, excess rainfall in 2014 began before El Niño fully developed. Also, annual mean temperature was the historical maximum reaching a yearly average of 19.4 °C.

Figure 27.6 shows the annual cycle of mean and maximum Paraguay River level at Asuncion for the years 2013, 2014 and the average from 1980 to 2014. The peak reached on July 2014 (7.45 m) was the Ninth recorded since 1905. Only twice (1905 and 1983) the level was greater than 10 m but the number of exposed population was less than in 2014.

As of July 9 2014, 231,360 persons and 49,189 families were affected, and the number of medical interventions was 27,344 (SEN 2014).

Paraguay and Parana rivers all along their length have been always important routes of communication and commerce of Paraguay; for this reason a lot people, communities, farmers and agro-forestry companies have settled on margins. This population is impacted by flooding, losing their homes, possessions, jobs, causing a great social, economic, health and environmental impact (Céspedes and Ríos 1985). Health risk is higher if the population lives in a low area where the hydrology of the terrain makes streams to converge (Fricas and Martz 2007). This is the case of

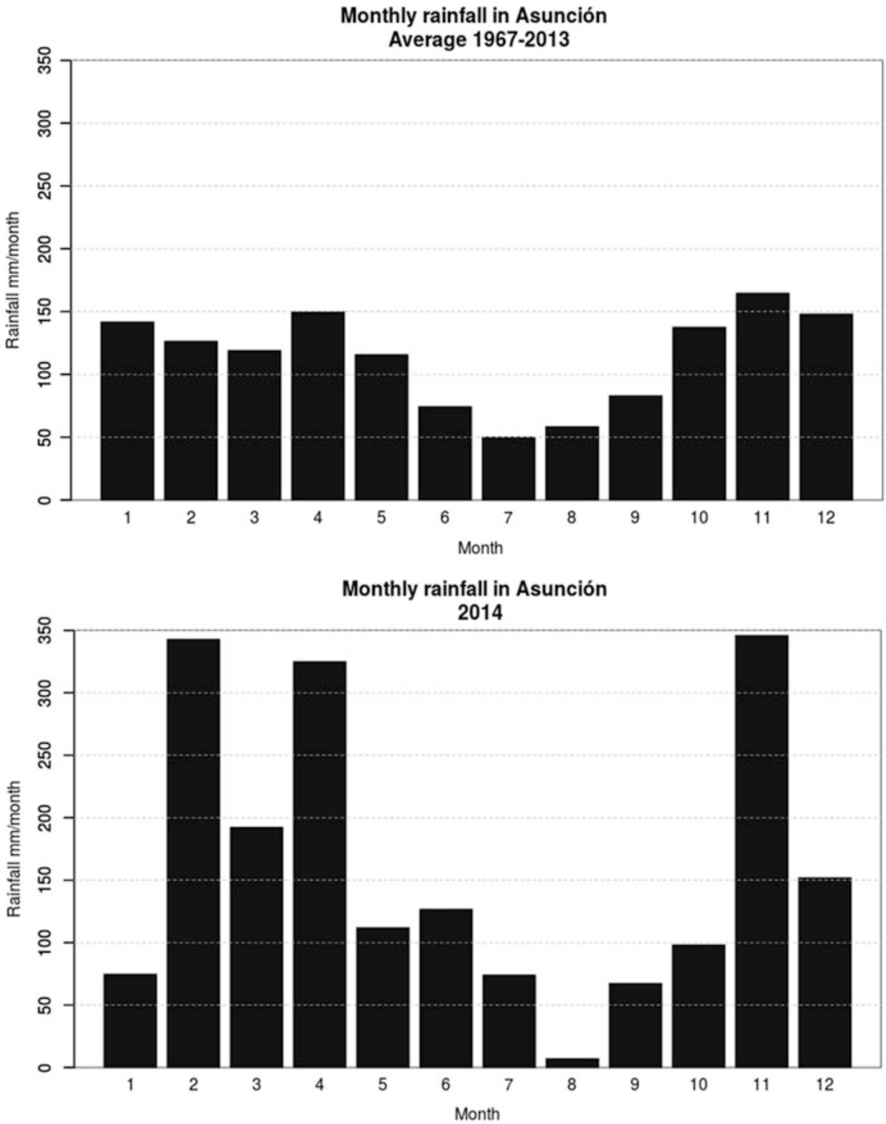

Fig. 27.5 Mean monthly accumulated rainfall (mm) at Asunción, Paraguay. *Above*: average from 1967 to 2013 and *below*: year 2014

vulnerable areas of Paraguay where the Parana and Paraguay Rivers actually converge.

Figure 27.7 shows percentage of disaster victims by the flooding of 2014 at each main region of the country.

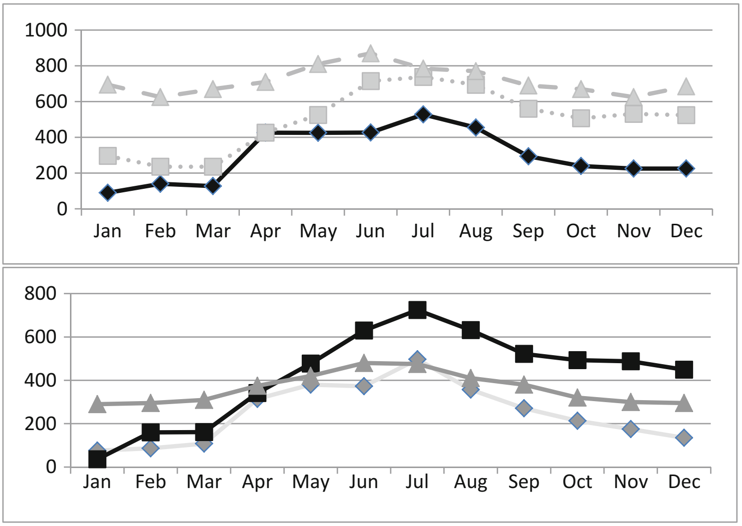

Fig. 27.6 Annual river level (cm) cycle at Asunción (*light gray*: 2013; *black*: 2014; *dark gray*: average 1980–2014). *Above*: monthly maxima. *Below*: monthly means

Paraguay River Flood in the Press

> In Paraguay, the press reflects and/or creates public opinion about climate change and variability (Coronel et al. 2015).

A summary of the flood and its impacts according to ABC Color Newspaper (Asuncion) is shown in Table 27.4.

Climate Variability and Extremes, and Hydro-Climatic Related Infectious Diseases in Paraguay

Hydro-climatic related infectious diseases (H-ID) are discussed for the period 2009–2014 with emphasis on 2014 because of the increased environmental stress associated with floods.

With regard to others ID not discussed here, Dengue fever, Malaria and Yellow Fever, the number of cases (N) of Dengue peaked in 2013 (N = 131,123, with an incidence rate of 1,960/100,000 inhabitants), decreasing to only 2,601 in 2014. Malaria decreased from 91 cases in 2009 to only 11 in 2013 and 8 in 2014, whereas there are no reports of Yellow Fever since 2008 (MSPBS 2015). On the other hand, H-ID increased during 2014 (Table 27.5). Other ID which have increased during 2014, probably due to the floods, were influenza type disease (ILI) and meningoencephalitis.

Unfortunately Hepatitis A (HA) and leptospirosis (LS) are not notifiable diseases in Paraguay yet and they are certainly under-reported. A research made about the

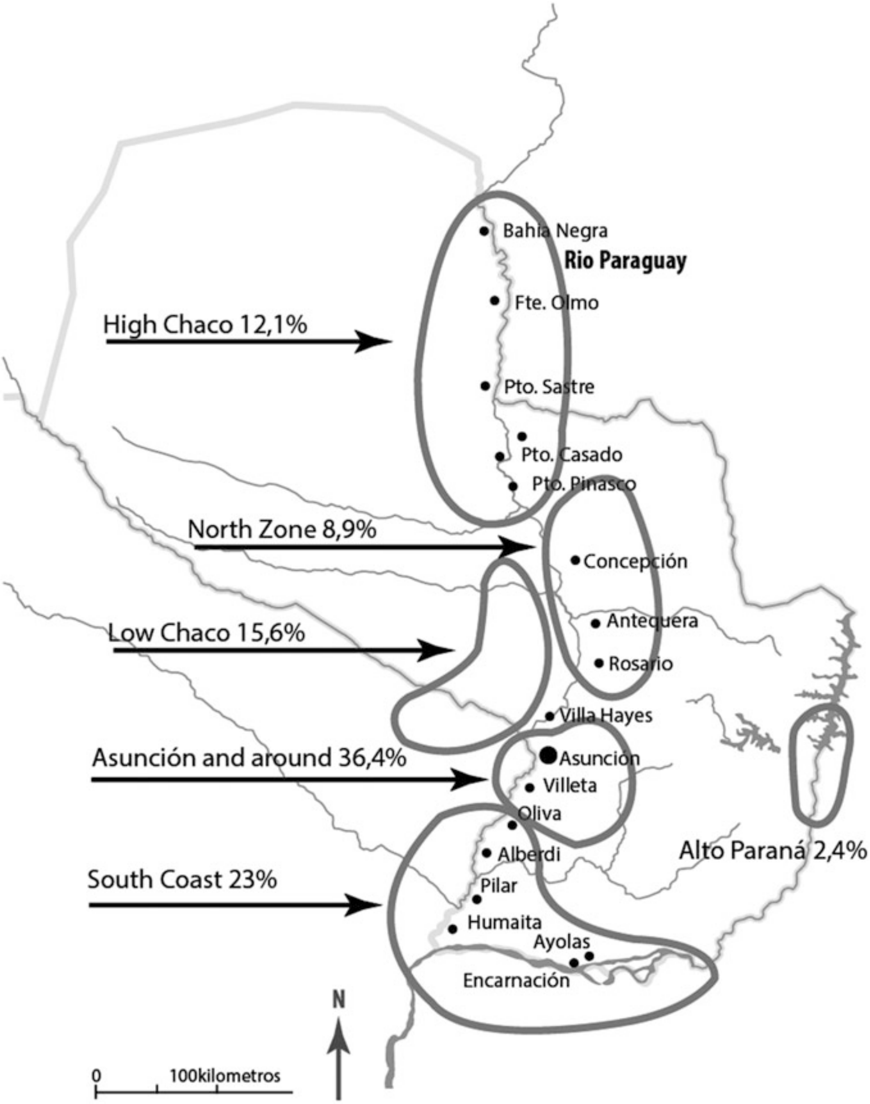

Fig. 27.7 Percentage of victims of the floods in 2014 by regions of Paraguay

compared seroprevalence of Dengue and LS in riverside communities (Carmen del Parana) shows that the frequency of the latter is similar to the one found for Dengue (Cabello et al. 2010). Herein, Hantavirus, Leishmaniasis and Acute diarrheal diseases are briefly discussed.

Table 27.4 Summary of the chronology of Paraguay River Floods 2014–2015 and impacts in ABC Color Newspaper (www.abc.com.py)

Date	Press news
June 13, 2014	"Dengue, Cholera, Malaria and Leptospirosis are some of the diseases subject to national and international monitoring when floods and landslides occur"
June 26	"*The Senate declares emergency due to flooding*"
June 30	"*Is Paraguay facing a new silent disaster*"? http://www.ifrc.org/es/noticias/noticias/americas/paraguay/inundaciones-en-paraguay-junio-2014/)
July 01	*Paraguay records the first case of chikungunya virus, t*he risk of infection grows by the flood of the Paraguay River (MSP). There are 231,360 people affected (Secretary of National Emergency) in Asuncion; about 75,800 people have fled their homes
July 06	"Exodus of 25,000 indigenous people" from their flooded communities to Asuncion and regional capitals
August 24	*The* level of the Paraguay River is now almost five feet less than the peak reached in July
October 31	*The Paraguay River level decreased to 4.52 meters*
November 26	*River levels increase again*(Directorate of Hydrography of the Navy)
December 18	*Asuncion does not have good drainage and on days of heavy rain becomes dangerous*. A Brazilian tourist died in March after being swept away by the floods
February 02, 2015	"*Chikungunya fever Warning: 36 indigenous cases in Asunción and its sub-urbs*". "*MSP will oversee the operational control of the mosquito that trans-mits the disease*"

Hantavirus

Hantavirus was first diagnosed in the Chaco region in 1995 after the El Niño event 1992–1993 that increased rodents due to excess rainfall (Rojas and Scribano 2010). The maximum number of cases occurred in 2011. This peak was mainly attributed to ecological pressure generated by the felling of trees and forest fires which reduce the population of natural predators of rodents (MSPBS 2014).

In 2014, 287,435 hectares (ha) of Paraguay's Chaco forest were converted to other uses (236,869 ha in 2013 and 268,437 ha in 2012). In January 2015 in Paraguay, the average deforestation was 607 ha/day (http://www.guyra.org.py).

Acute Diarrheal Disease

The incidence of ADD reached 40/100,000 people throughout the country and in all ages in 2014 (45 % in children <5 years), 13 % more than in 2013, and an increased level of 50 % over the last 5 years (MSPBS 2014) (Table 27.5).

Table 27.5 Comparative infectious diseases in Paraguay from 2010 to 2014

	ADA	Hantavirus	Visceral Leishmaniasis	Hepatitis A	Dengue	ILI	Meningo-encephalitis
2014	152,092	12	116	×	2601	425,698	676
2013	127,217	2	107	4	131,213	407,381	360
2012	120,600	19	76	38	31,778	351,980	nd
2011	101,266	74	114	8	42,264	300,436	nd
2010	117,761	10	145	27	13,563	235,925	nd

ADA Acute diarrheal disease, *ILI* influenza-like illness, *nd* no data
Source: Authors elaboration from data of the "Dirección de Vigilancia de la Salud". Ministry of Public Health and Social Welfare (MSPBS 2013, 2014), Paraguay

Visceral Leishmaniasis

Visceral Leishmaniasis has increased by 80 % over the past 8 years (from N = 66 in 2006) which seems to be possibly associated with environmental changes such as deforestation, damming, irrigation and urbanization (OMS 2014). The maximum number of cases (N = 145) was reported in 2010. The number of confirmed cases increased in 2014 (N = 116) by 8 % compared with 2013 and most of them are, according to the data of SENEPA (2013), from the regions with excessive rainfall and floods.

Uruguay

The Country: Health Vulnerability to Climate Change, Variability and Extremes

The Uruguay's Third National Communication to the United Nations Framework of Climate Change (MVOTMA 2010) briefly resumes the vulnerability of the health sector as follows:

1. Changes in morbi-mortality due to high/low temperature;
2. Extreme meteorological events (e.g., heavy rainfall, inundations; wind storms);
3. Vector- and Waterborne infectious diseases, where temperature and humidity favours the development and survival of the agents.

Uruguay has an area of 179×10^3 km^2 and a population of 3.4 million. The country is bordered to the West by the Uruguay River and to the South by the Rio de la Plata river estuary (38×10^3 km^2) shared with Argentina and the Atlantic Ocean to the South-East. The country is divided by the Negro River in two halves, northern and southern Uruguay (Fig. 27.8). Both Uruguay and Negro Rivers are flood-prone systems.

The last Dengue epidemic in Uruguay occurred in 1916 (Basso 2010). A reinfection by the Dengue vector the mosquito *Aedes aegypti*, which had been eliminated in 1958, was detected in 1997. The risk of propagation of Dengue fever is associated with temperature, rainfall (Ortoz Bultó et al. 2006; Basso et al. 2010; Caffera 2010), and demographic and socio-economic factors (Hales et al. 2014). Although autochthonous cases have not been confirmed to date, there is a potential health risk due to current climatic conditions favoring its re-emergence (Ciganda et al. 2009; MSP 2014) and the future climate scenarios presented in section "Near-Future Climate Scenarios (2011–2040)". The good socio-economic and health status, the preventive measures, the distance from epidemic focus in Paraguay, jointly with cold winters, has been the barrier to the spread of Dengue to Uruguay until present.

Fig. 27.8 Uruguay River floods and northern river-side inundations as of July 14 2014 (SINAE 2014b)

Climate Variability: Excessive Rainfall, Flooding, Well-Being and Health

Uruguay has been subjected to strong hydro-climatic variability and extreme weather events over the last few decades (Nagy et al. 2008a), particularly the last one (Verocai et al. 2015). Rainfall (Fig. 27.9) and Uruguay River flow (Fig. 27.10) show extremes, i.e., 823 mm in La Niña year 1989 and 2,060 mm in El Niño year 2002; the floods of 2007 and 2014, and the droughts of 2005–2006, 2008–2009, and 2010–2011. During 2009 both drought and floods occurred.

The Uruguay river shows a great monthly and inter-annual variability from 1 to $22 \times 10\ m^3/s$ with a long-term yearly average of $5.6 \times 10^3\ m^3/s$ (Fig. 27.10) which was partly associated with ENSO events (Nagy et al. 2008b, 2014a).

The largest number of evacuees occurred during the floods in 1959 (45,000) and 2007 (12,000). In 1997–1998 most of the Northern Uruguay River side lowlands

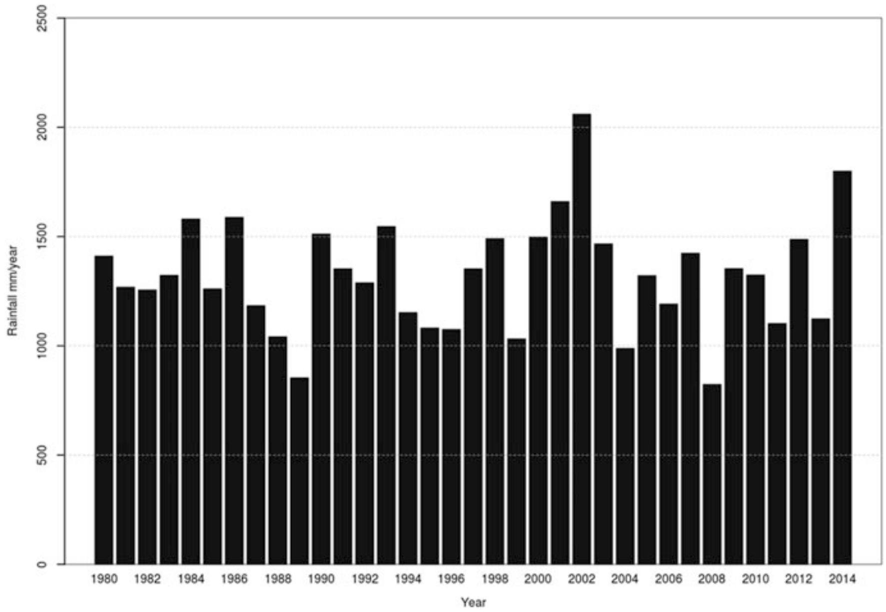

Fig. 27.9 Yearly accumulated rainfall in Uruguay from 1980 to 2014. From INUMET (2015)

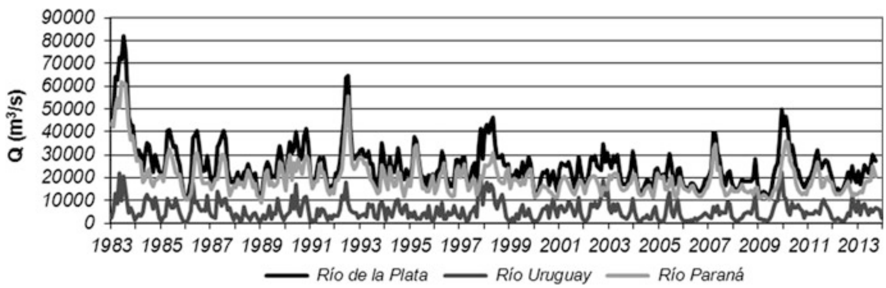

Fig. 27.10 Monthly time-series of Rivers Parana and Uruguay discharge and their accumulated inflow to the Rio de la Plata river estuary from 1983 to 2013 (Verocai et al. 2015)

remained partially flooded for several months (SINAE 2010). During the Uruguay River floods of 2014 only 2,000 people were displaced (SINAE 2014a) and impacts on well-being of populations and health were mainly related to psycho-social stress. In recent years, in some of the vulnerable areas, houses have been built outside flood zones and many families were resettled with state support (SINAE 2014a).

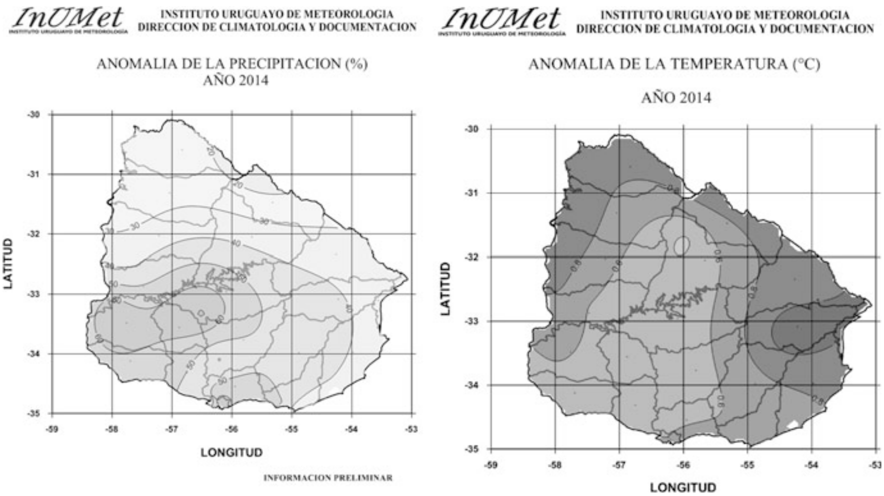

Fig. 27.11 Climatic anomalies of Rainfall (*left*) and temperature (*right*) in Uruguay for 2014 (INUMET 2015)

Uruguay's Climate Anomalies in 2014

The year 2014 was characterized by extreme positive anomalies of rainfall (1,800 mm/year) and temperature (18.4 °C), which were +30 % and +0.7 °C greater than the 1961–1990 average respectively) (Fig. 27.11) (INUMET 2015).

During late January and February 2014 rainfall at South-western Uruguay was the maximum ever recorded in summer (SINAE 2014a). In July floods occurred in the northern Uruguayan Riverside (SINAE 2014b) when river flow reached its fourth historical daily maximum on July 7.

Climate Variability and Hydro-Climatic Related Infectious Diseases in Uruguay

In Uruguay, increased rainfall and flooding have been associated with outbreaks of Hantavirus and Leptospirosis, whereas droughts have been linked to outbreaks of Hepatitis A (Guedes et al. 2009; Ciganda et al. 2009). Table 27.6 summarises climatic factors and Infectious Diseases (ID) from 2005 to 2014.

Hepatitis A

In Uruguay, prior to 2007, Hepatitis A was an endemic disease with outbreaks in children and young adults, primarily in areas with lack of potable water (Tanaka 2000), outbreaks occurred during periods of drought.

Table 27.6 Climatic factors (yearly mean temperature and rainfall) and occurrence of hydro-climatic related infectious diseases (H-ID) in Uruguay (2005–2014)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Climatic factors and cases of H-ID										
Temperature (°C)	18.1	18.2	17.4	18.1	17.7	17.8	18	18.3	17.7	18.4
Rainfall (mm)	1,322	1,192	1,424	823	1,354	1,325	1,103	1,487	1,124	1,800
Hepatitis A	2,944	1,878	564	411	229	90	37	21	40	18
Leptospirosis	83	66	134	53	42	97	18	65	66	165
Hantavirus	18	13	10	9	5	18	6	13	16	19

Elaboration of the authors from data of the Ministry of Public Health (MSP 2015) and INUMET (2015)

In 2005 the incidence rate of HA was close to 90/100,000 inhabitants. Since 2005 the health strategy was aimed at blocking outbreaks through vaccination. Between 2005 and 2007 the population at risk was vaccinated and since 2008 vaccination became mandatory allowing a significant and sustained decline in the incidence rate and the disappearance of outbreaks (Romero et al. 2012).

Free and universal vaccination was a key measure of climatic adaptation to cope with the extreme drought in 2008–2009. The infection rates decreased from 90 to 1/100,000 inhabitants.

Leptospirosis

Episodes of excessive rains, overflowing sewage during floods, alkaline soils and high temperatures favor the transmission of Leptospirosis in Uruguay (Braselli 2010). The disease is spread when humans accidentally come into contact with infected animals, water, land or contaminated products, in flood-prone zones, without good sanitation, near landfills. As of 2005 Uruguay was ranked first in South America by annual incidence of LS per million population, 25/million population (Pappas et al. 2008). This disease is well reported in Uruguay, which is not the case for many countries.

During the floods in 2007 and 2014 infection rates increased from 1 to close 5/100,000 inhabitants (50/million). A positive correlation was found between yearly rainfall and the number of cases (N) of LS from 2005 to 2014 (r: 0.73; $p < 0.02$; Fig. 27.12). This relationship began by 2001 when the number of cases increased to 2.6/100,000 inhabitants. Since then the cases of LS remain close to 25/million population for typical yearly rainfall (125–145 cm/year). The maximum ever registered was 250 (Rivero and Rago 2011) coinciding with the El Niño-related rainfall maximorum in 2002 (2,060 mm/year) followed by 180 cases in 2003, a normal wet year (1,470 mm/year).

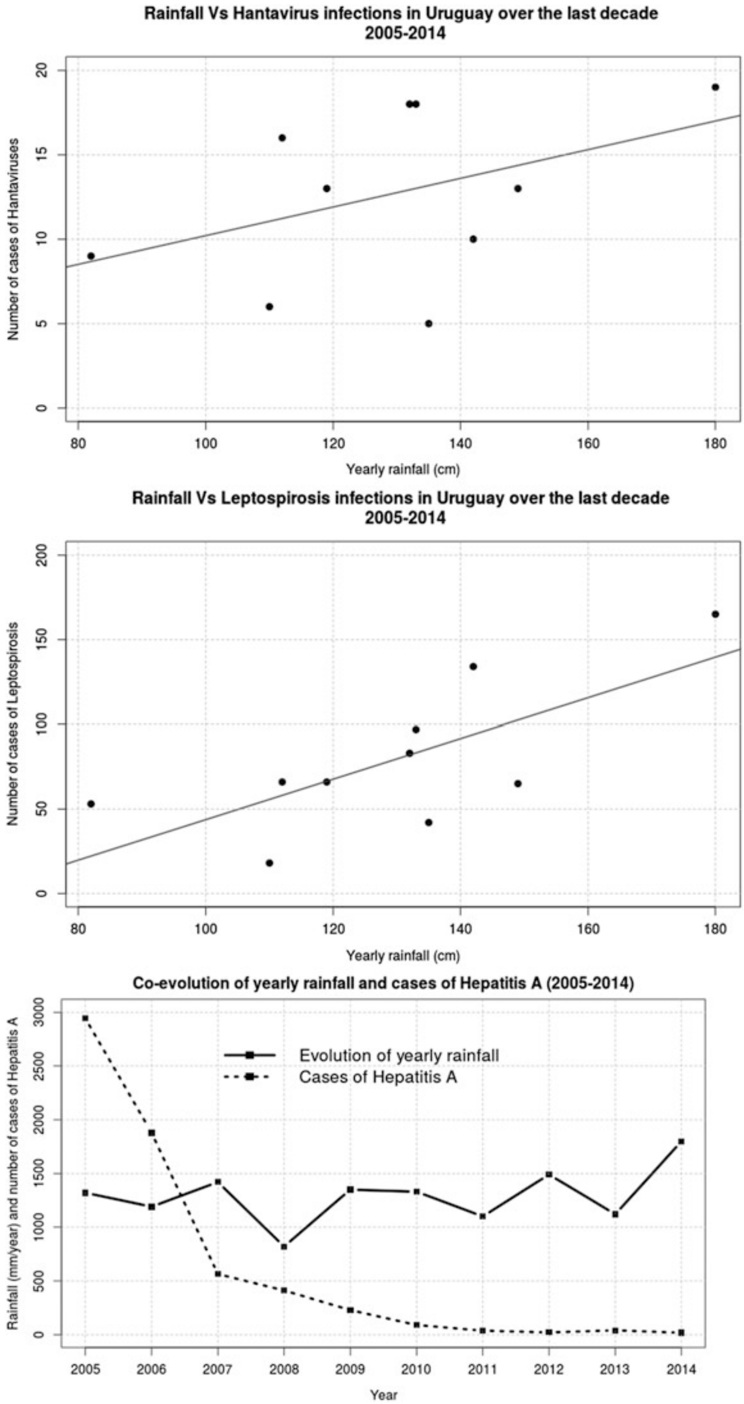

Fig. 27.12 Relationships between yearly accumulated rainfall (in cm) in Uruguay (2005–2014) and the confirmed number of Leptospirosis (*above*), Hantavirus (*middle*), and Hepatitis A (*below*)

Hantavirus

The number of cases of Hantaviruses, a rodent-borne ID, peaked during wet El Niño (CP mode) years 2005 (N = 18), 2010 (N = 16) and 2014 (N = 20), potentially explained as mice are obliged to leave their burrows by excessive rainfall and thus come into contact with people it infects. A positive slight correlation was found between yearly rainfall and the number of cases of HV (r: 0.44; $p < 0.2$).

Cyanobacteriae Blooms and *Escherichia coli* at Estuarine Waters, Montevideo

The Rio de la Plata river estuary is subjected to increased nutrient load, damming, temperature and rainfall increases, ENSO-related floods and decreased salinity (Nagy et al. 2002, 2008a, b; Nagy 2005) all of which favor fresh-water cyanobacteriae blooms. The main bloom recorded occurred during El Niño-related high Uruguay River discharge in 2002–2003 (López and Nagy 2005; Nagy et al. 2008a). The impact of these blooms on public health is not known yet (Ciganda et al. 2009).

Floods, local rainfalls and storm surges increase both the survival of fecal coliforms and their flow from the mix of rain- and waste-water at Montevideo (Nagy et al. 2013, 2014b; Verocai et al. 2015). Regulatory limits were exceeded mainly in January 1998 and less in 2003 and 2010. A monitoring and communication programme allows reducing health risks which results are published on weekly basis (http://www.montevideo.gub.uy/ciudadania/desarrollo-ambiental/playas) and if fecal coliform values do not comply with the limits, a sanitary flag is posted in the affected beaches to communicate possible health risks and prevent exposure of swimmers (Nagy et al. 2014b).

Bolivia

Mamoré River and Its Watershed in Amazonian Region

The Mamoré River is located in the plain of Moxos, Department of Beni, North-Eastern Bolivia (Fig. 27.13), in the Amazon basin. This plain is flood-prone and sensitive to ENSO events and has been declared a national disaster area repeatedly. Since pre-Columbian era floods have been associated with El Niño. However, in recent years they have also been associated with La Niña or neutral years. The floods in the city of Trinidad, Capital of Beni, are from both local and remote hydrological processes that rely on hydro-meteorological conditions in the Mamoré river basin in the middle level and basin headwaters in the Andes (Ramírez et al. 2008).

Fig. 27.13 Map of Bolivia. Highlands (*green*), lowlands (*white and gray*). The city of Trinidad and Mamore River in the Beni region are shown

Excessive Rainfall and Floods in 2007 and 2014

The rainfall in the Beni plains is associated with large synoptic systems: Bolivian High, the Intertropical Convergence Zone, the Jet Stream at low levels and southern winds associated with the polar anticyclone which usually occur in winter causing persistent rainfall during 3–4 days.

Distribution of the climatic average monthly rainfall (in mm) is shown in Fig. 27.14. Outliers were reported in January 1992 (793.7 mm), which was 300 % more than the monthly climatic reference (262.3 mm) (Ramírez et al. 2008).

During the 2006–2007 summer (an El Niño CP mode year), heavy rains from December to March increased flow causing floods. This behaviour was different

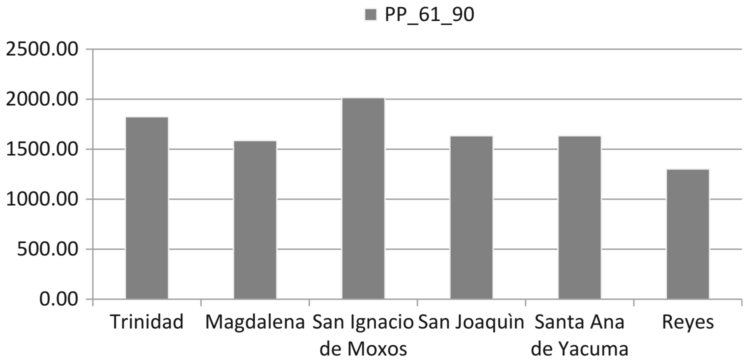

Fig. 27.14 Distribution of average annual rainfall (1961–1990) for Beni. Elaborated by the authors from data of the National Service of Meteorology and Hydrology (SENHAMI 2008)

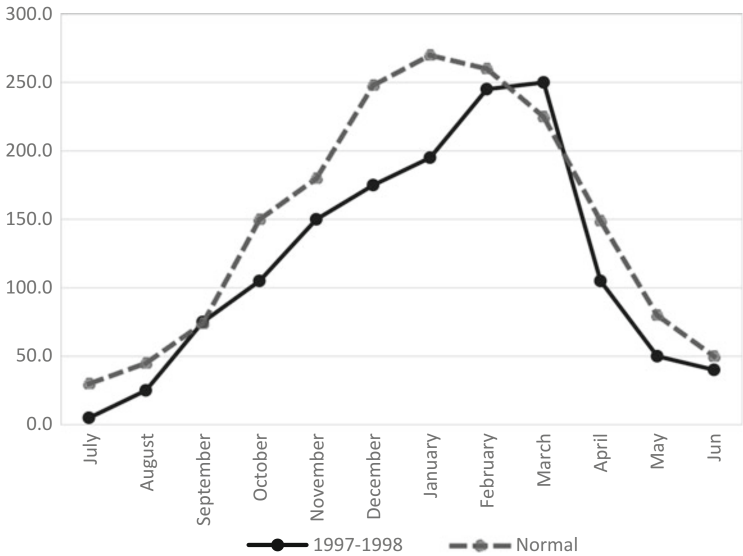

Fig. 27.15 Pampas of Moxos in the Bolivian Amazon. Comparison of rainfall (in mm) in July 1997–June 1998 compared to normal (CAF/CEPAL 2000)

from the historical record that maintained the normal level of rivers (SENHAMI 2008).

Rainfall in 2006–2007 was concentrated in January and February which caused the flooding of the Mamore River in March 2007, while the spring (September–November) was negatively anomalous. A similar behaviour, but more intense in spring occurred during the very strong El Niño of 1997–1998 (Fig. 27.15).

Flooding Area

Flooding is defined as the state of water flooding in areas that are normally dry, due to the temporary rise of a river, lake or another water body (Quiroga et al. 2008). In Mamore River basin the flooded area has increased from near 1.5 million in 1998 up to 10 million hectares during El Niño 2007. To delineate the flooded area nine MODIS satellite images from March and April 2007 were used (Fig. 27.16). These images show the greatest impact on the Mamore River mouth (2.5 million hectares) north of the city of Trinidad. Within this flooded area outbreaks of yellow fever and increased number of cases of diarrhea have been reported due to the mix of drinking water with sewage waters. The flooding of pastures increased livestock weight loss and mortality.

The cause of floods in the Beni is excessive rainfall in short periods of time, associated with the confluence of rainwater from peripheral regions and the subsequent overflow of rivers, creeks and streams. Other related causes are low soil infiltration, increased flows, and changes in land-use in the middle part of the basin (with a deforestation rate of 10,000 ha/year), where the highest levels of rainfall 3000–6000 mm/year are recorded (SENHAMI 2008).

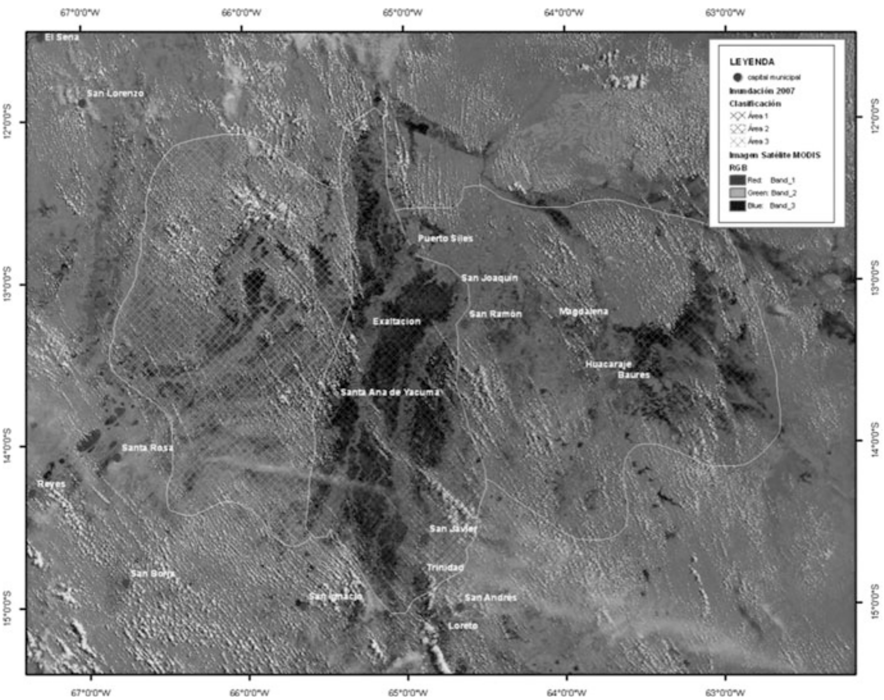

Fig. 27.16 Flooded area. Water is seen in *dark black* and *dark gray colors* according to either clear or turbulent water respectively. From PNCC (2008) based on MODIS images from NASA

A similar process follows the basin headwaters in the Andes, with steep slopes, low vegetation cover and high forest degradation, all of which increase surface runoff and sediment transport by water erosion, reducing the hydraulic radius and causing the rivers to overflow. January and February have a high probability of flooding, occurring within days.

Climate Variability and Change

Local consequences of ENSO events (El Niño/La Niña) have a recurrence cycle of about 4 years, although the historical record shows a variation of 2–7 years (Gutiérrez et al. 2005).

Dispersion of ENSO events seems to be shortened and intensified, perhaps due to climate change. In recent years events that can be considered having a moderate magnitude (Fig. 27.17) exceeded the historical records of precipitation (which might be due to CP mode years 2006–2007 and 2014–2015), causing strong impacts triggered by population mobilization to the lowlands. Thus, the increase in variability, extremes, and exposed settlements at lowlands increase human vulnerability.

The recent trend of precipitation in Beni is an increase of 30 % in summer (January and February) and decreases in early spring, delaying the rainy season.

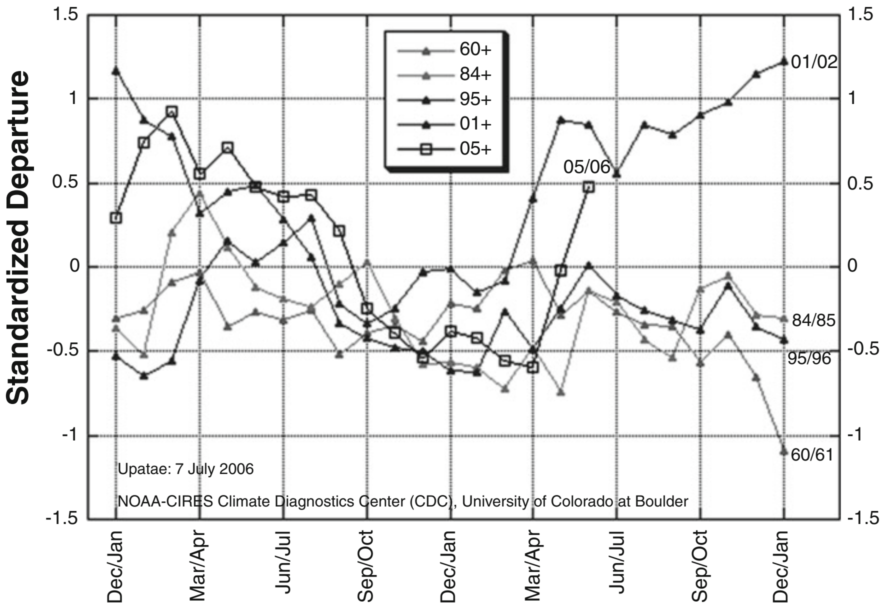

Fig. 27.17 Multivariate ENSO Index (MEI) for 4 weak moderate El Niño events since 1950 vs. 2006 condition. From NOAA/ESRL/Physical division—University of Colorado Boulder/CIRES/CDC 2006

The climate change scenario A2, model ECHAM 4 (grid of 25 km) in the plains of Moxos shows a 10 % decrease in precipitation and an increase in temperature up to 5.5 °C by 2030 (Seiler 2009).

Flooding in Beni have occurred in conditions of moderate El Niño coupled with deforestation in the upper reaches of the watershed and the retreat of glaciers due to climate change. These factors have intensified the magnitude of this type of events.

Impacts of Floods on Well-Being and Health

The overflowing rivers caused loss of homes and belongings, cuts of basic services, and pollution of drinking water. The increased retention of excess of water caused the increase of vector-borne diseases, loss of grasslands in pastoral areas (5,564,589 ha, FEGABENI 2008), loss of biodiversity and domestic animals, in addition to damage to infrastructure (Table 27.7).

The extent of damage affected many people. Therefore schools were used as temporary shelters, delaying educational activities. As of February 21, 2015 there are more than 20,000 families affected in Bolivia as a result of excessive rains and hail, many in the Beni region.

Table 27.7 Summary of impacts of flooding in Beni 2006–2007

Item	Unit	Quantity	Additional risks	Estimated damages (US$ millions)
Population with flooded areas	Inhabitants	35,000	Food availability	35 to 70
			Emerging epidemics	
			Households	
			Basic services	
Livestock	Heads	200,000 (8 % of the total, CEPAL 2007)	Diseases	60
			Death	
			Weight reduction	
			Cattle food	
Infrastructure	Highways	Not estimated yet	Damage to highways	70 (first estimation)
Total				200

Elaborated by the authors based on data from Pan American Health Organization (PAHO)/WHO (2007) and Beni Government

Human Health Impacts

The floods exceeded the capacity of the health system in Beni and health emergencies multiplied, i.e., increased exposure to snakebites in dry areas or shelters.

As of late January 2007, the number of registered cases of acute diarrheal disease (ADD), acute respiratory infections without pneumonia, Pneumonia, Malaria and Leishmaniasis increased. The high incidence of cutaneous Leishmaniasis in Bolivia is exacerbated during La Niña (Gómez et al. 2006; Garcia et al. 2009). In addition, the first case of Leptospirosis was reported in Beni in the flooded area (Aparicio-Effen 2010).

Disaster Reduction and Climate Change Adaptation Measurements

Flooding in Beni led the government to formulate a plan of rehabilitation and reconstruction, and adaptation measures through social investment funds: "National Mechanism for Adaptation to Climate Change", which was an important milestone in the development of public policies to address climate change in the country (Table 27.8).

Table 27.8 Rehabilitation, reconstruction and adaptation plans in Bolivia. Mechanism for Adaptation to Climate Change (NCCPB 2007)

Intervention term	Measures
Short-term	Relocation of settlements in fragile areas
	Flood protection infrastructure
	Rehabilitation of road infrastructure
	Epidemiological program for emerging diseases due to flooding
	Rehabilitation of livestock systems and other subsistence systems
	Dissemination and awareness
Mid-term	Drainage development
	Construction of artificial lakes
	Construction of connection and irrigation channels
	Management of the tributaries of the Mamore River
	Recovery of ancestral technologies for water management
Long-term	Integrated watershed management
	Water capture and transfer to regulate droughts and floods.
	Afforestation and reforestation
	Biological corridors and environmental services

Conclusion

The precedent items permit us to say that ENSO events and the occurrence of extremes often in coincidence with ENSO events allows a better understanding of plausible future impacts of climate change. This should be the basis for systematizing the lessons learnt aimed at consolidating strategic adaptation actions from planning systems.

Overall Discussion

> In the face of uncertainty particularly in relation to issues such as climate change adaptation and monitoring, learning and adaptive management become essential, the concept of "learning to manage by managing to learn" becomes an essential part of the Vulnerability, Impact and Adaptation assessment process (Metternicht 2014).

ENSO Variability and Extremes

The case studies of Paraguay, Uruguay and Bolivia and the historical background show a relationship between ENSO events, well-being of the population and health. Excessive rainfalls and flooding are associated with El Niño in Paraguay, Uruguay and Bolivian lowlands. Although climatic history suggests that these anomalies were more or less quantitatively related to the strength of El Niño (see section "Hydrometeorological Disasters", Fig. 27.3), in recent years strong anomalies have been related to weak or developing El Niño events. The year 2014 is an example. This could possibly be related to the different modes of El Niño ("classic" or Eastern Pacific-EP, "Modoki" or Central Pacific-CP), whose occurrence implies anomalies who differ depending of the mode in several regions at the studied countries as well in regions of Argentine and Brazil as explained by several authors (Ashok et al. 2009; Ren and Jin 2011).

Increased ENSO-linked climate variability in the countries of the region led to "learning to manage" or to cope with climate variability (Climate Variability Adaptation—CVA). However, "managing variability" seems not to be enough because of the ongoing changes in climatic patterns and the high level of dependence their economies have on climate, water resources, and grasslands (Coronel et al. 2015).

Is There an Adaptation Deficit?

> Weather and climate extremes might propel adaptation both to a stable climate and its characteristic extremes, as well as to underlying changes, if they reveal vulnerabilities, cause damage, and make slow change more noticeable. In theory, extremes act as focusing event that overcome barriers to adaptation and accelerate policy response (Travis 2014).

The effects of floods and the relationship between excessive rainfall and the number of cases of infectious diseases (ID) suggest the existence of an adaptation deficit to current climate, at least for strong anomalies and extremes beyond the coping range of both natural and human systems. However, as suggested by Metternicht (2014), and Travis (2014), weather and climate extremes might be the engine to better understating climate impacts and fostering adaptation by means of learning to manage risks under uncertainty.

Some improvement has been made in Uruguay since the extreme flood in 2007, such as the implementation of the National System of Response to Climate Change and Variability (SNRCC 2010, 2014), despite it focuses on climate variability (Nagy et al. 2015), and the National System of Emergency (SINAE) which might explain the relatively low number of evacuees in July 2014. In Bolivia the Beni floods in 2007 also led the government to develop adaptation plans. However, only the reduction of losses and damages due to excessive rainfall and floods will be the answer to these plans and learnt lessons. Extremes such as the example of Paraguay River in May–July 2014 are a good test to assessing plans. Will Paraguay learn the lessons from the ravaging flooding of 2014?

Metternicht (2014) synthesizes the lack of pro-active adaptation in the region as follows: "*Regardless of Vulnerability, impacts and adaptation (VIA) assessments performed in the region, there is still a prevailing overall reactive approach based on rescue and relief. Finally, it is evident that the need for climate change adaptation in Latin America, and in other developing regions, is growing in urgency, and while actions should be taken based on VIA results, there is a need to strike the balance between assessment and action*".

Is Available Information Enough to Estimate Future Risks?

> Better evidence is required regarding future risks to health from global climate change in order to inform adaptation (public health) policy development (Hales et al. 2014).

Usually future risks in the absence of climate change are estimated using regression methods for three development futures: base case, high growth and no-growth scenarios (Hales et al. 2014). However, global climate models (GCMs) hardly give good estimates of climate extremes but of yearly and seasonal plausible futures. In addition to this, the infectious diseases reported in this article are strongly dependent on rainfall patterns. Unfortunately, GCMs for the region as in many others are more consistent for temperature than for precipitation. In this regards, climate futures are highly uncertain to assess future risks associated with rainfall and flooding. Warming and land-use changes might reduce floods despite similar or even greater rainfall and the latter also favours erosion process.

Future vulnerability scenarios should include:

- The influence that successive rainfall anomalies and the interaction with temperature have on the development and spread of H-ID.
- Changes in demography, GDP and health investments.
- Adaptive capacity variables, i.e., weather and climate forecast capabilities, early warning systems (EWS), and risk-management capacity (flood disaster management).

Summary and Conclusion

The increase of extreme hydro-climatic events in the region, their likely expected future increase (IPCC 2012, 2013), and the observed trends and relationships between excessive rainfall, floods and landslides with well-being and ID presented in this article suggest that despite the different climatic, socio-economic and public health status, extreme floods have severely impacted Bolivia, Paraguay and Uruguay (and the whole La Plata and Amazonia basins) since 2007 and might continue in the near-future.

In addition to warming and changing rainfall patterns, the sustained increase of deforestation in Paraguay and Bolivia is negatively impacting both the local and global environment, and possibly triggering H-ID.

Disaster management essentially revolves around flooded areas with a primary focus on rescue, relief and rehabilitation (Sayed and González 2014). This is true for the studied countries, where the approach should evolve from the current reactive actions to a flood-prone areas evacuation approach. In this regard, some improvements have been made in Uruguay and Bolivia since the extreme floods in 2007. "*There is a need to evolve to an analysis of adaptation options identified to arrive at well-defined practical and feasible measures*" (Metternicht 2014).

Adaptation plans are good, their implementation is better, and their review after verification (by means of exercises and the occurrence of extremes) is even better. The best plans will likely fail under extremes: they have to be able to reduce impacts. Both low income countries as Bolivia and Paraguay and a high income country as Uruguay (although in the lower limit) are in need to prevent future extreme floods that decouples exposure and vulnerability from economic growth. This may be done by:

- Reducing the exposure.
- Fostering modeling, forecasting, and EWS.
- Developing pro-active plans.
- Incorporating better science information.
- Improving after—disaster actions.

The example of Uruguay's vaccination plan for Hepatitis A—in addition to the very good water and sanitation status of the country—(see Aparicio-Effen et al. 2016) is an example of how an endemic disease can be eliminated, which has been verified after successive droughts.

Available information of hydro-climatic related infectious diseases in Paraguay and mainly in Uruguay shows that they are sensitive to excessive rainfall and floods. Evidence, mainly from Uruguay, suggests that Hantavirus and Leptospirosis have increased after the successive very strong ENSO events of 1997–1998 (El Niño) and 1999–2000 (La Niña) and the strong El Niño 2002, varying since 2005 in relation to total yearly rainfall. These ID as well others reported for Paraguay and Bolivia, i.e., ADD or Leishmaniasis, have increased during floods, which is likely to have occurred with under-reported Leptospirosis too.

The case of Beni floods in the Bolivian Amazonian lowlands in 2007, the extreme and long flood in the Paraguay River, and the severe one in the Uruguay River in 2014, suggest that the relationship between El Niño strength, timing and mode (CP or EP), and rainfall might have been changing over the last decade. This increases uncertainty even before the lessons learnt from ENSO-linked extremes from 1983 to 2002 (dominated by classical El Niños or EP mode) were incorporated into risk-management plans. This might possibly be due to a lack of progress (even a decline) in predictability of ENSO events, as suggested by several authors (Barnston et al. 2012; Luebbecke and McPhaden 2013), and/or the increase in the occurrence of El Niño CP Mode events (McPhaden 2013).

However, perception of an increased risk due to extreme hydro-climatic extremes seems to be well established, regardless of its complex and varying phenomenology.

Are UruPaBol countries well adapted or at least better adapted to climate stressors than they were two decades ago? Although the aim of this article was not the assessment of the current status of VIA and risk-management, the answer seems to be yes. Nevertheless, it is not as good as it should be. Is there an adaptation deficit? Yes, and it will continue in regards to extremes. The goal is to cope with typical variability (coping range) and to reduce the deficit under extreme events.

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Chapter 28
Territorial Solutions, Governance and Climate Change: Ecological Sanitation at Praia do Sono, Paraty, Rio de Janeiro, Brazil

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Abstract The area comprised of the so-called Mosaico Bocaina is highly environmentally vulnerable due to real estate speculation, large construction projects and conventional tourism, which put forth an unequal, predatory form of development. The current context of climate change and water crisis in Brazil (particularly in the Southeast) amplifies the vulnerability of traditional and coastal communities. Therefore, the development of participatory alternatives to promote equity is fundamental to address territorial needs, thus generating solutions that consider the local context and traditional knowledge and increasing the resilience of affected communities. Based on the fact that sanitation was considered a priority for Praia do

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Sono—and through an approach that not only combines permaculture, education and sanitary engineering, but also establishes a dialogue between academia, local community and public managers—the Observatory of Sustainable and Healthy Territories, a partnership between the Oswaldo Cruz Foundation (FIOCRUZ), the National Health Foundation (FUNASA) and the Forum of Traditional Communities (FCT) has developed comprehensive social technologies. Raisin awareness in the community aims at the fully incorporating of the proposed solution in a future step. This chapter systemizes the process (from the prioritization to the establishment/implementation of the technological solutions adopted) and analyzes its potential for producing autonomy, equity and sustainability, providing social technologies with the potential to empower communities to provide solutions to mitigate environmental impacts and increase the resilience to climate change.

Keywords Traditional communities • Ecological sanitation • Ecology of knowledge • Climate change and health • Observatory of sustainable and healthy territories

Introduction

Human-induced climate change will affect the lives of most populations in the next decade and it will have its greatest impact on the most disadvantaged populations on the planet (Bowen and Friel 2012). The IPCC report *Climate Change 2014: Impacts, Adaptation and Vulnerability* shows how these groups (such as coastal populations, the urban underprivileged and traditional communities) are under greater risk of socio-environmental impacts (IPCC 2014).

The socio-environmental impact of climate change relates to extreme climatic events such as floods, landslides, desertification, sea-level rise, an increase in global temperature, etc. Also, climate change will bring broad impacts on society through a changing water cycle. Future scenarios indicate that, in general, current spatial patterns of water quality and quantity will be altered (UNU-INWEH 2010).

Contextualizing it to Brazil, a severe drought in 2014 impacted the Central-Western and Southeast regions, leading to a need for water rationing in at least 142 cities in 11 states including São Paulo, one of the largest cities in the country (Hackley 2014). In addition, studies show that most of rains in Midwestern and Southern Brazil are supplied by water evaporated in the Amazon (UNICEF Brazil 2009). As drying occurs in Amazonas, rainfall declines in these regions as well.

Besides that, in areas where adequate access to sanitation does not exist, the change in water resources will amplify existing problems, leading to more severe events of water contamination (UNU-INWEH 2010). This panorama shows how we must think globally, but also, at the same time, act locally.

In 2000, heads of state adopted the Millennium Declaration providing the formulation of eight Millennium Development Goals (MDGs), aimed at the objective of radically reducing poverty worldwide. One target under MDG 7 was to halve the proportion of the population without sustainable access to safe drinking-water and basic sanitation by 2015 (WHO 2009). Nevertheless, sanitation was the most neglected MDG, not inspiring many solid public policies. While there was significant progress towards the Millennium Development Goal target for drinking water, sanitation failed woefully short of the target (UNU-INWEH 2010).

In an effort to attend to the marginalized goals of the MDGs, the UN promoted the Rio + 20 Conference carried out on June, 2012 in Brazil where the Post-2015 Agenda, the Sustainable Development Goals (SDGs)—as well as its development process—were first agreed. Sustainability was highlighted as a critical dimension in all fields of knowledge and action (UN 2012).

Therefore, sanitation must be addressed in a broader context as part of an overall strategy to increase global equity. The role of sanitation in education and the empowerment of local communities is critical (UNU-INWEH 2010). Thus, the goal of this study is to address SDG 6, which ensures the availability and sustainable management of water and sanitation for all.

The current evidence of ecological imbalance, climate change and an expansion of social inequalities underlines the unsustainability of the hegemonic mode of production and consumption, which threatens life as we know on Earth (Gallo and Setti 2014a).

The "eco-efficiency" approach to sustainable development has been dominating environmental, social and political debates, introducing solutions for "economic and ecological gain" (Jaenicke 1993). However, although actions like that may have a positive impact in the preservation of environmental resources, they do not integrally consider the social issues on the territory they are impacting. They focus only on the economic and the environmental, but neglect the social pillar. All around the world, the creation of National Parks is preceded or followed by the dislocation or expulsion of native populations from the territory, a simply remedial attitude that ignores the role of traditional populations in environmental conservation (Alier 2007).

The idea of "environmental justice" has lately been gaining traction for prioritizing the living conditions and the protagonism of marginalized populations. It highlights the importance of autonomy, sustainability and equity in addressing the needs of native communities and peoples (RBJA 2010).

The idea, therefore, more than pointing toward a specific result, is empowering people and producing autonomy, equity and sustainability, especially for excluded and/or vulnerable populations. In this process, the development of sustainable and healthy territories is the consequence of addressing different points of view on what the social development of space and territorialities is. These views that can possibly change the hegemonic mode of production and consumption, causing counter-hegemonic rationales to emerge (Gallo and Setti 2012a, 2014a), as stated in the document *Sanitation as a Key to Global Health: Voices from the Field* (2010):

> access to sanitation does not automatically equate to use and change in behaviour. Therefore, education, empowerment and community-participation are equally critical, as evidenced by the success of community-led total sanitation. When coupled with national

government support and programming, this can make significant inroads (UNU-INWEH 2010).

Therefore, the impact of climate change is the intersectoral responsibility of all actors involved, especially the most directly affected, such as traditional communities. Their protagonism is crucial for promoting prevention and/or mitigation actions that recognize their needs and implement adaptation plans (Tran et al. 2014).

In order to evaluate vulnerabilities and possibilities concerning the adaptation to climate change, it is important to understand situations specifically. In the case of traditional communities, the role of their knowledge (such as, for instance, permaculture) in the development of strategies for tackling climate change has been recognized. This new perspective integrates both academia and traditional communities into one ecology of knowledge, promoting new perspectives and developing social technologies (Williams and Hardison 2013; Ford 2012; Dagnino 2009).

This implies, among other actions, the implementation of territorialized agendas, a counter-hegemonic perspective. In order for agendas to meet requisites and be effective, their implementation implies the involvement of different actors in a participatory governance process that is capable of ranking priorities (based on the needs of the territory) and building technological/political solutions (based on the ecology of knowledge and using strategic/situational management and communication processes) (Gallo and Setti 2012a, 2014a).

In this context, since 2009, the Oswaldo Cruz Foundation (Fiocruz)—together with the Forum of Traditional Communities of the Municipalities of Angra dos Reis, Paraty and Ubatuba (FCT)—has been carrying out a set of strategies to promote the sustainable development and the health of traditional communities in protected areas at the so-called Mosaico Bocaina (Gallo and Setti 2012b).

The process led to the creation of the Observatory of Sustainable and Healthy Territories of Bocaina (OTSS), whose goal is coordinating agendas and promoting actions in the territory. These actions produce actual technologies and solutions that promote equity, autonomy, sustainability, as well as generate information, critical knowledge and collective intelligence.

This chapter describes the development and the implementation of the first eco-sanitary module in OTSS's opening project, the Ecological Sanitation of the Caiçara Community at Praia do Sono, Paraty, Rio de Janeiro—RJ, in the Southeast of Brazil. This project highlights how the use of a social technology for ecological sanitation can contribute to the empowerment and perpetuation of traditional communities in the Mosaico Bocaina, as a way to resist the advance of real estate speculation and conservationism, since it underlines that the presence of traditional communities on the territory is sustainable.

Moreover, the chapter also evaluates the contribution of the project to the autonomy of the FCT and the community, its impact on equity on the territory, the sustainability of its sanitation solutions, its potential to be replicated in other communities, as well as its possible contribution for addressing climate change, approaching solid actions based on SDG 6.

Methods

Action research is OTSS's methodological approach of choice (Gallo and Setti 2012a, 2014a). This methodology is a type of social research associated with concrete actions to solve collective problems. To be considered a participatory action research, the participation of people involved in the issues addressed is required. Thus, researchers and participants work together finding a collective solution through an exchange of knowledge and learning. This form of work can be called an "Ecology of Knowledge". To promote this method, the use of participatory techniques—such as: (1) participant observation in the field; (2) seminars; (3) participatory planning workshops; (4) team monitoring meetings between researchers and various other actors involved, especially the community where the action will be implemented—are required (Thiollent 1986).

As postulated by Glavovic et al. in *Climate Change and the Coast: Building Resilient Communities* (2015):

> The point of departure is building human, social and political capital through deliberative issue framing and learning, and enhanced democratic attitudes and skills. These outcomes facilitate a transition to the second-order process outcomes of community-oriented action and an institutional culture that facilitates behavioral change aligned with sustainability goals (Glavovic et al. 2015).

An ecosystemic approach—together with a communicative approach in the strategic/situational planning—was used to facilitate the permanent articulation of the different actors involved, generate information to be used in the decision-making process, as well as create opportunities for dialogue, participation, learning and networking. These can promote autonomy and the development of inclusive social technologies based on the Ecology of Knowledge. The whole process was systematized based on participant observation reports in the field, in seminars, in workshops about planning and in team meetings.

In order to generate agreement on the agenda, on the priorities to be focused on and the community in which to start, the bibliography and other documents were reviewed, a participant observation strategy was put forth and strategic planning workshops were carried out in partnership with the FCT.

Secondary sources were used not only to characterize the territory, but also to produce maps and the Phase I Plan for the ecological sanitation project at Praia do Sono (INEA 2011). Next, a field visit was conducted by researchers together with locals through the territory of research (Praia do Sono) for 4 days in 2013. In the visit, water courses were characterized and drainage basins were delimitated and characterized by the georeferencing of tributaries and nearby dwellings with a GPS.

After characterizing the territory, the literature was reviewed. Five field visits were conducted by the sanitation team (FUNASA, FIOCRUZ and FCT), between July and September of 2014. Similar experiences also took place for permaculture and ecological sanitation for the establishment of benchmarks such as: (1) The Caiçara Permaculture Institute (IPECA), at Pouso da Cajaíba, Paraty; (2) The Institute of Permaculture and Ecovillage of the Atlantic Forest (IPEMA), in

Ubatuba, São Paulo; (3) The Ecovillage EMAUS, in Ubatuba; (4) The Quilombo da Fazenda, in Ubatuba and (5) The Ecovillage Tibá, in Rio de Janeiro.

Thereafter, a proposal was made and discussed in workshops. The goal of these workshops was to organiz to introduce technological alternatives for sanitation, as well as discuss them with all actors involved: community, the municipal government of Paraty and environmental institutions of the region (State Institute for the Environment/Juatinga's Ecological State Reserve—INEA/REEJ and Cairuçu Environmental Protection Area—APA Cairuçu). A shared prototype was established.

To promote mobilization and environmental education, workshops with leaders, activities in schools and open meetings (in which the project was introduced and agreed on) were carried out in the community between August and October, 2014. In order to promote agreement and to accompany actions, workshops on strategic/situational planning were organized on June/2014, August/2014 and December/2014 with the whole OTSS team. Meetings on monitoring were also organized monthly by the sanitation team.

To evaluate the results, the approach developed and adopted by OTSS—which analyses three dimensions (autonomy, sustainability and equity) of evidence on effectiveness in sustainable and healthy territories, well as their respective parameters—was used (Gallo and Setti 2012a, 2014a).

Agreeing on the Agenda, Establishing the Territory and Defining the Priorities

Territories are central in ecosystemic approaches. Investigations and formulations are always based on a living territory, on a territoriality, that is, the values and practices occurring in a space and time that characterize social production. This space and time are based on a different reality in which the dominant rationality clashes with the emergence of other forms of life. This requires projects and actions that are capable of comprehending and, consequently, changing territory-based social practices, generating individual and collective autonomy (Santos 2003; Gallo and Setti 2012a, 2012b, 2014a, 2014b). The region was characterized, and elements that could help establishing priorities and determining in which community the project would be implemented first were identified.

The Southeast of Brazil is extremely vulnerable because of its high population density and the influence of hydrometeorological systems that alternate intense periods of rain (with floods and landslides) and droughts (Marengo and Camargo 2008; Machado 2014; PBMC 2014). The region is currently going through its most important water crisis, which has been significantly affecting three states: São Paulo, Rio de Janeiro and Minas Gerais (Hackley 2014). Among others, climate change, deficient basic sanitation and improper infrastructure for the correct use of water worsened the crisis, causing rationing and instability in the water supply (Bowen and Friel 2012). In this context, it is urgent and fundamental to organize regional agendas that consider public policies that promote sustainable development, the attenuation of impacts and the awareness of the population on water management and treatment, on the reutilization and proper disposal of solid waste, as well as on modes of production and consumption. On the Map of Vulnerabilities to Climate Change Impacts on the Social, Health and Environmental Areas, the so-called Green Coast, a microregion within the scope of this study, had the highest environmental vulnerability index, especially Paraty and Angra dos Reis, in the state of Rio de Janeiro. The index includes characteristics of the biophysical systems that are vulnerable to the climate, as well as a time series of extreme meteorological events. The region also had the highest regional average in the general vulnerability index, composed of indexes related to the social environment of families and health (Barata et al. 2011).

The Mosaico Bocaina was created in 2006 to integrate the management of the many reserves existing in the area under the three spheres of government, thus contributing not only to the preservation and conservation of natural resources and fish stocks, but also to the promotion of the sustainable development of this territory in the states of Rio de Janeiro and São Paulo—more specifically the regions of the Serra do Mar, Serra da Bocaina (the northern coast of São Paulo), and the Upper Paraíba Valley and the Ilha Grande Bay (the southern coast of Rio de Janeiro) (MMA 2006), as shown in Fig. 28.1.

With a total of 216,000 ha of forests (including buffer zones) under special conditions of management and protection, the Mosaico Bocaina includes 51 traditional communities of three different ethnic groups (Caiçara, Indigenous and Quilombola). The region is part of the Serra do Mar Biodiversity Corridor, one of the richest areas of the Atlantic Forest in terms of biological diversity (Gallo and Setti 2012b).

Because of their geographical location, coastal communities are already in a context of vulnerability and exposed to stress (Glavovic et al. 2015). In the Mosaico Bocaina, in the mid 1970s, large construction projects and a form of predatory tourism produced social, economic and environmental change in the region. This intensified the unplanned urbanization in the coast, social inequalities and the pressure over the territories of traditional communities, leading to an unequal, predatory mode of development that worsened the situation even further.

Based on a shared identity throughout the territory and with the goal of advocating for the rights of traditional communities, in 2006, the Forum of Traditional Communities of Angra dos Reis, Paraty and Ubatuba (FCT) was created. The goal of the FCT is not only to protect the territory by participating in the implementation of public policies and stimulating technological solutions that use traditional knowledge, but also to organize resistance campaigns, promote affirmative agendas that assure a sufficient quality of life, maintain natural resources and civil rights, stimulate the legalization of the land and make the ways of life of traditional peoples more visible.

Based on that, the first step of the project was the integrated and participatory creation of a territorialized agenda. In the earlier workshop sessions, the major issues were identified, which led to the development of a Matrix of Issues affecting

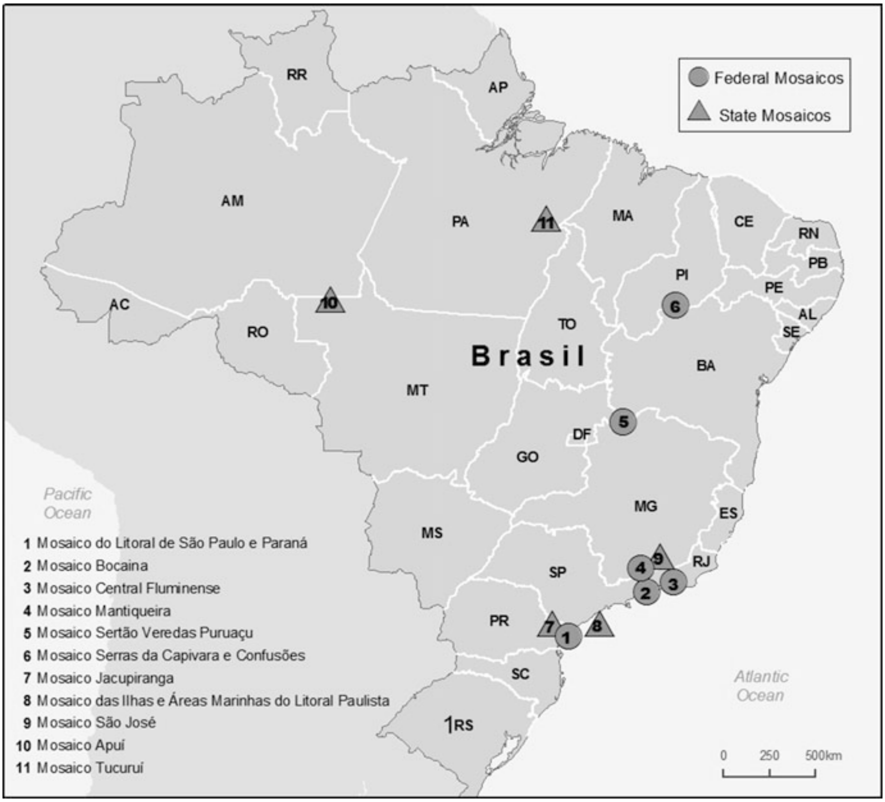

Fig. 28.1 The Mosaico Bocaina (number 2) in Brazil. Geographic Information System (GIS) from OTSS

the health of the communities (one of which the organization of a collection, treatment and disposal system for domestic waste) (Gallo and Setti 2012b).

Based on this Matrix and on the fact that the FCT had established that the initial territory studied would be the municipality of Paraty, OTSS started discussing which communities it should act on first, choosing, later on, the Caiçara communities most deprived of services, and, finally, settling on the community at Praia do Sono (Gallo and Setti 2012b).

From then on, the immediate goal of the ecological sanitation project became the universalization of domestic sewage treatment and the cleaning of the rivers at Praia do Sono using social technologies. The implementation of individual or condominial (in which more than one home contribute to the treatment unit) systems was planned. Technologies with a low cost of implementation and operation (which are simple to maintain and that fit the context of the community, promoting autonomy and sustainability) were chosen.

Characterizing the Territory of Praia do Sono, Drawing Maps and Planning Phase I

After planning workshops, seminars and field visits—which included all interested parties (the civil society, federal and state environmental agencies, the municipal government, the FCT, the OTSS and social leaders)—a panorama of the region was drawn and ecological sanitation solutions started being studied.

Praia do Sono is part of the Juatinga State Ecological Reserve (REEJ), a protected area with around 100 km^2, in the southernmost part of the state of Rio de Janeiro, in the municipality of Paraty (Fig. 28.2). It was created in 1992 as a response to demands of local Caiçara communities for the local ecosystem—which includes rocky shores, remnants of the Atlantic Forest, *restingas* and mangroves—to be preserved.

The reserve is part of the Cairuçu Environmental Protection Area (APA Cairuçu), a Federal Conservation Unit of 338 km^2 created in 1983. Since constructions are allowed within the APA, it was necessary to create the reserve to protect the territory of traditional communities, which were suffering a strong pressure from real estate projects. REEJ encompasses the Caiçara communities at Praia do Sono, Ponta Negra, Martim de Sá, Ponta da Joatinga, Pouso da Cajaíba, Praia Grande da Cajaíba, Calhaus and Mamanguá with a population of around 1400 people (INEA 2011).

As indicated in Fig. 28.3, there are twelve population centers, some with less than 50 members, distributed along the coast. These people live of artisanal fishing, subsistence agriculture and, more recently, tourism. These communities are: Cairuçu das Pedras, Saco das Enchovas, Martim de Sá, Ponta da Rombuda, Praia da Sumaca, Saco Claro, Saco da Sardinha, Ipanema, Gaietas, Itaoca, Praia Grande

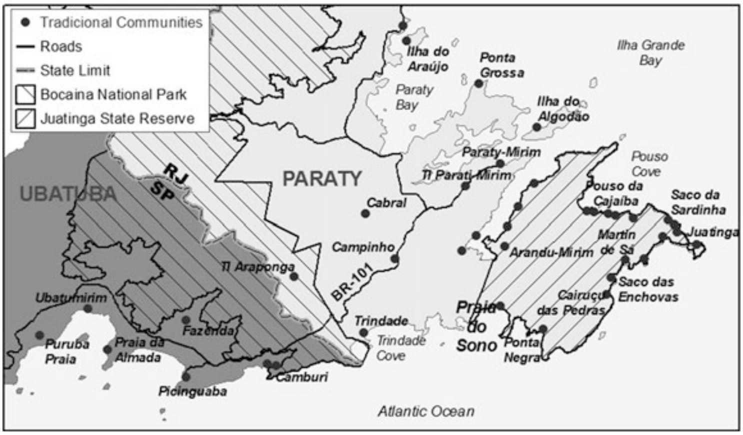

Fig. 28.2 Map of REEJ in the state of Rio de Janeiro, close to the border with the state of São Paulo. GIS of OTSS

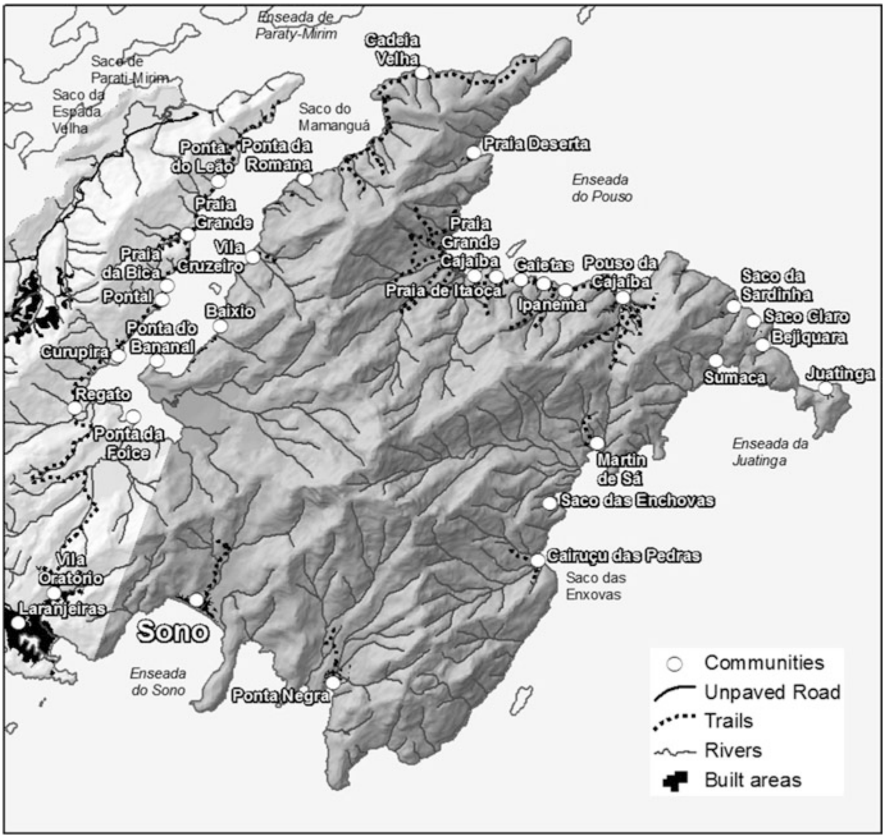

Fig. 28.3 Map of the population centers and communities at the Juatinga Ecological Reserve. GIS of OTSS

da Cajaíba and Costeira da Cadeia Velha. These communities relate to one another and, despite the precarious access, use the city of Paraty as a center for goods and services (INEA 2011).

There are 314 native people (177 men and 137 women) living at Praia do Sono, which represents 22 % of the total population of REEJ (INEA 2011). The people that were born and raised in the region of the reserve—independent on whether they actually lived there throughout their whole lives—are considered "natives" or "Caiçara." Therefore, the sense of belonging and identity is deeply connected to the territory.

The main economic activity at Praia do Sono is tourism, that is, working in restaurants and bars, camping sites, bed and breakfasts, or with vacation rentals, followed by transportation in boats and artisanal fishing. There are 202 constructions there, including houses of natives (124); houses for dwelling or renting (3); bars and restaurants (27); camping sites (24); properties owned by vacationers (8);

as well as fishing ranches (15); and a flour mill (1). However, the Caiçara culture has to do not only with the economic activities they carry out (functional territory), but also with other activities that represent the territory symbolically (INEA 2011). The community includes the headquarters of its Neighborhood Association, a municipal school and a church.

Results and Discussion

The field work consisted of characterizing water courses, as well as georeferencing its tributaries and nearby houses in technical visits, following the course of the rivers. The georeferenced delimitation and characterization of the Rio da Barra drainage basin established the course of tributaries and houses so that future actions concerning the decontamination of the river can be carried out. The results are shown in Figs. 28.4 and 28.5.

The water supply at Praia do Sono is precarious. The water is collected from the Cachoeira river in an unprotected area and does not receive any form of treatment. The raw water is distributed through improvised hoses assembled by the residents themselves. There is a distribution network built by the municipal government of Paraty, but it was not concluded, so it remains unused. Rio da Barra, the major river there, is polluted by domestic sewage—80.5 % of houses have septic tanks, but 19.5 % still dump sewage directly into the river.

To make matters worse, since the region is very touristic, the significant increase in the floating population causes problems like water shortages. A project for rearranging tourism in the area—assuring environmental sustainability, a high-quality experience for visitors and the maintenance of the residents' quality of life—is underway. It was not yet implemented, but there is a plan to establish criteria for visitation (such as a maximum number of visitors, the so-called "load capacity") (INEA 2011).

Through participant observation in field visit and workshops, it was verified that houses separate effluents. Kitchen/cleaning effluents (greywater) and wastewater (blackwater) go to different places. The absence of grease traps and the direct release of greywater into the environment indicate that the population does not see that portion of domestic waste as "pollution." The primary treatment of waste using cesspits or septic tanks was considered sufficient for blackwater.

Through workshops carried at the Neighborhood Association, at the REEJ and at the municipal government of Paraty, it was possible to clarify the relationship between the contamination of surface and underground water and the release of domestic sewage into septic tanks or cesspits or directly, in natura, on to rivers. The explanations not only raised the awareness of the community and of many other local actors, but also stimulated the audience to question their realities and suggest new paradigms.

The mapping of houses in the area of direct influence of the Rio da Barra showed that 44 houses needed improvement, 15 of which will be selected along with the

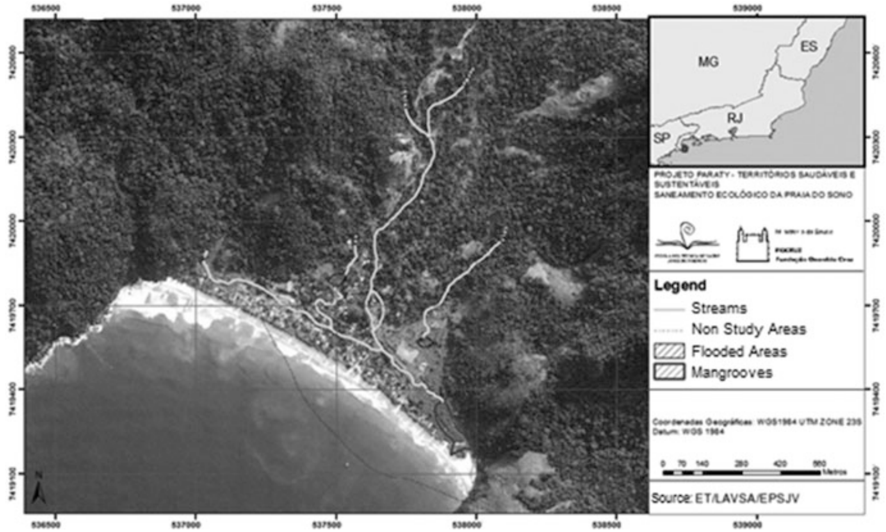

Fig. 28.4 Characterization of the Rio da Barra drainage basin

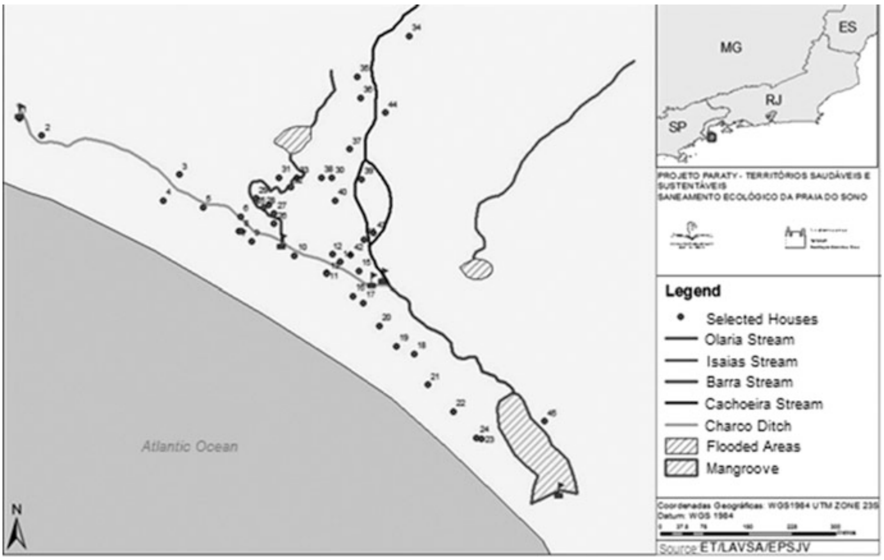

Fig. 28.5 Residences in the area of direct influence of the Rio da Barra drainage basin

Community for Phase I of the implementation of the ecological sanitation system. In the future, the technology will be implemented throughout the community, depending on acceptance and mobilization (Fig. 28.5).

The Prototype

The proposal was based on the Ecology of Knowledge, and its development was conducted by a multidisciplinary team of Caiçaras, educators, permaculture specialists, academics and technicians of many institutions. The prototype was developed from a dialogue between sanitation engineering and permaculture, representing a positive association between technic and popular knowledge. There was consensus that the alternatives suggested should emphasize the autonomy and citizenry of the local population, promoting empowerment and the dissemination of an easily-replicable social technology.

Six technical visits were carried out throughout Brazil to collect possibilities for a benchmark of existing alternatives that include knowledge on sanitary engineering and permaculture, stimulating a conversation between academia and practice via an ecology of knowledge. Based on these visits, the alternative chosen with various actors of the territory was evapotranspiration tanks (TEvap). This technology is already used in Ceará (Icapuí), as a form of sanitation in five coastal communities (Pinheiro 2011; Coelho 2013).

A system of flush toilets connected to a network of underground sewers (sewerage) that carry sewage away from homes to be discharged into the environment after sewage treatment has engineering requirements and is costly. Modified and simplified options, typically of lower cost and functioning with lesser flows, have been developed to accelerate access, especially in the developing world (WHO 2009). The waste is then managed locally, empowering population and promoting autonomy.

The Martim de Sá Municipal School of the Caiçara community at Praia do Sono was chosen as the first instance for Phase I because it is located at the center of the community and because of the symbolic power it has, being an adequate facility for disseminating knowledge and providing environmental education to children.

Like in most constructions there, the waste that comes from the kitchen goes directly to a river at the back of the school lot. Blackwater, however, takes a different route and goes into a cesspit near the access to the school restrooms. The existing treatment system was ignored because it does not meet the minimum requirements in the current environmental legislation.

Instead of a linear system, as observed in conventional sanitation models, a closed-loop system, based on ecological sanitation, was suggested. The system uses the sewage as nutrients for the soil, generating produce and water for the atmosphere via evapotranspiration.

The suggested system consists of: (1) grease trap, receiving only kitchen effluents (greywater); (2) septic tank, receiving effluents from the grease trap and the restrooms (greywater and blackwater) for primary treatment; and (3) evapotranspiration tanks (TEvap), after the septic tank, for secondary treatment.

All around the world, it is very common to see plants being used in sewage treatment (EPA 2000). However, water with a high concentration of pathogens and a heavy organic load requires pretreatment for reducing organic matter and solids and post-treatment for reducing the excess of nutrients and pathogens before finally releasing it to the ground or in bodies of water (Galbiati 2009). Since TEvap is a closed system, no final effluents are expected. Therefore, no post-treatment was included in the project.

The post-treatment includes, in the lower part, the anaerobic digestion of organic matter. In the upper part, the mineralization, filtration and absorption of nutrients and water by the roots of plants take place. Nutrients leave the system and are incorporated into the biomass of plants. The water is eliminated via evapotranspiration. There is no way to pollute the ground because there is no subsuperficial runoff.

The tank is a masonry prismatic chamber with impermeable walls and bottom. The inside of the tank (Fig. 28.6) includes (1) a pyramid-shaped septic tank made with perforated bricks, where the anaerobic digestion takes place. The empty spaces are filled by (2) multilayered porous materials with decreasing granulometry—rubble, gravel and sand, respectively—for filtration. Finally, it is covered with a layer of soil so a (3) root zone, where nutrients and water will be absorbed by plants, forms.

Finally, plants that grow fast, demand lots of water and are well adapted to wet soils are sowed. The effluent is then completely absorbed by plants and evaporated through the soil. Banana trees and elephant ears are most recommended for being

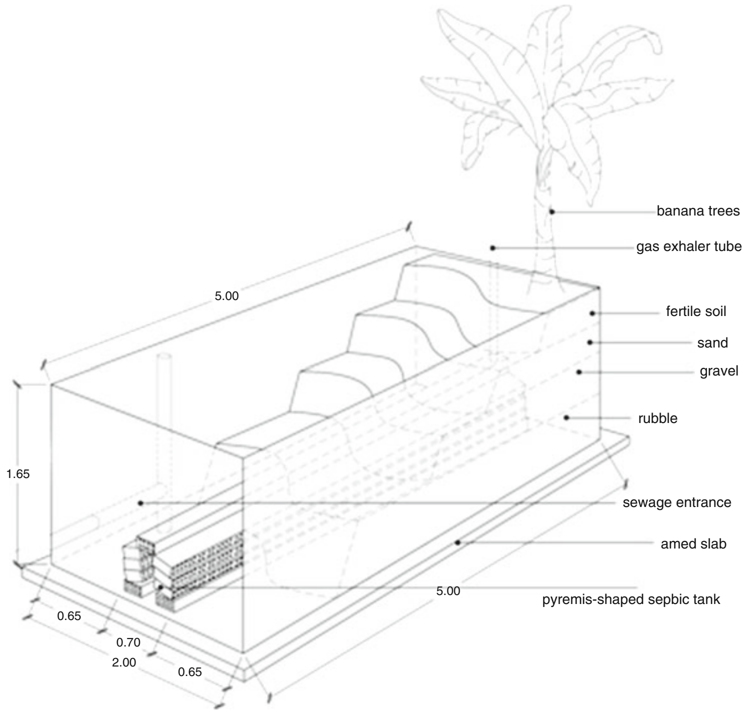

Fig. 28.6 The prototype: evapotranspiration tank. OTSS

common in the region and well adapted to very wet soils, like that of the TEvap (Galbiati 2009). Producing food can be a positive consequence of the technology, The process must be monitored to guarantee no contamination on the generated fruits from the system.

During the construction of the sanitation modules, local residents will be hired to transfer social technology through an ecology of knowledge and to be trained as multiplying agents in future constructions, either as part of the project or through other initiatives. After a practical pondering on the process, the team was able to review its ideas collectively and create new forms that are better adapted to the environment and the community, meeting the inherent needs of the social technology selected.

Conclusion

To reduce the impacts of climate change, it is fundamental to promote actions in territories that can be replicated in other regions, thus producing environmental, health and autonomy gains for population. Still, it is important to focus on marginalized groups such as coastal and traditional communities that are more vulnerable to climate change.

The ecological sanitation technology contributes to the autonomy of the FCT and the communities. Moreover, it promotes equity in the territory, its sanitation solutions are sustainable, it is potentially replicable in other communities, and may contribute to addressing climate change with a solid action based on SDG 6.

In addition, promoting sustainable and healthy territories assumes an interchange of knowledge and experiences focused on developing solutions that are adapted to the needs of the territory. Selecting the most adapted social technology, considering aspects of the territory, using local materials and investing in the training of a workforce empowers local actors, as well as makes them more autonomous, thus assuring the sustainability of the solution.

Moreover, when target communities are involved, they see themselves as an active part of the process, which makes them think of their reality and the possible paths they can follow.

The implementation of the sanitation process improves their quality of life, promotes equity, generates resilience and mitigates the socio-environmental impacts of climate change.

Using an ecology of knowledge, the Project for the Ecological Sanitation in the Caiçara Community of Praia do Sono developed a social technology at the Mosaico Bocaina region that can be replicated, which brings new forms of social action and new ways of implementing public policies forth to public actors.

The development of this technology in the region promoted intersectorial and inter-stage approaches, bringing public actors together both for the implementation of this project and for the planning of its implementation in other territories, which is congruous with OTSS's mission of promoting socio-environmental sustainability, reducing the vulnerability of traditional communities and promoting their inclusion and autonomy.

The ecological sanitation project and its inclusion in the agenda of sustainable and healthy development is, itself, potentially sustainable and promotes the autonomy of the local population. The reach of the project will be evaluated in a future phase.

It is expected that, after the effectiveness of TEvap as a solution for ecological sanitation is demonstrated in the Mosaico Bocaina regions, this model can be implemented and monitored so as to be replicated in other traditional communities, promoting environmental justice and social equality, as well as reducing their vulnerabilities and improving their well-being.

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