Climate Change Adaptation Planning in Latin American and Caribbean Cities

FINAL REPORT: ESTELÍ, NICARAGUA

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Climate Change Adaptation Planning in Latin American and Caribbean Cities

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ICF GHK
2nd Floor, Clerkenwell House
67 Clerkenwell Road
London
EC1R 5BL

T +44 (0)20 7611 1100
F +44 (0)20 3368 6960

www.ghkint.com

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Job number	J40252837
Prepared by	Climate-related hazard assessment Dr Rawlings Miller, Dr Carmen Lacambra, Ricardo Saavedra, Clara Ariza, Christopher Evans Urban, social and economic adaptive capacity assessment Dr Robin Bloch, Nikolaos Papachristodoulou, Jose Monroy Institutional adaptive capacity assessment Dr Zehra Zaidi, Prof Mark Pelling Climate-related vulnerability assessment Dr Rawlings Miller, Dr Robin Bloch, Nikolaos Papachristodoulou, Dr Zehra Zaidi, Thuy Phung, Chris Evans Strategic climate adaptation institutional strengthening and investment plan Dr Robin Bloch, Nikolaos Papachristodoulou, Jose Monroy
Checked by	Dr Robin Bloch, Nikolaos Papachristodoulou

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Abbreviations

ACI…………………………………………………………………………………Adaptive Capacity Index

APROE..Agencia de Promoción Económica Local
Local Economic Development Agency

CCAD………………………………………………Comisión Centroamericana de Ambiente y Desarrollo
Central American Commission for Environment and Development

COCOPRED……………………...Comité Comunal de Prevención, Mitigación y Atención a Desastres
Communal Committee of Disaster Prevention, Mitigation and Attention

COLOPRED…………………………...Comité Local de Prevención, Mitigación y Atención a Desastres
Local Committee of Disaster Prevention, Mitigation and Attention

COMUPRED……………….........Comité Municipal de Prevención, Mitigación y Atención a Desastres
Municipal Committee of Disaster Prevention, Mitigation and Attention

CMIP3……………………………………………………*Coupled Model Intercomparison Project phase 3*

ENACAL……………………………………..…Empresa Nicaraguense de Acueductos y Alcantarillados
Nicaraguan Water and Sewerage Enterprise

ENSO……………………………………………………………………………*El Niño Southern Oscillation*

EWS…………………………………………………………………………….…*Early Warning System*

FAREM-Estelí…………………………………………………………..Facultad Regional Multidisciplinaria
Regional Multidisciplinary Faculty Estelí

GDP…………………………………………………………………………..…*Gross Domestic Product*

ITCZ…………………………………………………………………...*Inter-Tropical Convergence Zone*

INETER... Instituto Nicaragüense de Estudios Territoriales
Nicaraguan Institute of Territorial Studies

INSFOP..Instituto de Formación Permanente
Institute of Sustained Capacity Building

INPRHU……………………………………………………….…………….Instituto de Promoción Humana
Institute of Human Development

LAC…………...…………………………………………………...……….*Latin America and the Caribbean*

MARENA……………………………………….……Ministerio del Ambiente y los Recursos Naturales
Ministry of Environment and Natural Resources

MIDINRA……………………………………....Ministerio de Desarrollo Agropecuario y Reforma Agraria
Ministry of Agricultural Development and Agrarian Reform

MSME……………………………………………………………………*Micro, Small and Medium Enterprises*

NGO………………………………………………………………………...*Non-Governmental Organization*

NWS………………………………………………………………………….....*National Weather Service*

ONDL……………………………………………………………………Oficina Nacional de Desarrollo Limpio

National Clean Development Office

PRRAC……………………………………Programa de Reconstrucción Regional para América Central
Central America Regional Reconstruction Programme

SDC………………………………………………………*Swiss Agency for Development and Cooperation*

SICA……………………………………………………………Sistema de Integración Centroamericana
Central American Integration System

SINAPRED……………….Sistema Nacional para la Prevención, Mitigación, y Atención de Desastres
National System for Disaster Prevention, Mitigation and Attention

SINIA-MARENA……………….…………….Sistema Nacional de Información Ambiental de Nicaragua
Nicaragua National Environnemental Information System

UNDP………………………………………………………….....*United Nations Development Program*

UNEP………………………………………………………………*United Nations Environment Program*

UNFCCC…………………………………….*United Nations Framework Convention on Climate Change*

USGS…………………………………………………………………….*United States Geological Survey*

WCRP………………………………………………………………World Climate Research Programme

Glossary

The following glossary is from the United Nations' International Strategy for Disaster Reduction (UNISDR) terminology on disaster risk reduction (2009 version). The terms are defined by a single sentence. The comments paragraph associated with each term is not part of the definition, but is provided to give additional context, qualification and explanation.

Adaptation

The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Comment: This definition addresses the concerns of climate change and is sourced from the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The broader concept of adaptation also applies to non-climatic factors such as soil erosion or surface subsidence. Adaptation can occur in autonomous fashion, for example through market changes, or as a result of intentional adaptation policies and plans. Many disaster risk reduction measures can directly contribute to better adaptation.

Capacity

The process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions.

Comment: Capacity development is a concept that extends the term of capacity building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems, and the wider social and cultural enabling environment.

Climate change

The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by 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. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

Comment: This definition can be paraphrased for popular communications as "A change in the climate that persists for decades or longer, arising from either natural causes or human activity."

Coping capacity

The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

Comment: The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during crises or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

Comment: Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation.

Disaster risk

The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

Comment: The definition of disaster risk reflects the concept of disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped, in broad terms at least.

Exposure

People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

Comment: Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.

Forecast

Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area.

Comment: In meteorology a forecast refers to a future condition, whereas a warning refers to a potentially dangerous future condition.

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Comment: The hazards of concern to disaster risk reduction as stated in footnote 3 of the Hyogo Framework are "… hazards of natural origin and related environmental and technological hazards and risks." Such hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis.

Mitigation

The lessening or limitation of the adverse impacts of hazards and related disasters.

Comment: The adverse impacts of hazards often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures encompass engineering techniques and hazard-resistant construction as well as improved environmental policies and public awareness. It should be noted that in climate change policy, "mitigation" is defined differently, being the term used for the reduction of greenhouse gas emissions that are the source of climate change.

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Comment: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.

Risk

The combination of the probability of an event and its negative consequences.

Comment: This definition closely follows the definition of the ISO/IEC Guide 73. The word "risk" has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in "the risk of an accident"; whereas in technical settings the emphasis is usually placed on the consequences, in terms of "potential losses" for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks.

Vulnerability

The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Comment: There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time.

Source: extracts from UNISDR terminology (2009 version), http://www.unisdr.org/we/inform/terminology

Executive summary

The *Climate Change Adaptation Planning in Latin American and Caribbean Cities* project intends to inform policy making and climate change adaptation planning in small and medium-sized cities. The focus is on floods and landslides, which are two of the most common climate-related risks in cities across the Latin America and Caribbean region.

Five cities were therefore selected: Castries, Saint Lucia; Cusco, Peru; El Progreso, Honduras; Estelí, Nicaragua and Santos, Brazil. For each involved city, five main activities were carried out. These are:

1. A climate-related hazard assessment focused on floods and landslides
2. An urban, social and economic adaptive capacity assessment
3. An institutional adaptive capacity assessment
4. A climate-related vulnerability assessment;
5. Based on the findings of the four assessments, a combined strategic climate adaptation institutional strengthening and investment plan, which will complement and be integrated into existing urban, environmental and disaster risk reduction planning instruments for each city.

The figure below graphically shows the process and main activities carried out under the project.

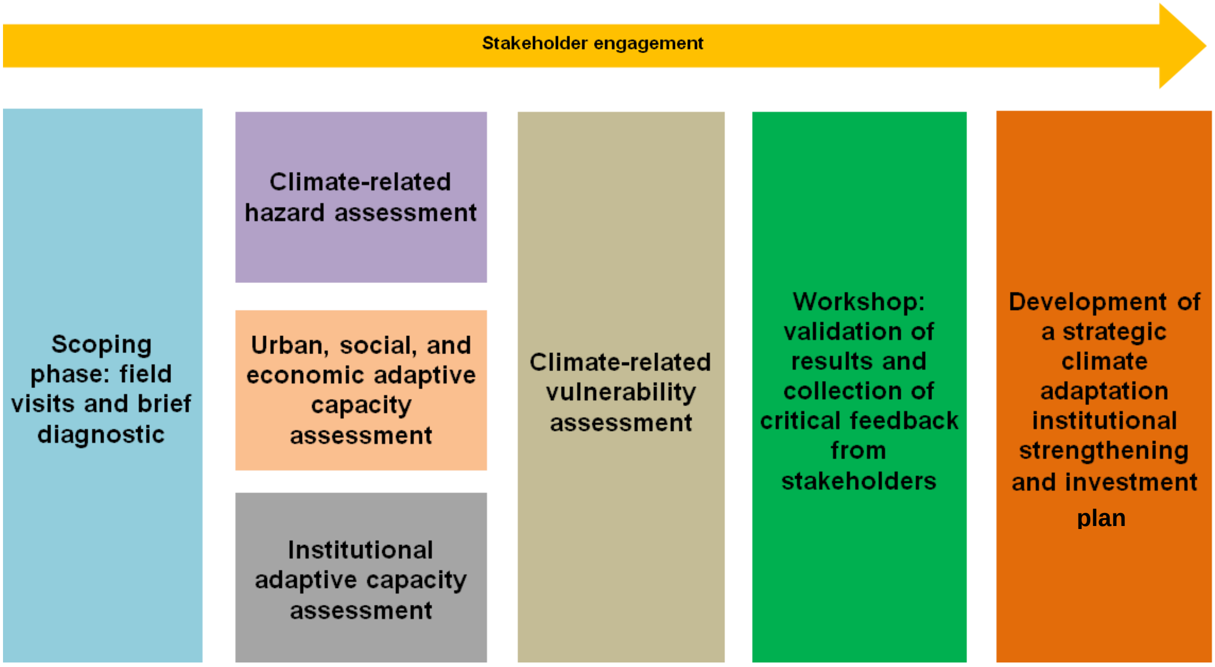


Figure 0.1: The process and main activities of the project

A summary of the key findings of this report now follows.

Understanding the problem of flooding and landslides

Climate related flood and landslide hazard risks

Estelí is susceptible to floods, while landslides do not pose a significant risk. The Estelí River and its two tributaries, the Zanjón de los Cedros and the El Zapote Ravine, run through the city; flooding is the result of the overflow of water streams during the rainy season.

Over the years, Estelí has been affected by various flooding events and their associated damages. Hurricanes Fifi (1974), Irene (1971), Joan (1988) were the cause of significant devastation. However, Hurricane Mitch in 1998 was by far the most damaging disaster for the city: it affected 42,000 people, destroyed major infrastructure and led to the collapse of the local economy. Floods experienced in recent years, during the period 2000-2008, have resulted in significant losses for Nicaragua – and for Estelí.

Weather records for the 40 year period 1960-2003 suggest an increase in temperature and a decrease in total rainfall, though there has been an increase in the proportion of rainfall that occurs in heavy events (McSweeney et al., 2010). The climate assessment analysis illustrates that temperature is projected to continue to increase in the future, while both the total precipitation and the rate of precipitation for the dry and wet seasons are projected to decrease. The decrease in precipitation can reduce threats of floods and landslides. However, the uncertainty in precipitation projections, particularly associated with extreme events, and other non-climate factors that affect flood and landslide risks need to be considered in applying these conclusions.

Linking the potential climate projections to the way urban development is taking place is essential in understanding the possible effects that climate change could have in Estelí. Although climate projections do show a potential decrease in precipitation and a rise in temperature, which might result in a decrease in flood and landslide risk, the trends in urban development could actually lead to risk remaining constant or increasing.

Urban development and exposure to disaster risk and climate change

Estelí is experiencing strong demographic growth and urban expansion. Poverty has gone hand in hand with growth in the city. This has affected the level of exposure to climate change hazards: urban development has often occurred in an unplanned manner, with low-income populations settling in risk areas, notably in proximity to water streams. Rural-urban migration has been the main driver behind urban growth in Estelí. Low-income newcomers have often settled through spontaneous land invasions along the Estelí River or the El Zapote and Zanjón de los Cedros Ravines, thus creating a problem of land incompatibility and exacerbating exposure to climate hazards. This is of the most importance, as growth is projected to continue in the city. The way in which urban development takes place constitutes a major challenge for Estelí: guiding urban growth, controlling settlement in risk areas as well as the provision of basic urban services are essential in establishing a pattern of resilient and sustainable urbanization in the city.

Further, the analysis undertaken in the assessment phase illustrated that there is a visible geography of vulnerability in Estelí. Combining the sensitivity of settlements (based on the physical condition of dwellings) with the adaptive capacity of dwellings (based on the percentage of poverty) allowed identifying what are the most vulnerable areas amongst the three districts making up Estelí. Given the higher concentration of poverty in Districts II and III, the analysis ranked them as having a high vulnerability to flood risk; District I is characterized by a medium vulnerability to flood risk, due to its relative good social indicators. Landslide risk, concentrated in the South of the city, mainly affects District I. The vulnerability was ranked as medium in the District.

Institutional vulnerability issues

Given its past records in disasters, notably following the devastating effects of Hurricane Mitch in 1998, and the persistent exposure to hazard, Nicaragua developed a proactive and integrated system for disaster risk management. The result was the creation of the National System for Disaster Management and Prevention (SINAPRED) in 2002, establishing a policy and legal framework for a comprehensive and multi-sector approach to disaster risk management.

A decentralization and decision-making devolution process is embedded within SINAPRED, which allowed local authorities to take the lead in establishing Disaster Risk Management (DRM) strategies, notably through COMUPREDs (Municipal Committee of Disaster Prevention, Mitigation and Attention). Joining up different government and civil society stakeholders, led by the Mayor and Civil Defense and operating under an annual work plan, the COMUPRED was established as a permanent structure in 2011. It is complemented by the presence of two COCOPREDs (Community Committees for Disaster Prevention and Attention). These structures have allowed Estelí to have an overall high coordination capacity for organizing logistics and response procedures in an emergency: all parties respond to a single response plan led by the Mayor and Civil Defense. Furthermore, there is accurate local knowledge of vulnerable populations and infrastructure.

Despite the progress made in terms of addressing hazards and developing DRM strategies, institutional challenges persist. One of the main issues that emerged from the institutional assessment is the primary focus on disaster mitigation and response in most risk management organizations in Estelí: risk management, in both policy and practice, is reactive and response-led; the priority is given to coordinating actions when a disaster does occur. A shift towards a more proactive approach incorporating climate change adaptation planning could prove beneficial. This would imply understanding the main hazards linked to climatic change as well as their roots, and trying to address and diminish them.

Strongly tied to this, the analysis illustrated that there is no local level institution with climate change adaptation planning as part of its direct mandate or budgetary allocation. Climate change planning is a joint action undertaken by Civil Defense and the Environment Department within the Municipality of Estelí. Thus, in dealing with the potential effects of climate change, developing, coordinating and implementing strategies, the existence a single government institution concentrating actions could prove to be instrumental. For instance, although the Estelí Municipal Council approved a Municipal Climate Change Adaptation Plan in 2011, the strategies identified in the plan have not as yet been implemented due to a lack of resources, funding and clarity of organizational responsibility. To date, most stakeholders in the city are unaware of its existence. As such, the presence of a single organization with a mandate in climate change action might help in the implementation process of climate change adaptation strategies.

Finally, there was an acknowledged issue regarding an overall lack of financial resources. Despite a strong national policy framework, limited availability of financial resources has resulted in a low level of preparedness and long-term risk reduction planning at the sub-national level. The government has yet to develop a financial strategy to support the mainstreaming and implementation of risk management planning in the country. Limited financial resources have been made available to support local institutions for responding to and preparing for disaster risk. Although Estelí has developed a DRM system with sound capabilities in response and coordination, the system is limited by a lack of resources: the limitations are primarily financial but they also imply human and physical capabilities, as well as weak infrastructure and essential services in the city. Future efforts to promote climate change adaptation and planning will need to build on the strong local coordination networks in Estelí by providing financial and technical support for increased institutional capacity.

Strategic climate adaptation investment and institutional strengthening plan

The findings of the assessments provide the basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions that can be linked or incorporated into existing priorities, sectoral plans and planning instruments in Estelí. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon.

The plan draws accordingly on the conclusions and the feedback obtained during a workshop held in Estelí in March 2013. The feedback served to validate assessment findings, update or readjust them and establish a set of specific actions to be proposed based on the needs and major issues identified by stakeholders. This process helps ensure that the proposed climate change adaptation measures can be mainstreamed within the policy and institutional framework, and form part of an overall climate change adaptation strategy for Estelí.

The overreaching goal of the strategic plan is to increase resilience to floods and landslides in Estelí. On the basis of planning themes, specific measures to address particular urban development challenges as well as institutional shortcomings are identified. These measures also promote a more sustainable and resilient urban development process. Finally, a set of specific actions that can be undertaken to implement climate change adaptation measures are proposed.

The planning themes that create the foundation for a climate change adaptation strategy to help Estelí build its resilience against floods and landslides, both now and in the future, are:

(i) investment in drainage, sanitation and waste removal services, and improved implementation of land use and urban planning laws; (ii) capacity building in city level government institutions engaged in climate change planning and risk management; (iii) mechanisms for data collection, storage and dissemination to be created and/or improved for better climate monitoring, risk planning, and information sharing; (iv) Improved budgetary resources and climate financing for long-term recovery and building resilience against climate change hazards; (v) cross-scale integration of risk management practices; (vi) a shift from disaster management to long term risk reduction and climate change adaptation to ensure a proactive and forward-looking system of risk governance.

An integrated strategic plan requires the use of both structural and non-structural measures. Our proposed measures thus follow a “no-regrets” approach, and they include, *inter alia*: investing in the city’s rain water treatment infrastructure; prioritizing and enhancing civil society’s awareness to risk; capacity building in national and city level government institutions engaged in climate planning and risk; improved mechanisms for data collection, storage and dissemination; integrated land use planning and risk-sensitive zoning; and improved budgetary resources and climate financing.

The timing and scale of local climate change impacts affects the types of measures to be adopted and prioritization of investments and action. The main challenge for policy- and discussion-makers is to implement a climate change adaptation process that considers the trade-offs between current development priorities and long-term risks and embraces uncertainty. The ability and willingness of key actors to address climate change impacts will be of utmost importance.

1 Introduction

1.1 About the project

An ICF GHK consortium was commissioned in May 2012 by the World Bank's regional Urban and Disaster Risk Management Unit for Latin America and the Caribbean (LAC) (LCSDU) to carry out second phase activities for the initiative *Climate Change Adaptation Planning in Latin American and Caribbean Cities*. This initiative started in April 2010 and will be completed in 2013.

The wider initiative seeks both to build and to strengthen capacities for adaptation to climate change in LAC cities. The primary focus is cities in the region less likely to have had access to climate change (CC) adaptation training, finance, or knowledge networks. In practice, this implies a focus on medium and small-sized cities, as larger cities have more human and financial resources to draw on.

Five medium-sized cities were therefore selected: Castries, Saint Lucia; Cusco, Peru; El Progreso, Honduras; Estelí, Nicaragua; and Santos, Brazil.[1] The first phase involved an initial institutional mapping and rapid diagnostic for the initiative. The second phase assignment's objective is to inform policy making and adaptation planning at the city level by incorporating local and international technical knowledge, tools and expertise into existing planning structures to better respond to the adverse effects of climate change.

The emphasis is on floods and landslides, which are two of the most common climate-related risks in cities across the LAC region. Poorly planned and managed urban development and spatial expansion also contributes to flood and landslide hazard risks. **The ultimate goal is to strengthen local adaptive capacity and to increase urban resilience through mainstreaming climate change adaptation into current planning systems.**

For each involved city, there were four main activities specified for the second phase:

For each city, there are four main activities within the second phase. These are:

1. A climate-related risks assessment focused on floods and landslides
2. A socio-economic adaptive capacity assessment
3. An institutional adaptive capacity assessment
4. Based on the findings of the three assessments, a combined strategic climate adaptation institutional strengthening and investment plan, which will complement and be integrated into existing urban, environmental and disaster risk reduction planning instruments for each city.

The outputs from the above-mentioned activities in this assessments report constitute a critical input for the main output of the overall initiative in its third phase: a regional Guidebook for city officials on urban adaptation to climate change.

1.2 Outline of the report

This report is divided into the following sections:

- ***Climate-related hazard assessment.*** This section first provides an assessment of current inland flood and landslide hazards for Estelí. It then considers how climate change may impact these existing flood and landslide hazards by mid-century.

[1] The selection of the pilot cities was based on the following: a) survey results from Phase 1 of the project; b) diversity of geographic region and climate; c) recommendations provided by World Bank staff leading operational activities across LAC, ensuring the cities' political willingness, interest, and commitment to working with the initiative; d) prevalence of floods and/or landslides as major climate change-related risks; and e) availability of climate risk-related data.

- ***Urban, social and economic adaptive capacity assessment.*** The section assesses how vulnerability to climate-related hazards is linked to topographical, human settlement and urban development characteristics: the location and condition of settlements and the materials used in their construction have a direct impact in the level of exposure they have for landslide and flood risk. Studying these variables allows assessment of how the urban development trajectory of Estelí impacts upon climate change vulnerability in the city.
- ***Institutional adaptive capacity assessment.*** The institutional assessment focuses on the disaster risk management and urban planning structures and capacities of institutions and stakeholders in Estelí and how they take into account and incorporate climate change adaptation.
- ***Climate-related vulnerability and risk assessment.*** Using the information from the three previous assessments, this section synthesizes information on landslide and flood vulnerabilities, focusing on physical risk, urban, social and economic conditions and institutional arrangements to create maps that identify the most vulnerable areas and populations within the city exposed to flood and landslide hazards. The analysis considers the exposure, sensitivity, and adaptive capacity of settlements and considers exposure of critical infrastructures to flood and landslide hazards, and provides an informative screening of which settlements and critical infrastructures are more likely to be affected by and be vulnerable to landslides and floods some 30 years into the future (i.e., the 2040s).
- ***Strategic climate adaptation investment and institutional strengthening plan.*** The *Climate-related vulnerability assessment* provides the basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions that can be linked or incorporated into existing priorities, sector plans and planning instruments in Estelí. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon.

The above-mentioned assessment approach is broadly consistent with the Urban Risk Assessment (URA) tool developed by the World Bank, but at the same time incorporates aspects that can add a dynamic element to the analysis.[2]

Assessments in the URA tool are associated with three levels of complexity (primary, secondary, and tertiary). The primary level provides an ‘entry point’ to assess the challenges posed by climate-related hazards. The secondary level provides a more ‘refined’ analyses to identify and map the most vulnerable areas and populations exposed to climate-related hazards and to consider how hazards may change in the future. Finally, the tertiary level undertakes specific probabilistic risk assessments and makes use of advanced risk management tools.

Progression from the primary to the tertiary level in any city or town is dependent upon the availability of what can be significant amounts of data, the technical capabilities of relevant staff and actors, and the ability and willingness of politicians, officials and others to commit what can amount to not inconsiderable financial resources and time to conducting assessments – and to building policy, strategy and action plans on the basis of findings.

Box 1 below elaborates on our experience for the case of Estelí.

Box 1 Box 1 Using the URA for Assessment in Estelí

The Terms of Reference for the phase two activities described above derives from the World Bank’s Urban Risk Assessment tool. As will be seen in the sections of this report which follow, we were able to apply the URA approach to guide and create our assessments for each city, in a process which saw good collaboration with local governments and other stakeholders.

[2] World Bank (2011) *Urban Risk Assessment: An Approach for Understanding Disaster and Climate Risk in Cities*. Urban Development and Local Government Unit; Finance, Economics and Urban Department, The World Bank.

Some provisos are nonetheless required. The URA is avowedly a flexible tool, as it needs to be. In Estelí, data availability and time and resource constraints meant the following adaptations to the 'pure' URA approach:

1. **Climate-related risks assessment for floods and landslides**: It was possible to assess present-day current flood and landslide hazard levels, which are well-understood and have been studied for the city. Precipitation data was not locally available, and despite repeated requests, was not provided by the responsible national agencies. It had to therefore be drawn from international data bases. This did permit consideration of thresholds linked to past events to be used to tailor the climate change analysis and, consequently, consider how changes in hazard levels for a period of some 30 years in the future. Full assessment of the risk levels for the flooding and landslide hazards, both currently and for the future, was not possible as the financial and demographic data necessary was not made available to us at either local or national level, again despite repeated requests. In addition, the projections for future changes in hazard levels on account of climate change is broad-brush rather than detailed, as this of detail requires such efforts as hydrologic/hydraulic modelling under future scenarios. This certainly does not preclude future elaboration of risk levels (i.e. detailed risk assessment) in the future on the part of government authorities and other stakeholders in Estelí. The findings of our analysis based on simpler approaches can in fact provide guidance regarding the best use of funds for conducting such a vulnerability and risk analysis (e.g., which hazards are likely to worsen, are there potential hotspots where hazards may get even worse, amongst others.). The first assessment in this report is therefore titled – and more correctly seen as – a climate-related hazard assessment.
2. **Socio-economic adaptive capacity assessment**: In Estelí, the availability of data meant that it was possible, within the time frame, to conduct socio-economic assessment, and ascertain the exposure and sensitivity of urban residents to current and future flood and landslide hazards. We attempted to add to and 'thicken' the URA approach with more detailed consideration of the dynamics of both urban and economic growth, change and development for Estelí. Adding this dimension makes assessment more dynamic (i.e., 'adaptive') – accordingly, we have re-titled this assessment to emphasize these urban and economic aspects.
3. **Institutional adaptive capacity assessment**: The partial willingness of stakeholders to share their experience in planning, primarily for urban development and disaster risk, rather than climate change itself, permitted an adequate assessment within the time frame. Our assessment attempted to incorporate the dimension of how institutions in Estelí had changed over time, notably in the past decade, again to stress the element of dynamism that has (or may have) inhered to the institutions under study.
4. **Climate-related vulnerability and risk assessment**: To compensate for the limitations on risk assessment, we developed a wider vulnerability assessment than originally intended. This is based on the findings of the three preceding assessments, and identifies and maps, to the degree possible, the most vulnerable neighborhoods, populations and infrastructures within the city that are exposed to floods and landslides hazards both currently and in the future. This should be seen as an overview of vulnerability, rather than full assessment: this vulnerability 'screening' could usefully be complemented by fuller and more detailed vulnerability analysis on the part of local stakeholders in the future. The assessment concludes with a section on risk information, which suggests studies and data collection activities to continue the development of pertinent risk information for Estelí.
5. **Combined strategic climate adaptation investment and institutional strengthening plan**: In a workshop in March 2013 in Estelí, there was some participation by stakeholders in discussing initial assessment findings and suggesting future strategy and concrete measures for adapting to current and future flood and landslide hazard risks. This interaction forms the basis for the plan as outlined in this report. It should be emphasized that, by design, this plan has no particular institutional affiliation or 'official' status – it, and the assessment and analysis upon which it is founded, now stands as a contribution offered to a debate that is already occurring on climate change adaptation in Estelí. Again, stakeholders in Estelí will be able to adopt and elaborate the measures proposed as they see necessary.

1.3 Context and study area

Estelí is a city located in North-Western Nicaragua, about 150 kilometres north of Managua. The city sits within the Department of Estelí in the Las Segovias region. The Department is composed by six municipalities. These are Estelí, La Trinidad, Condega, San Nicolás, San Juan de Limay, and Pueblo Nuevo. It is connected with the rest of the country through the Pan-American Highway.

Estelí is thus centrally located within Nicaragua with a heterogeneous topography of hills and plains ranging from approximately 1,000 to 1,600 meters above sea level. With a surface of 795 square kilometres, the Municipality of Estelí is one of the six municipalities of the Department of Estelí. Estelí acts as both the seat of the Estelí Municipal Government and of the Estelí Department.

The climate is warm and sub-humid (Aguó, AW1, AW2). The average mean precipitation is 825mm and mean temperature 21.5°C. Temperature extremes have been reported as high as almost 34°C and as low as 5.5°C. At the municipal level, the average monthly temperature is 26°C and precipitation varies between 800mm-1,200mm. Estelí has a dry season during the winter, from November through April, and a rainy season during the summer, from May through October.

Estelí is located in an area characterized by rich biodiversity. The natural reserves of Quiabú, Moropotente Miraflores, Tomabú and Tisey La Estanzuela surround the city. The morphological structure of Estelí is marked by the presence of water flows. It holds a water-bearing stratum of great importance for the region (SINAPRED, 2011).

The Estelí River runs along the city for six kilometres and divides it from Northeast to Southwest. The El Zapote ravine also runs through the city, while the El Zanjón de los Cedros ravine runs through the South, following the Pan-American Highway until finally joining the Estelí River. These water streams are responsible for the floods occurring within the urban core of Estelí (SINAPRED, 2011). As in the rest of Nicaragua and Central America, Hurricane Mitch set an important precedent in disaster risk management because of its devastating effects.

Estelí is also marked by several environmental challenges. The city suffers from important water pollution problems, as wastewaters are directly dropped into water streams and Estelí lacks an efficient sewage system. Further, within the urban core, deforestation and soil erosion issues are a cause of concern. These issues contribute to environmental degradation in Estelí and raise environmental management concerns that are closely linked to urban planning strategies and disaster risk reduction.

The administrative boundaries of urban Estelí are the basis for the area of study (see Figure 1.1). Given the important rural-urban linkages of the city, of necessity there is discussion of the area’s social, economic and spatial dynamics within the regional context in the urban, social and economic assessment.

Figure 1.1 Satellite photo of Estelí, Source: Google Maps.

2 Climate-related hazard assessment: floods and landslides

2.1 Introduction

This chapter evaluates present and future floods and landslides in Estelí. According to our interviews with the Estelí municipal government, Estelí is considered vulnerable to floods but not landslides; this assessment constrained by the information available suggests the same.

Flood and landslide hazards are considered in this chapter. Each hazard is discussed and draws from available information and data. This chapter divides the analysis into the following sections:

- **Methodology:** a discussion of the approach for analysing how climate change may impact floods and landslides
- **Physical description**: an overview of physical characteristics in Estelí that are relevant to floods and landslides, and the meteorological drivers of events associated with flood and landslide hazards
- **Floods**: a general description of floods relevant to Estelí, a summary of prior events, and a description of the flood resources used to inform disaster management and municipal planning
- **Landslides**: a general description of landslides relevant to the Estelí region and a description of the landslide tools used to inform disaster management and municipal planning
- **Future hazards**: an overview of future changes of climate and the potential impacts on future landslide and flood threats relevant to Estelí, including a section describing gaps and limitations.

2.2 Methodology

This analysis utilized existing resources used by Estelí government to consider how flood and landslide hazards may change by mid-Century (2040s and 2050s). To effectively inform future urban planning, it was important that this approach be appropriately aligned with the available local data and tools. The steps taken to consider how climate changes by the 2040s may impact the timing and frequency of future landslide and flood events included:

1. Review available information describing the physical system such as hydrology and geomorphology to understand the drivers that affect landslides and floods.
2. Collect and investigate data on past landslide and flood events in Estelí to assess the degree of impact per event and the conditions that precipitate events.
3. Assess available resources used by the municipality to describe zones susceptible to landslides and floods, and to inform emergency planning.
4. Assess and process available future precipitation and temperature data for mid-Century.
5. Assess and perform the application of three distinct approaches that consider how climate change may impact the resources examined in Step 3.

Each step, available data, and tools are discussed in greater detail in Annex 1.

2.3 Physical description

This section provides an overview of the physical attributes that affect floods and landslides in the Estelí study area: land characteristics, hydrology, and climate and weather.

2.3.1 Land characteristics

The city of Estelí is located at an elevation of 885m (Corrales, 2005) (see Figure 2.1). Slopes in the Estelí region vary from 16% up to more than 50% (Ministry of Environment and Natural Resources, 2001). In general, low lying areas as found across most of the urban study area may be prone to flooding while steep areas may be prone to landslides.

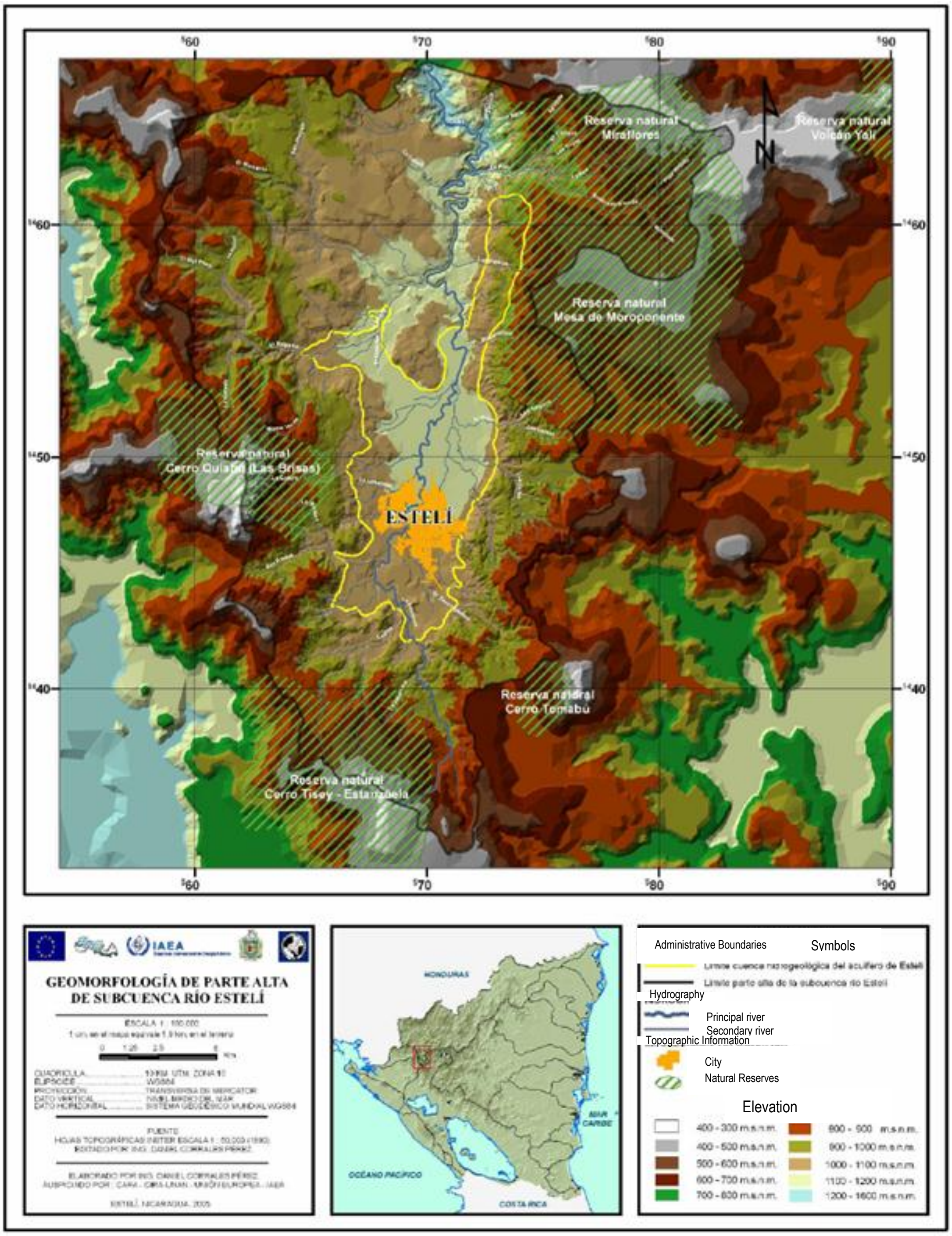


Figure 2.1 Geomorphology of Estelí. Source: Corrales, 2005.

The valley is formed by quaternary materials (conglomerates, gravel, silt and clay) that can reach a depth of 66m (Corrales, 2005) and differ from the tertiary materials that have also been found (Figure 2.2). The municipality of Estelí sits within a geologic depression comprised of alluvial deposits.

The mountain system surrounding the valley is of volcanic origin from the Tertiary period; with abundant fractures located NE-SW, NW-SE and N-S directions (see black lines on Figure 2.2). This is important as earthquakes may act as a trigger for landslides. The city of Estelí, does not have a record of seismic activity but is located in a region with high probability of being affected by seismic activity, given its proximity to the subduction zone of the Coco and Caribbean plaques. Because of this concern, the region has been classified to be at medium risk (Luna-González, 2001; CARE-COSUDE-ALCALDÍA, 2007) and, considering the natural instability of the area, this is something to be taken into consideration in short, medium and long term planning. If environmental conditions responsible for landslides are projected to increase, then areas of high seismic activity may become more prone to landslide damage.

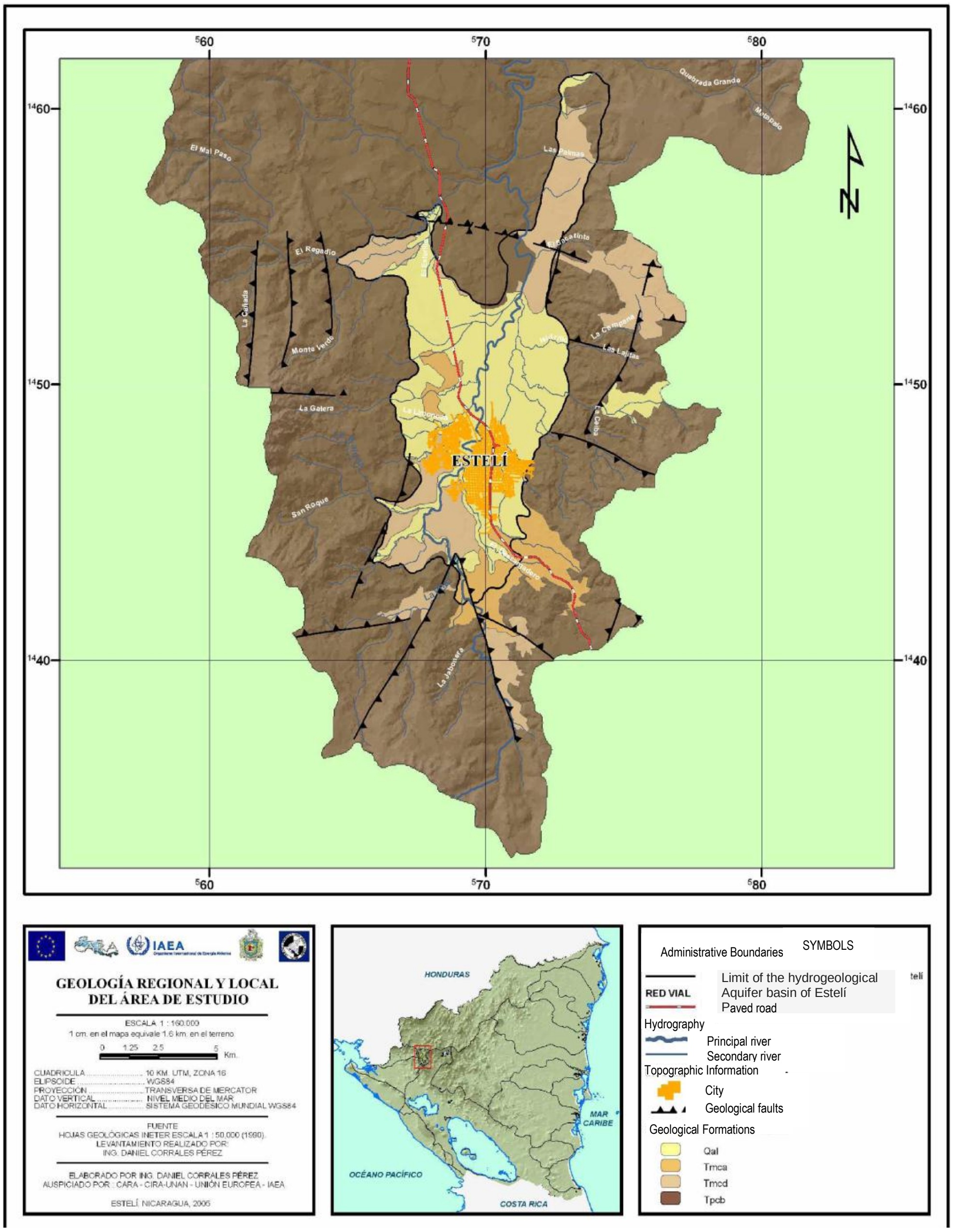


Figure 2.2 Geology of the department of Estelí. Note: Qal represents Alluvial Quaternary, Tmca represents Medium Tertiary conglomerates and andesites, Tmcd represents Medium Tertiary tuffs and ignimbrite, and Tpcb represents Tertiary Pliocene basalts and conglomerates. Source: Corrales, 2005.

2.3.2 Soils and forest types

Understanding soils and forest types are important in this assessment for two reasons: (1) the strength of the soils and root system are important factors in the potential for landslides, and (2) the capacity of the soils to retain and store water is an important factor for flooding.

Soils. The occurrence of different types of mass movement is determined by the lithology (CATIE et al., 2004):

- Andesites are susceptible to landslides of great magnitude because of the fractures;
- Basalts outcrops are susceptible to rock falls, landslides and detritus fluxes;
- Tuffs are susceptible to superficial landslides; and
- Agglomerates are susceptible to the detachment of big blocks.

Forests. Apart from lithology and the relief, forest cover is crucial in determining susceptibility to landslides, as forests protect the soils from erosion and hence reduce landslides probabilities.

Historically, forested areas covered most of the El Zapote watershed and areas adjacent to the Estelí River (see Figure 2.3). However, today the watershed is nearly extinct of its native vegetation, which used to include the stranded tropical trees known as *chilamate* and *matapalo*. Within the municipality, deforestation has exacerbated the rate of erosion (particularly in the northern half of the predominant watershed). The major reasons for such high rates of deforestation have included excessive grazing, selective wood and timber extraction, and forest-burning for agriculture purposes (Municipality of Estelí, n.d.).

Forest types that dominate the region include (Ministry of Environment and Natural Resources, 2001):

- Tobacco plantations in the lower areas located in plain or low slope areas;
- Annual crops (grains and vegetables) cover some slopes (8 to 30 percent);
- Undergrowth grasses and fragmented bushes are dominant along the foothills (SE and E of the city) with slopes greater than 50 percent;
- Grasses, isolated trees, and undergrowth grasses cover much of the other foothill areas (S and SW of the city); and
- Oaks, bushes, vegetable crops in plain areas and some isolated pine are located within the upper basin.

2.3.3 Hydrology

The Estelí valley is located within the boundaries of the Coco River Basin. As illustrated in Figure 2.3, there are numerous tributaries in the surrounding mountains that drain into Estelí valley and the Estelí River. The Estelí subwatershed has a drainage area of 1,326 km^2 (Corrales, 2005). In this system, the Estelí River runs south to north through the city with branches of streams and creeks extending through the area emptying into Coco river. During a drought or the dry season, most of these tributaries are dry or have pockets of dried up beds.

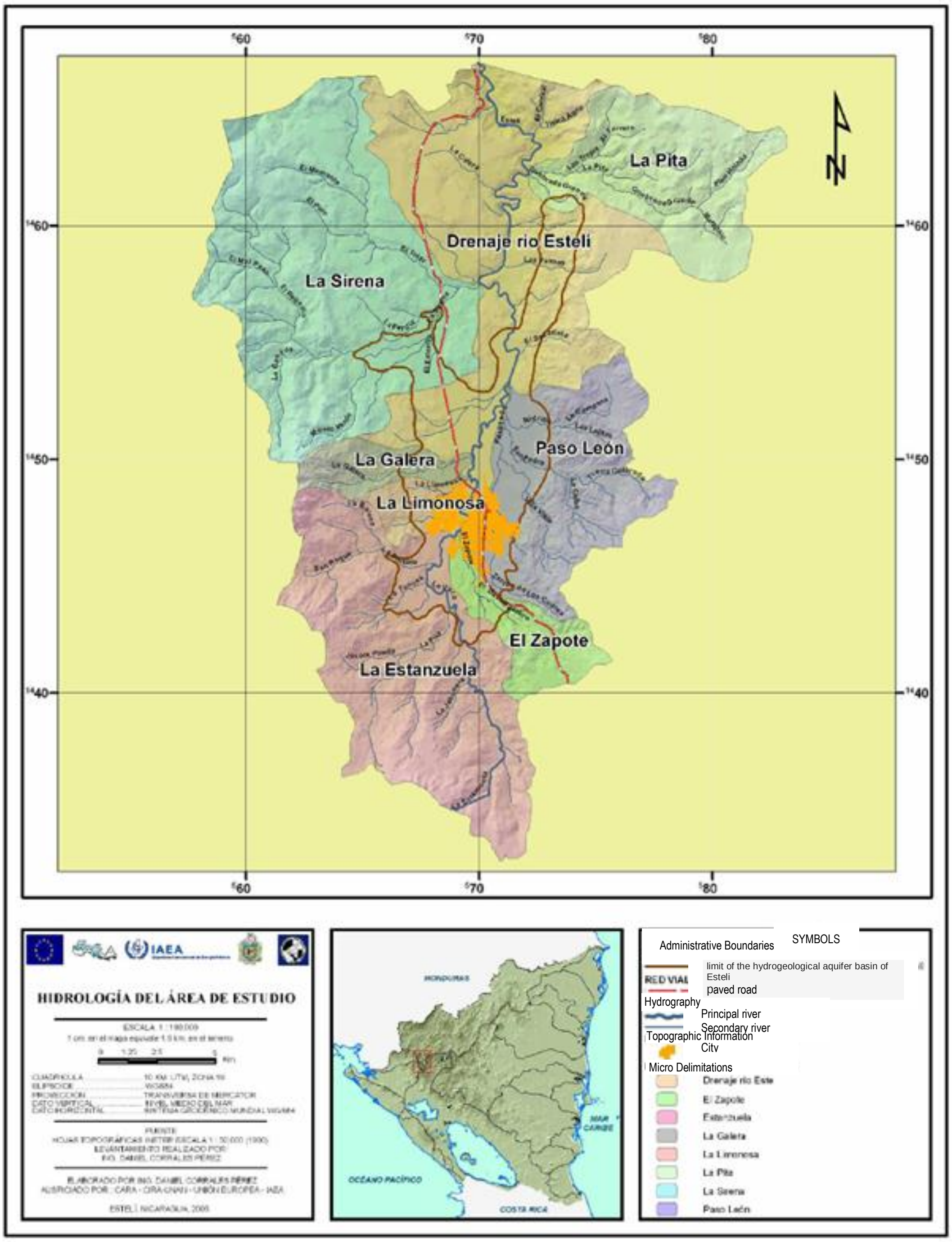


Figure 2.3 Hydrology of Estelí produced by the department of Estelí. Source: Corrales, 2005.

2.3.4 Climate and weather

Estelí climate is classified as "sub-humid dry" (Aguó, AW1, AW2; Hidrologic report), and experiences relatively high temperatures throughout the year marked by two distinct "wet" and "dry" seasons. The dry season occurs during the winter months, from November through April, and the wet season occurs during the summer months, from May through October.

Temperature. Estelí has hot and sub-humid temperatures throughout the year (Government of Reconciliation and National Unity, 2010). At the municipal level, the average monthly temperature is 26°C (Government of Reconciliation and National Unity, 2010). From 1970 to 1988, the average annual temperature for Estelí was 28.3ºC, with the lowest temperatures experienced in December and January and the highest temperatures in March and April (see

Figure 2.4 and Table 2.1). The relatively high temperatures promote high rates of evaporation (Corrales, 2005). Evaporation, a factor that is influenced largely by temperature, affects soil moisture and has been increased by deforestation. From 1971 to 1988, the highest mean monthly values of evaporation occurred in March and the lowest in September (Corrales, 2005).

Precipitation. At the municipal level, total annual precipitation varies between 800 mm to 1,200 mm (Government of Reconciliation and National Unity, 2010). The Inter-Tropical Convergence Zone (ITCZ) (see Box 2) and the Pacific and Atlantic monsoons largely control the seasonal rainfall in Nicaragua (McSweeney et al. 2010). In addition, the ITCZ influences local weather in June and July causing an increase in cloud cover and precipitation (which blocks sunlight), reducing temperatures at the surface (Corrales, 2005). The wet season in Nicaragua can vary considerably from year to year, in part, driven by variations in the El Nino Southern Oscillation (ENSO) (McSweeney et al., 2010). In addition, tropical cyclones and hurricanes contribute a significant fraction towards high wet-season rainfall totals (McSweeney et al., 2010).

In Estelí, the rainy season has a bimodal regime with precipitation peaking in May and September (INETER, 2004; Corrales, 2005). During the second half of July and the first half of August, a dry period termed the 'Canícular' occurs (McSweeney et al., 2010). As with other high-altitude climates in the region, Estelí receives approximately 880 mm of average rainfall per year, with wet months occurring between May and October where monthly rainfall averages are 134 mm, and dry months occurring between December and March where monthly rainfall is less than 10 mm (see Figure 2.5 and Table 2.1) (World Bank et al., 2001).

Table 2.1 Monthly average temperature and total precipitation for Estelí station from 1970 to 1988. Source: adapted from Corrales, 2005.

Month	Temperature (°C)	Precipitation (mm)
January	27.1	4.4
February	28.4	3.1
March	30.1	13
April	30.7	24.2
May	29.8	199.3
June	27.8	142.7
July	27.6	63.4
August	28.4	99.4
September	27.9	170.2
October	27.5	127.1
November	27.3	28.9
December	26.8	5.1
Annual	**28.3 (average)**	**881 (total accumulation)**

Where blue shading indicates the wet season and red shading indicates the dry season.

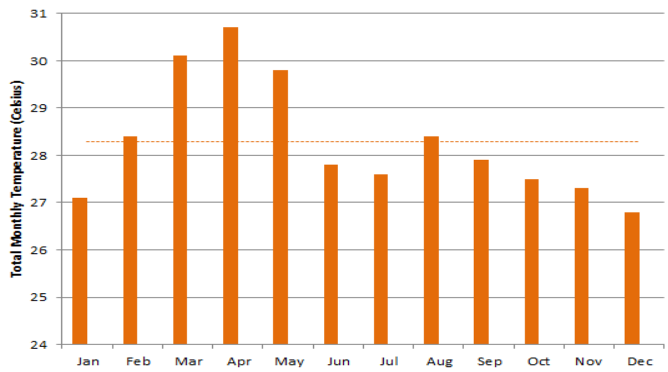


Figure 2.4 Average monthly temperature (°C) for Estelí station from 1970 to 1988 with the dashed line representing the average monthly temperature over the year. Source: based on data from Corrales, 2005.

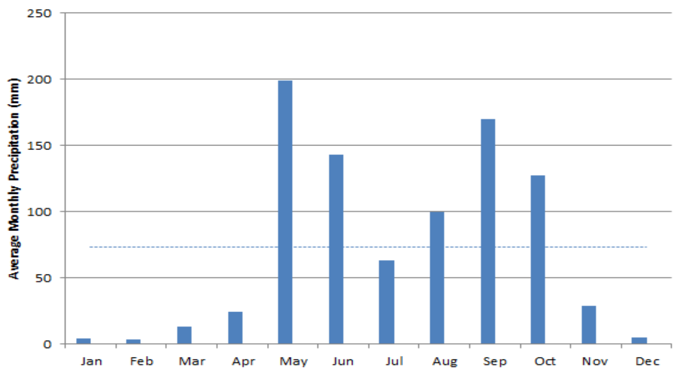


Figure 2.5 Average monthly precipitation (mm) for Estelí station for 1970 to 1988 with the dashed line representing the average monthly precipitation over the year. Source: based on data from Corrales, 2005.

Observed Trends. For Nicaragua, weather data from meteorological stations suggest significant increases in both mean minimum and mean maximum temperatures have occurred (comparable information does not exist for the city of Estelí). The following temperature trends have been observed:

- For Nicaragua, the mean minimum temperature has risen from an average of 15.5°C observed in 1957 to 1968 to 16°C observed in 1993 to 2002 (World Bank, 2009). This is consistent with a UNDP study which found the mean annual temperature for Nicaragua has increased at a rate of 0.2°C per decade since 1960, with a similar trend across all seasons (McSweeney et al., 2010).
- Comparing the period from 1957 to 1968 to the period from 1993 to 2002, Ocotal, a city located 68 km North from Estelí and with similar topographic conditions, reported an increase of 0.3°C in the mean minimum temperature, and an increase of 0.1°C in the mean maximum (World Bank, 2009).
- From 1960 to 2003, the average number of hot days per year (i.e., temperature exceeding the top 10 percent of the record) for Nicaragua has increased by over 16 percent to an additional 60 days, with the greatest increase noted in the summer months (June, July, and August). Hot nights have also increased by over 11 percent with an additional 43 days, with the greatest increase experienced in the fall months (September, October, and November). (McSweeney et al., 2010)
- From 1960 to 2003, the average number of cold days per year (i.e., temperature below the bottom 10 percent of the record) for Nicaragua has decreased similarly across all seasons by 5.5 percent or 20 days per year (McSweeney et al., 2010).
- The following precipitation trends have been observed (McSweeney et al., 2010):
- From 1960 to 2003, the average total rainfall per decade for Nicaragua has decreased by 5 to 6 percent. Within the last 15 years, the mean annual rainfall has decreased, particularly noticeable during the wet season.
- From 1960 to 2003, the proportion of rainfall that has occurred during heavy events (i.e., daily rainfall total exceeding the amount of precipitation associated with the top 5% of daily precipitation of the record) in Nicaragua has increased by 2.2 percent per decade.

From 1960 to 2003, the maximum 1-day rainfall per year has increased by 8mm per decade and the maximum 5-day rainfall per year has increased by 14mm per decade. These increasing trends occurred in both the wet and dry season.

2.3.5 Phenomena that affect weather conditions triggering floods and landslides in Estelí

Processes such as the Inter-Tropical Convergence Zone (ITCZ) and the El Nino/Southern Oscillation (ENSO) cycle impact the timing and magnitude of precipitation events (see Box 3). The ITCZ is one of the main factors responsible for the timing and magnitude of the wet season, producing intense rain events almost every year during the summer months. The ENSO cycle influences interannual precipitation in Estelí. Between June and August, El Nino events bring relatively warm and dry conditions while La Nina events bring cold and wet conditions (McSweeney et al., 2010).

Box 2 Overview of processes that affect Nicaragua climate

Inter-Tropical Convergence Zone

The Inter-Tropical Convergence Zone (ITCZ) is a region along the equator that extends hundreds of miles north and south and is characterized by heavy rainfalls and a horizontal band of clouds, as shown in the image below. This low pressure band exists because of the temperature variations in the atmosphere which drive the Hadley cell and converge the trade winds equatorward: in the northern hemisphere, clouds move in a southwesterly direction while in the southern hemisphere they move in a northeasterly direction. The results are convective storms, which are short in duration but with intense rainfall: it is estimated that 40 percent of all tropical rainfall rates exceed one inch per hour.

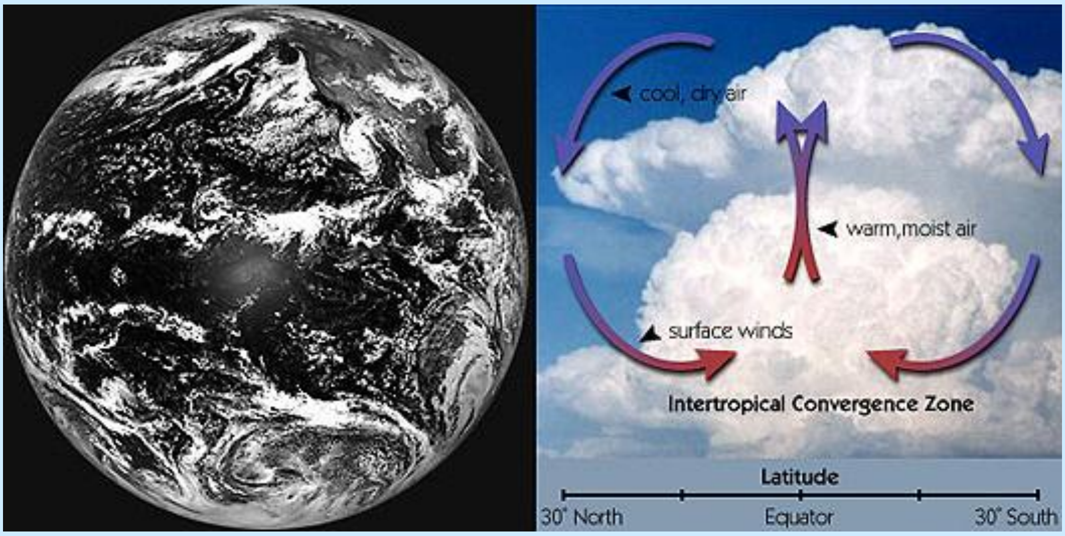
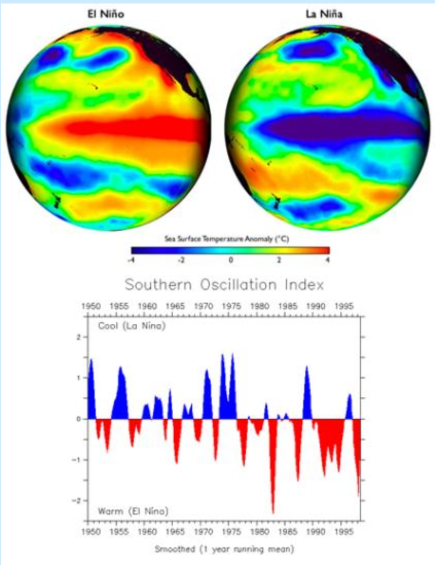


Figure 2.6 **Left: ITCZ image from the GOES 14 satellite; Right: Hadley Cell Circulation Source: NASA GES DISC.**



ENSO

The El Nino/Southern Oscillation (ENSO) cycle is the cyclical change in sea surface temperatures, rainfall patterns, surface air pressure, and atmospheric circulation that occurs around the Equatorial Pacific Ocean. The extremes of the ENSO cycle are termed El Nino and La Nina. El Nino is when the sea surface temperature in the Pacific becomes warmer than normal and the strength of winds reduce. Conversely, La Nina is when the sea surface temperatures become colder than normal and the strength of the wind increases. These events usually occur every 3 to 5 years and can last over 12 months.

Figure 2.7 Top: Sea surface temperatures for El Nino and La Nina events; Bottom: El Nino (blue) and La Nina (red) events from 1950 to 2000. Source: NASA GES DISC.

2.4 Current flooding hazard

Estelí is situated, as discussed above, along the Estelí River. Mountainous areas surrounding Estelí house tributaries that flow into the Estelí River. At an altitude of 885m, the city of Estelí is prone to flooding as it sits on a plateau at the foot of mountains that on average reach an altitude of 1,600m. These mountains are part of the protected areas of Estanzuela Tisey, Tomabú, and Quiabu-Las Brisas and are the source of tributaries that flow to the Estelí River. The Estelí River has a downward flow through the very gentle slopes and plains of the city. The Estelí River is prone to overflowing its banks during the rainy periods, flooding the surrounding areas in the city.

This section provides: (1) a description of the flooding in Estelí, discussing both the general conditions that cause or exacerbate flooding and the locations where flooding occurs; (2) a general summary of when prior flood events have occurred over time; and (3) a description of the flood tools used by the city planners and emergency management in the city of Estelí.

2.4.1 Description of floods

In the Estelí Municipality both the Valley of Estelí, including the urban area, and the area of Llanos de Colón-Campos Azules have been identified as large flood prone areas (CARE-SDC, 2007) where sudden floods occur as a consequence of:

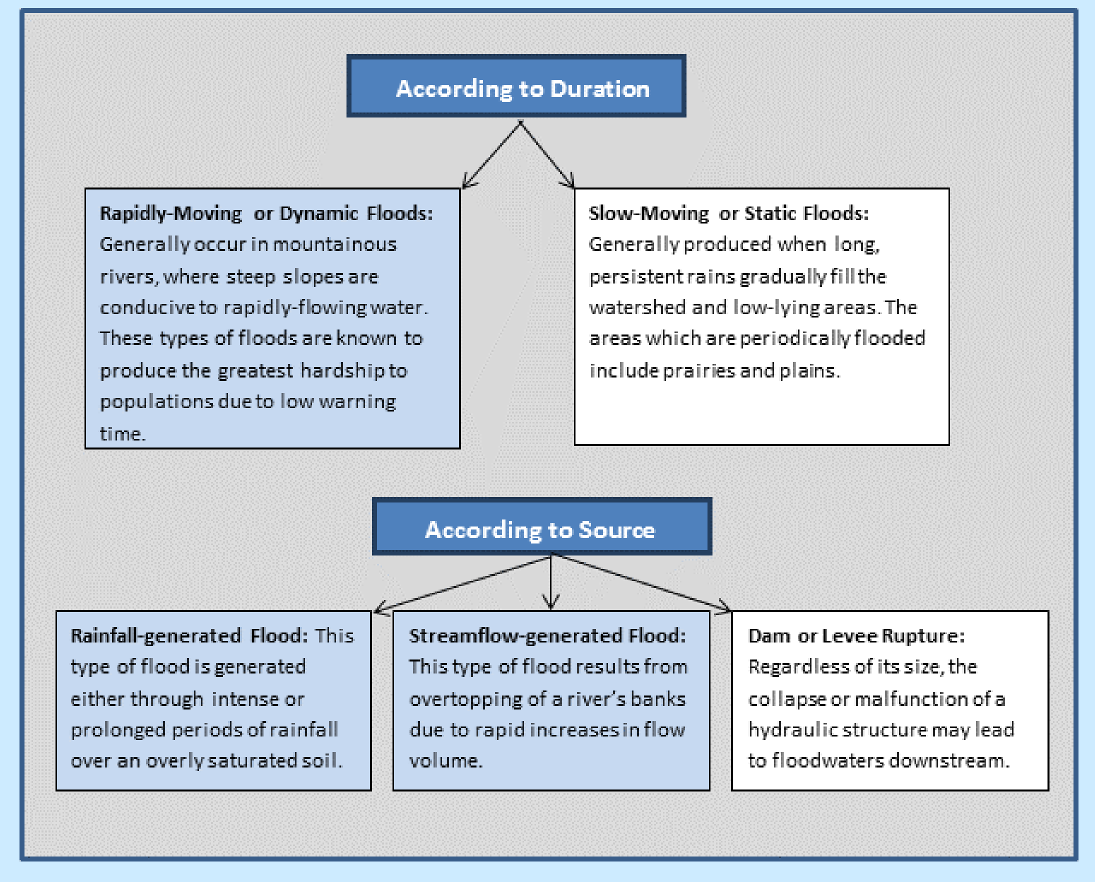
- Local land characteristics;
- The sharp transition from steep slopes with strong drainage to smooth relief with poor drainage;
- High surface runoff coefficients;
- High temporal rainfall concentration;
- Inappropriate watershed management; and
- The presence of vertisol clay soils over flooding plains (these soils easily form depressions when wet).

Related to flooding and of concern for the Estelí municipality is also the contamination of surface waters by sediment, domestic and agro-industrial sewage and solid waste (UNDP 2010). Another point for consideration is that local residents assert that the accumulation of sediments around bridges constructed after Hurricane Mitch has intensified flows and increased the risk of flooding in surrounding areas (specifically in the Panamá Soberana neighbourhood).

Different from river and stream overflows, flooding has been described in the city as a result of higher water table levels in badly drained soils. This increases the level of flooding risk in some areas of Estelí, particularly in the neighbourhoods of José Benito Escobar, Michigüiste and Camilo II.

Box 3 Categorizing floods in Nicaragua

A flood can occur when an intense and/or continuous rainfall exceeds both the saturation capacity of the soil and the carrying capacity of the nearby river; the result is an inundation of low-lying lands adjacent to the river. Floods can be categorized as one of two types according to: Duration and Source. The flowcharts describe the flood categories with the shaded categories are associated with the flood types most predominant in Estelí (INETER and SDC, 2005).



2.4.2 Past and present floods

Throughout history, the major disasters in Estelí have been floods caused by overflowing of the Estelí River and two of its tributaries, El Zapote Ravine and the Zanjón de Los Cedros, all of which cross the densely populated city from South to North over approximately 6, 2 and 4 km respectively, and add to about 11 km of water streams running through Estelí, mostly during the rainy season. Flooding from these water courses divides Estelí into three sectors: 1) neighborhoods to the East of the Zanjón de Los Cedros, 2) neighborhoods located between the Zanjón de Los Cedros and the Estelí River and, 3) neighborhoods to the West of the Estelí River.

A number of flood events have occurred associated with significant damage, including:

- Hurricane Mitch hit Estelí in October 1998 and has been by far the most damaging disaster in the city, with reports of 8 people dead and 12 missing, and affecting almost 42,000 people. During Hurricane Mitch, approximately 615mm of rainfall was recorded at the station Condega (about 25 miles from Estelí), which is nearly equivalent to a year's total rainfall amount. As a result, intense rainfall was considered the predominant cause for various flooding events throughout the country. As expected, the most affected areas within the city limits occurred adjacent to the Estelí River: its water heights reached 6 to 7 meters, as a result affecting more than 26 neighborhoods and 13 communities. This led to multiple flooding events: 189 kilometers were affected and two bridges were destroyed, while 446 homes and 30,000 people were affected directly. The flooding as a consequence of Hurricane Mitch destroyed 260 houses and affected 400; 11,394 hectare acres of crops were lost in the entire municipality. Nearly every sector in the local economy was affected. Following its aftermath, the local government has placed special attention on residential areas and on their overall resiliency against extreme weather events. (COSUDE, 2007)

- The flooding associated with Hurricanes Fifi (1974), Irene (1971), and Joan (1988) have led to the labelling of two areas as flood prone: the Valley of Estelí, including its urban center, and Llanos zone of Colon-Campos Azules (Ruiz, 2009).
- Flooding events in recent years (between 2000 and 2008) has resulted in significant economic losses to Nicaragua: between 1997 and 2006, such losses have amounted to an annual average of 2.71% of GDP (World Bank et al., 2001).

The 2010 and 2011 flood events were triggered by Hurricane Mathew and the effects of the Tropical Depression 12E, respectively. These events left major damage to the infrastructure of bridges necessary for local, national, and regional communication. In particular, the 2010 floods damaged the Chanillas Bridge, located north of the City over the Pan American Highway (the main route of national and international commercial traffic in Nicaragua) and thus cut all exchange between Estelí, the Northern areas of the country and Central America. This damage limited the international traffic, affected the flow of goods and commerce in Central America, and generated significant economic losses. The 2011 floods, in turn, damaged the Puente de Hierro, a bridge located also to the North of the city.[3] Unfortunately, the rainfall amounts associated with many of these floods is not well documented.

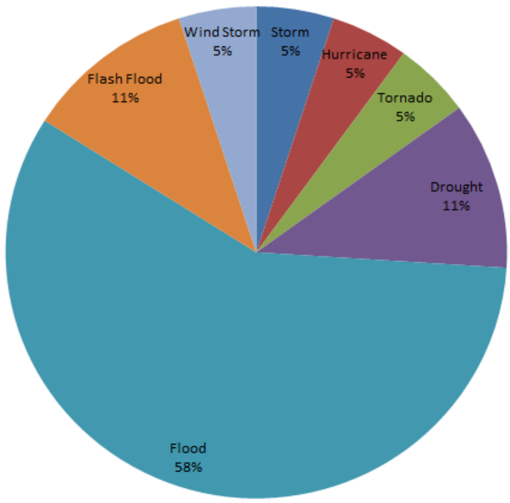


Figure 2.8 Proportion of climate related events reported in Esteli in 1992 to 2011 (19 events total). Source: based on data provided by the DesInventar Database (Version 9.5.12-201).

The DesInventar database provides a summary of the frequency and location of natural disasters in Estelí including flood and flash flood events from 1992 to 2011 (DesInventar Database (Version 9.5.12-201). Based upon this database, there were 11 floods and two flash floods reported in Estelí representing a substantial percentage of all reported disaster events (see Figure 2.8).

None of the disaster events occurred in the months from December-April. As illustrated in Table 2.2, reported floods in Estelí are isolated to the months of May through November which comprise the rainy season.

Table 2.2 Monthly distribution of climatic events related with floods or storms from 1992 to 2011; Source: based on data from DesInventar Database (Version 9.5.12-201)

Event as reported	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Flood					2	1		2	2	2	2		11
Flash flood						1		1					2

[3] This summary is based upon information provided by the following websites: http://www.cnn.com/2010/WORLD/americas/09/23/tropical.weather/index.html?hpt=T2); http://www.dartmouth.edu/~floods/Archives/2007sum.htm; http://www.laht.com/article.asp?CategoryId=23558&ArticleId=357671; http://www.wunderground.com/history/airport/MNMG/2012/11/28/DailyHistory.html?req_city=Esteli&req_state=&req_statename=Nicaragua; http://www.cigarcabana.com/nicaraguan-cigars.html#ixzz2DfRQ3Wax

Event as reported	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Hurricane					1								1
Grand Total					3	2		3	2	2	2		14

2.4.3 Flood planning and warning system tools

The Estelí municipality has developed a flood map that describes areas in and around the city which are prone to flooding. There are no vulnerability maps, formal emergency flooding management tools, or formal flood warning systems. Consequently, this analysis is limited to the information presented in the flood map.

Flood Map. The Nicaraguan Institute of Zoning Studies (INETER) developed a series of hazard maps at a scale of 1:5,000 for dynamic and static flood scenarios (INETER, 2002). The flood hazard maps are developed based on the intensity of the flood (i.e., depth and speed of water, duration of the flood) and the frequency of the flood occurring:

- *Intensity*. The INETER and SDC study determined the intensity using hydraulic modelling. The United States Geological Survey (USGS) Hydrologic Engineering Centers River Analysis System (HEC-RAS), a one-dimensional model that simulates the hydraulics of water flow through natural rivers and other channels, was used for hydraulic calculations and the HEC-GeoRAS, a tool for GIS-based analysis, was used to calculate inundation areas and depths of flow. This modelling was informed by the following pieces of information: ARC/INFO-TIN digital terrain, a topographical survey of the existing water channels, and river flows calculated using a hydrological study. The intensity is categorized from low to high based upon the depth of flooding, and if applicable, its velocity. A "high" intensity flood corresponds to a high loss of life and economy, a "medium" intensity flood corresponds to a lower loss of life and economy though not negligible, and a "low" intensity flood correspond to mild damage with no loss in human life.
- *Frequency.* Frequency of an event was based on precipitation return periods determined by the study to be an acceptable proxy for flood return periods. The return periods were divided into three categories: "high" corresponds to a precipitation event that statistically occurs less than every 10 years, "medium" corresponds to a precipitation event that statistically occurs between 10 to 100 years, and "low" corresponds to a precipitation event that statistically occurs every 100 to 200 years. A discussion of the development of precipitation return periods was not available, but it is likely limited by the available hydrometeorological data record (e.g., less than 50 years long and spatially limited).

Figure 2.9 illustrates the classification code considering both the intensity and the frequency of floods, where red is considered a high threat, dark yellow a moderate threat, and light yellow a low threat. The greatest danger for flooding exists in areas that are prone to frequent flooding (e.g., areas that may flood every 10 years or less) where the water level of the river during a flood event is high.

Flood Hazard Classification

Flood Intensity	High (> 2.0 m)			
	Medium (0.5 to 2.0m)			
	Low			

	(< 0.5m)			
		0-10	10-100	100-500
		Precipitation Return Period (Years)		

Figure 2.9 Flood hazard classification scheme used in developing flood maps for Estelí. Source: INETER, 2002.

The Estelí River flood hazard is high all along its course. The El Zapote and El Zanjón de Los Cedros are considered moderate flood hazards (as shown in Figures 2.10, 2.11, and 2.12).

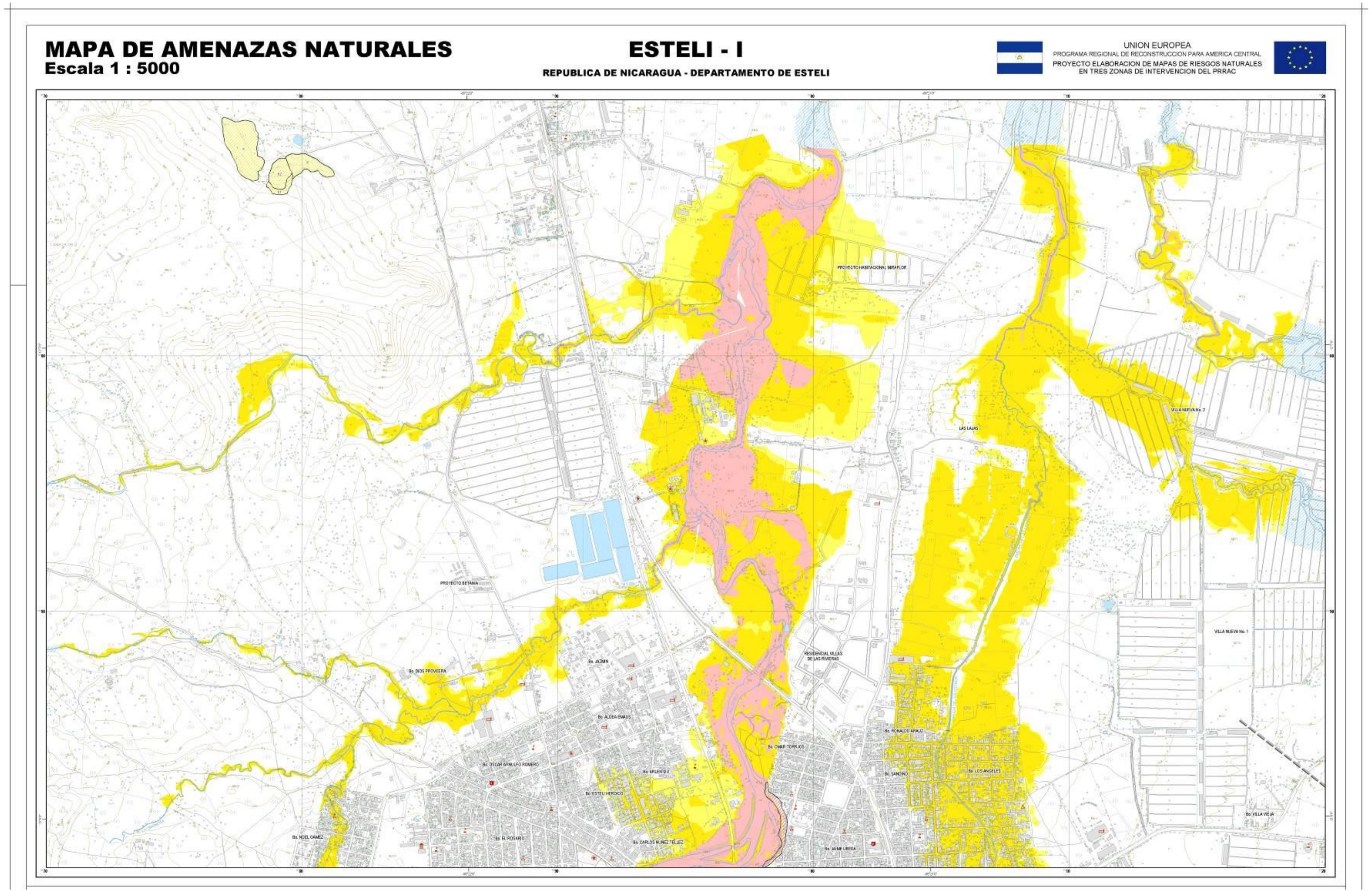


Figure 2.10 Flood map of the northern portion (upper basin) of Estelí. Source: INETER, 2002.

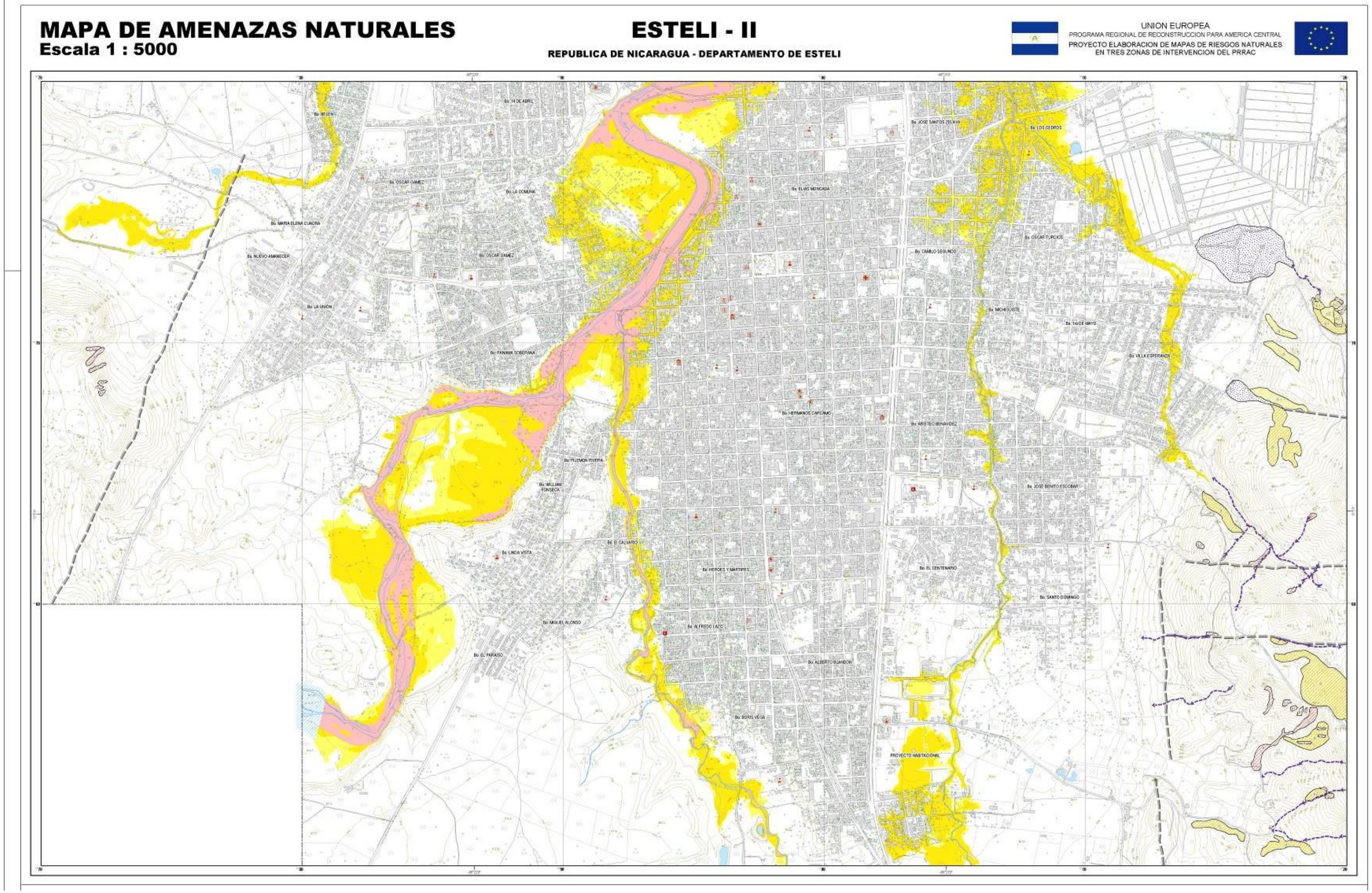


Figure 2.11 Flood map of the mid-portion of Estelí. Source: INETER, 2002.

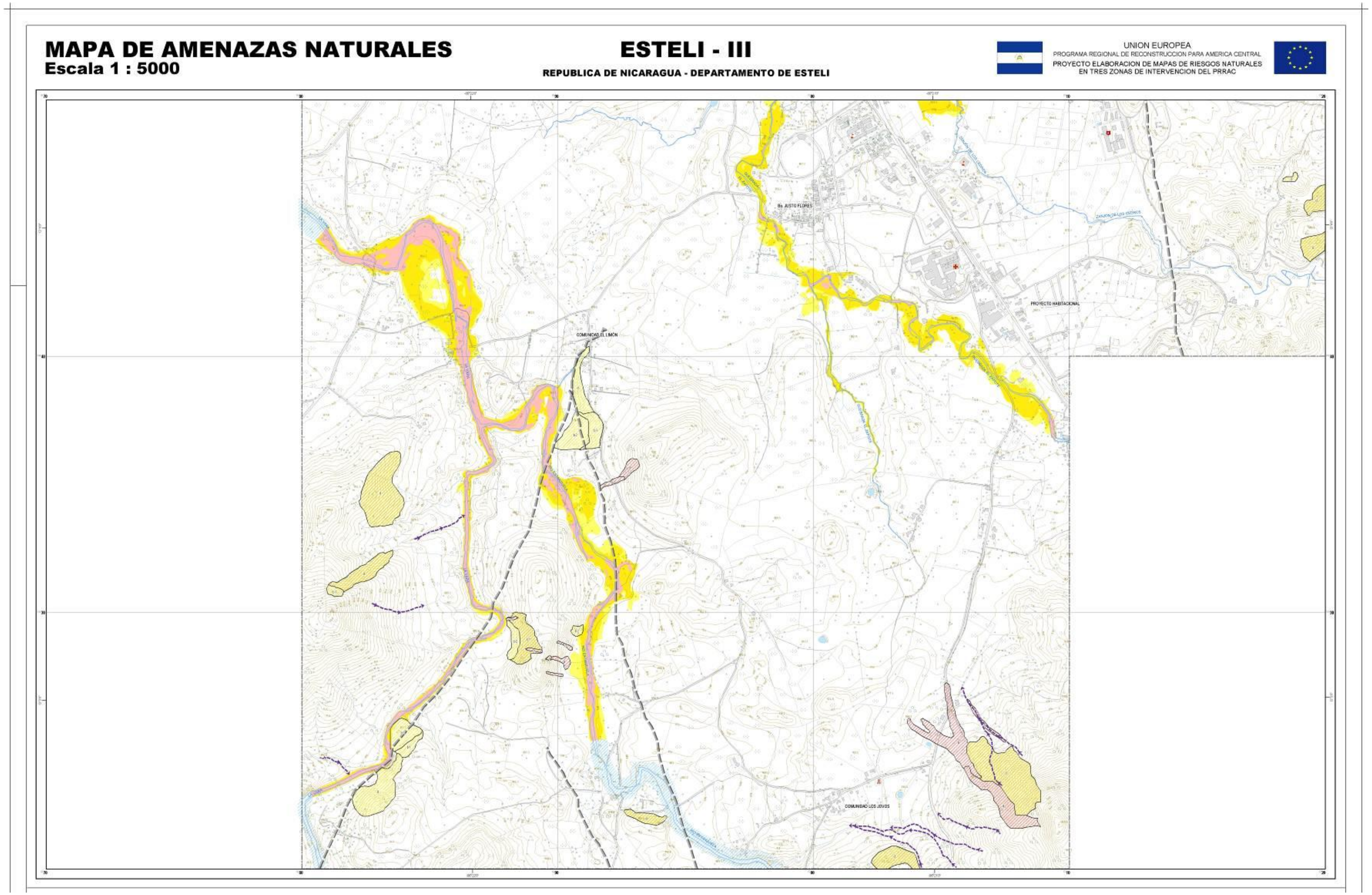


Figure 2.12 Flood map of the southern portion (lower basin) of Estelí. Source: INETER, 2002

Figure 2.13 Photo of pluviometer used in Estelí.

Flood warning systems. There is an existing early warning system that monitors rain levels and river level in the upper areas of the watershed. Farmers use pluviometers (or rain gages) to record daily precipitation and communicate with the Civil Defence (see Figure 2.13). The latter issues evacuation alarms according to the information provided by the farmers. According to the Civil Defence, the system has been effective.

2.5 Current landslide hazard

Landslides are generally caused by precipitation events and/or seismic activity. According to urban planning authorities and the Civil Defense, landslides have not occurred in the city of Estelí.

This section provides: (1) a description of the landslides in the Estelí region; (2) a summary of a potential location of a landslide event; and (3) a description of the landslide tools used by the city planners and emergency management.

2.5.1 Description of landslides

Common forms of landslides in Nicaragua include rock-fall, rotating of rocks, lateral displacement, translational landslides, and mud-slide (see Box 4 for a description). In addition to precipitation and superficial runoff, a number of factors contribute to landslide vulnerability in the Estelí region, including:

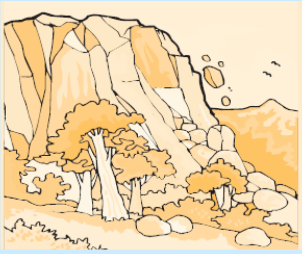
- ***Soil moisture***: The soil in Estelí can be highly saturated (>50%), which often leads to a cycle of continuing contraction and expansion according to the humidity level. During long periods of rainfall, such expansions may provoke irregular land subsidence. The result may cause structures to become unstable or may promote varying landslide types along sloped surfaces. (Municipality of Estelí, n.d.)
- ***Seismic activity:*** Seismic forces are also prevalent in the region. Although there are no epicentres within the municipality, there have been significant earthquakes in the 20th Century, occurring most recently in 1919 and 1922 where the magnitude reached a maximum range of 6.7 and 7.0, respectively. Seismic-induced landslides and risk areas in Estelí are classified as high risk if the soil is unstable, if excessive material has been excavated, and construction is too close to a fault line and has not followed proper design standards (Ruiz, 2009). This analysis does not focus on this factor given seismic activity is not related to changes in climate.
- ***Deforestation & erosion***: There are four protected areas in Estelí, including: Reserva Natural de Miraflor and Reserva Natural Cerro Tisey Estanzuela, Tomabu, and Cerro de Quiabu. These areas have become very degraded. Illegal timber extraction is common in the region as well as the consequent problems related to soil exposure and erosion in deforested areas. Within the municipality, deforestation has exacerbated the rate of erosion (particularly in the northern half of the predominant watershed).

Figure 2.14 Fault line and lack of vegetation in the surrounding of Esteli.

- ***Human activity***: Changes in landuse and vegetation can affect the stability of slopes. Through photographic analysis and in situ studies, SDC has been able to assign more than twenty principal areas at risk to landslides within the Municipality of Estelí, and the Department of Estelí. These locations include two critical rural sites – the Los Laureles and Las Calabazas communities – that are outside the urban perimeter of Estelí which have been exacerbated by excavation and other soil removal activities for the purposes of manufacturing concrete. From Figure 2.14, one is able to clearly discern the fault line and the lack of vegetation surrounding it (Ruiz, 2009).

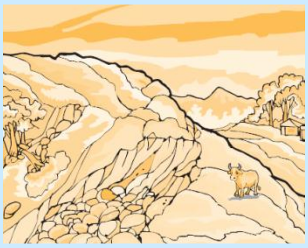
Box 4 Landslides in Nicaragua

Nicaragua is highly susceptible to landslides, defined as the movement of material along a slope, which are induced by gravitational forces, seismic events, rainfall events, and anthropogenic activity. Physical factors common to all at-risk areas include those where intense rainfall periods of short duration are prevalent, where topography is steep and vegetation has been removed, and where the soil type is fractured. There several types of landslide events (Ruiz, 2009):

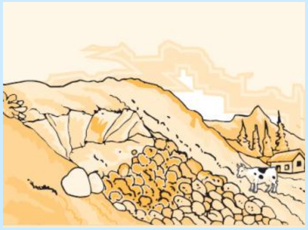


Rock-fall: Events in which massive rocks are detached from the larger entity and fall slope-ward (such events have been problematic to transportation infrastructure).

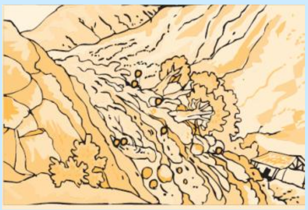
Rotating of Rocks: Common in volcanic zones, these are events in which fractured rocks are ultimately detached by a rotational action about its vertical axis.



Lateral Displacement: Movement of material laterally that is usually accompanied by additional fracturing. These generally occur in areas where soil is loose and of low quality (in response to the removal of vegetation).



Translational Landslide: This occurs when the fault line is undulated and the soil is loose.



Mud-slide: These are the most rapidly-moving form of landslides, generally composed of rocks and trees along a current of mud. These landslides are highly dangerous.

Several common effects resulting from a landslide include the loss of human and animal life, psychological stresses, intense erosion of the surface, physical damage to houses and infrastructure, natural damming of rivers, and agriculture damage.

2.5.2 Past and present landslides

During interviews with the urban planning authorities and the Civil Defense, it became apparent that there are no reports of landslides in the city itself. This is further supported by the DesInventar database version (Nicaragua 2012) which reported 25 natural disasters in Estelí (urban area) between September 1992 and January 2011 of which none are reports of landslides (19 events are related to climate and hydrological conditions, five events are fires and one event is an epidemic).

A potential area of concern for landslides is Cerro de la Guanabana, east of the city. This is an area that was exploited for mining sand. Photographs in Figure 2.14 show this area illustrating the very low population density and the return to the natural landscape. However, Google maps show aerial photos of this region taken in March that reveal a much drier environment. A detailed assessment of vegetation and soil cover changes on landslide susceptibility in the area would provide additional insight of the landslide susceptibility at this site.

Figure 2.15 Images of Cerro de la Guanabana from the lower areas closest to the city.

The Ministry of Environment and Natural Resources (2001) has calculated that landslides could potentially increase when a precipitation event reaches 150-200 mm (this calculation is derived from the soils carrying capacity).[4] This threshold could inform additional analysis if daily precipitation projections are available to determine if the frequency of these events is projected to increase.

2.5.3 Landslide planning and warning system tools

Landslide maps. Luna-González (2001) and CARE-COSUDE-ALCALDÍA (2007) identified different types of mass movements, based on both interpreting images and doing field assessments. This diagnosis and identification effort is shown in Figure 2.15. The map shows in red all active high risk areas for landslides, in orange are those at medium risk, and in yellow those at low risk.[5] This map shows the city of Estelí in purple and does not suggest it is at substantial risk to landslides.

[4] It is not clear from the information provided if this threshold is based upon a precipitation event or a monthly total. For purposes of this discussion, it is assumed this threshold is based upon a precipitation event.

[5] Areas prone to landslides in the municipality have been identified as: Cerro Tomabú-Las Cuevas, Cerro la Montaña, hills near Los Chilamates community, Loma Las Sozas, SE Cerro El Grande, Cerro Las Ventanas, Cerro Las Limas-Las Tablas-Cerro Grande Sur, Meseta Las Lagunillas, Cerro El Picacho, Cerros Límites Oeste del Valle Santa Cruz, Cerro El Divisadero, Micro-basin Potrero Grande-Jocote Pando- La Rinconada, Micro-basin Río Aguas Frías, El Terrero and Apagüís. Laguna de Miraflor plateau, La Naranja, Cuesta Cucamonga, west of La Meseta Ocote Calzado, Cerro El Camote, Cerro La Joya, Los Brazuelos-Potrerillos, Mountains surrounding Isiquí, Communities of Isiqui, La Quinta, and El Carrizo, East of Cerro San Pedro, Cerro San Pedro, East of the city of Estelí (not urban), Las Calabazas-Corre Viento, area of El Descargadero, Mountains bordering the Santa Cruz Valley NW-SE, Cerro El Quebracho, southern and southeaster slopes of Cerro La Fila, Loma El Morado, Cuenca Quebrada Grande Norte, Cerro El Grande, area of La Narizona y Rodeo de los Bueyes, Valle Regadío y Valle Arriba, Cerro El Encino, Cerro la Primavera-Santa Elena, Llano La Parada, SE-NO-S valley of San José del Rodeo, La Labranza Plan Grande, Los Laureles community and Las Calabazas community.

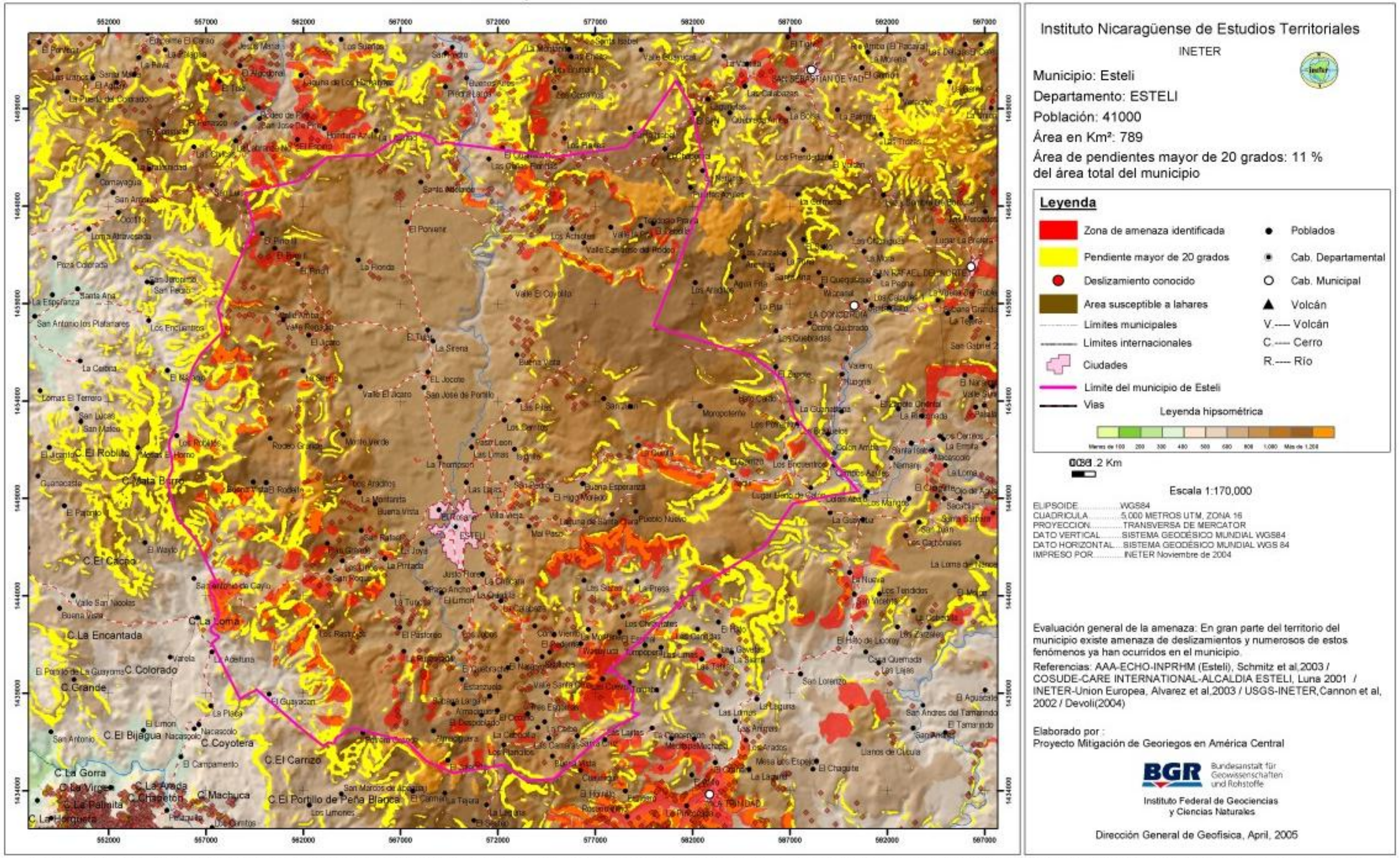


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Figure 2.16 Municipal Map of Landslide Hazards. The map shows in red all active high risk landslides, in orange are those at medium risk and in yellow those at low risk. Source: INETER (2005).

Additional landslide analyses for Nicaragua suggest the following (Ruiz, 2009):

- For translational and rotational landslide events, the following causal agents have been identified: general topography, vegetative covering, presence of springs which induce erosion and catalyze landslide events, and the inadequate removal of earth from slope-ward areas.
- When considering landslide-prone areas for other types -such as mudslides, rock falls, and lateral displacement events-, the task of identifying such locations throughout Estelí is more difficult. Generally, these events are prevalent in areas where the slope exceeds 30-degrees and where vegetation has been removed. In the case of rock falls, special attention is given to areas near poorly constructed roads, where vibrational forces from traffic and inadequate retaining wall support may succumb to the heavy weight of rock and earth.

Though the identified causal agents are not primary climate stressors, there is a direct connection between vegetative health and climatic conditions. Additional work considering how the vegetation may change in response to climate change may reveal possible future changes in this causal agent.

INETER produced a map that indicates areas of potential landslide hazards for the municipality of Estelí (see Figure 2.16). The landslide hazard is compartmentalized into three rankings: low threat, medium threat, and high threat. The description of the landslides that were considered for each threat is discussed below.

High threat is associated with the following extremely destructive landslides:

- Debris flows that are fast moving landslides of water and debris that can be triggered by heavy precipitation events. The landslides can be longer than 100 m with a width less than 20 meters.
- Landslides can occur in response to the lateral erosion of the river where the river has scoured the river walls causing mass movements.
- A translational landslide (i.e., mass movement along a fractured surface) that may be caused by material sliding down a sloped surface or the movement of displaced material overlying the original ground surface.
- Medium threat is associated with:
- A shallow translational landslide (i.e., mass movement along a fractured surface) that may be caused by material sliding down a sloped surface or the movement of displaced material overlying the original ground surface.
- A landslide that is a debris flow occurring where a fault scarp exists (i.e., where land has previously been displaced by movement along the fault line). These locations are covered in vegetation.

Low threat is associated with:

- Very slow moving landslides that involve the entire floor and may be recognized by the presence of ripples in the form of 'terraces.' These landslides tend to occur in areas that have been deforested for cultivation and grazing.
- A landslide that is a debris flow occurring where a fault scarp exists (i.e., where land has been displaced by movement along the fault line). These locations are covered in vegetation.

The blue circles in Figure 2.16 have been added to the map to illustrate landslide threat areas for Estelí. Low to medium threats are illustrated in yellow, high threats are illustrated in red (shading outside of the blue circle demonstrates flood threat). The city of Estelí is not shown to be at risk to landslides. There are areas to the south and southeast of the city that are at medium to high threat of landslides, along with a few additional pockets of locations to the west and north.

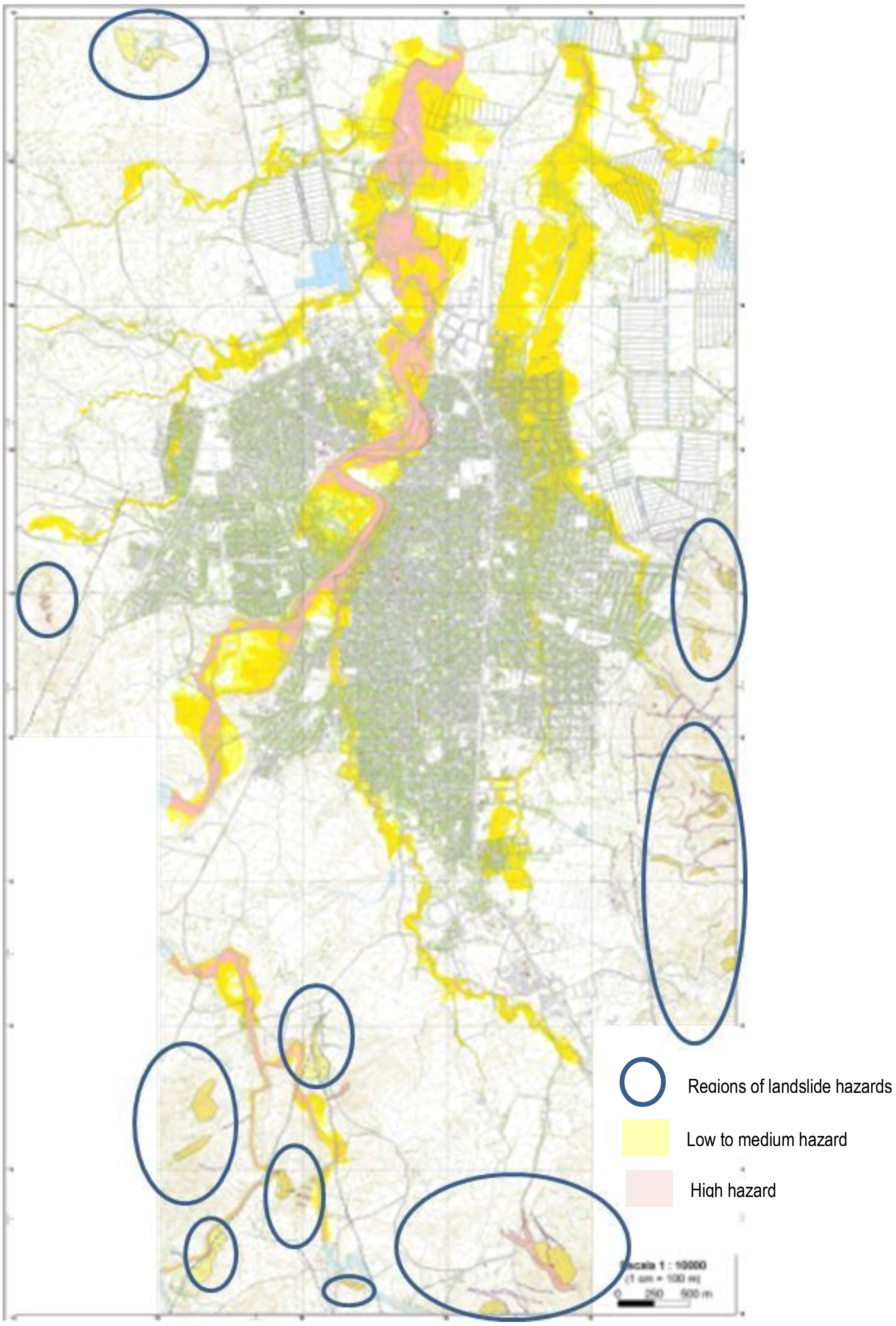

Figure 2.17 Landslide hazards identified by the Map of Natural Hazards 1:5000 Estelí. The blue circles indicate landslide hazards (yellow is low to medium hazard, red is high). Flood hazard is also shown in the figure. Source: INETER, 2002.

2.6 Future flood and landslide hazards

This analysis uses available information and data to identify areas within the study region that are vulnerable to flood and landslides. This analysis reviewed available climate change projections and considered their impact on these existing hazards. This analysis does not account for future changes in the landscape (e.g., deforestation or urbanization) that may shift and/or expand current areas threatened by landslides and floods.

Projections of how precipitation may change under a changing climate can help inform future vulnerability to flood and landslide events. Runoff is not treated in this analysis given the lack of stream gage sites in Estelí. Unfortunately, there are limited information on how precipitation is projected to change in the future and significant uncertainty associated with those projections. The findings presented should be carefully applied to the municipality planning within the context of the associated uncertainty.

2.6.1 A changing climate

According to the Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), Nicaragua is expected to encounter increased climatic variability as a result of increases in temperature and decreases in precipitation:

- Increases in temperature: For 2020 to 2050, average temperatures may increase between 1 and 2˚C and between 3 and 4˚C by the end of the Century, with the greatest increase projected for the Pacific coast. (World Bank, 2009)
- Decreases in precipitation: At the national level and from 2020 to 2050, annual precipitation is projected to reduce. The exceptions are along the Atlantic coastline where precipitation is projected to become more intense, and along the Pacific south region where precipitation is projected to slightly increase. (World Bank, 2009)
- Decrease in intense rainfall events: At the national level and by the 2060s, the proportion of total rainfall that falls during heavy events is projected to experience small decreases for each of the seasons. In addition, the totals rainfall associated with the maximum 5-day rainfall per year is also projected to experience small reductions (McSweeney et al., 2010).

These projections are consistent with the analysis presented here. By the 2040s, Estelí is projected to experience warming temperatures and a reduction in precipitation.

The remainder of this section discusses seasonal and monthly changes in temperature and precipitation, based on results from an ensemble of climate models for low and moderately-high emission scenarios (see Box 5 and more detail in Annex A.1). Seasonal changes were developed for Estelí in the 2040s. The 2040s was the preferred time period of the projections for planning purposes. However, the available projections for the 2040s is decadal (not the preferred thirty year average) and is only available at the seasonal scale (not at monthly). To supplement this data, additional 30-year average monthly projections available for the 2050s were also developed. The projections in the 2050s were included to provide an additional level of scrutiny for quantifying the associated uncertainty with precipitation projections in Estelí. The two time periods, however, are only one decade apart and show similar trends.

Box 5 Scenarios for this analysis

Scenario 1: The climate model ensemble average under the low (B1) emission scenario.

Scenario 2: The climate model ensemble average under the moderately-high (A2) emission scenario.

Seasonal change in the 2040s for temperature and precipitation. By the 2040s, the average increase in seasonal temperature is projected to be approximately 1.1^{o}C for Scenario 1 and 1.4^{o}C for Scenario 2 relative to a 1970 to 1999 baseline (see Figure 2.17, the shaded bars indicate the average projection simulated by all the climate models for a given Scenario). Seasonal precipitation is generally projected to decrease substantially during the summer months and minimally during the other times of year, although a small number of climate models project that the climate could become wetter (see Figure 2.18). It should be noted that the bar on Figures 2.17 and 2.18 indicates the range of the projections across all climate models, and may be misleading when considering uncertainty given the end points of the bar are based on single climate model projections (i.e., the bar does not demonstrate whether and where the majority of climate model projections cluster).

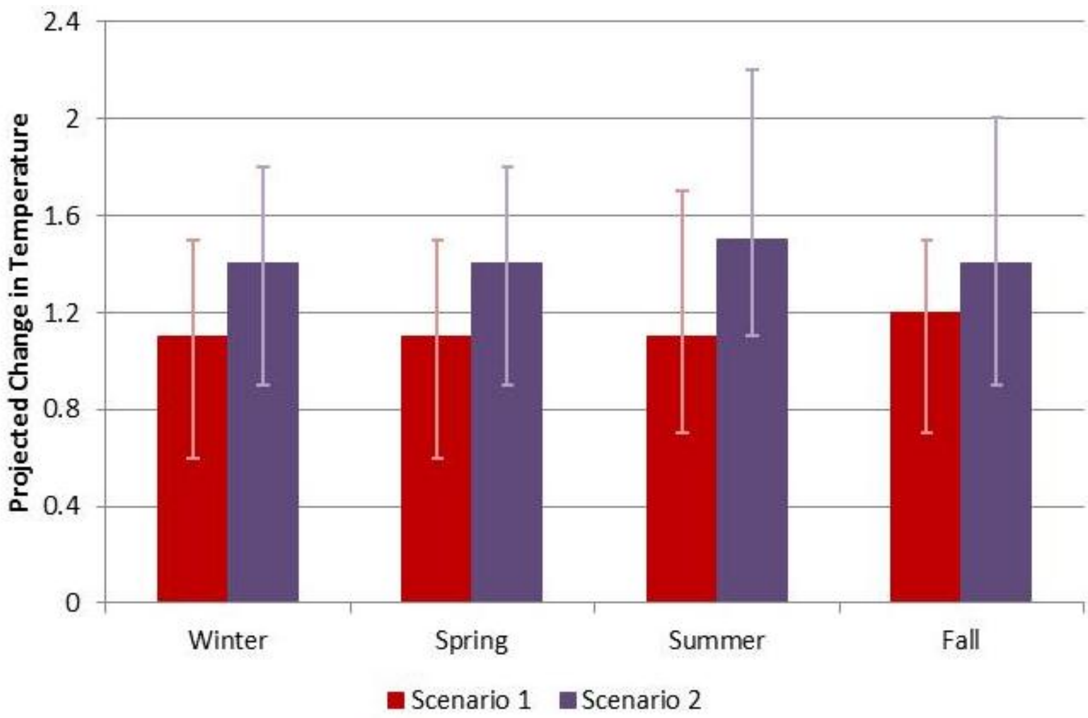

Figure 2.18 Projected change in temperature (°C) in the 2040s relative to 1970 to 1999 baseline. Source: Based on data collected from McSweeney et al., 2010.

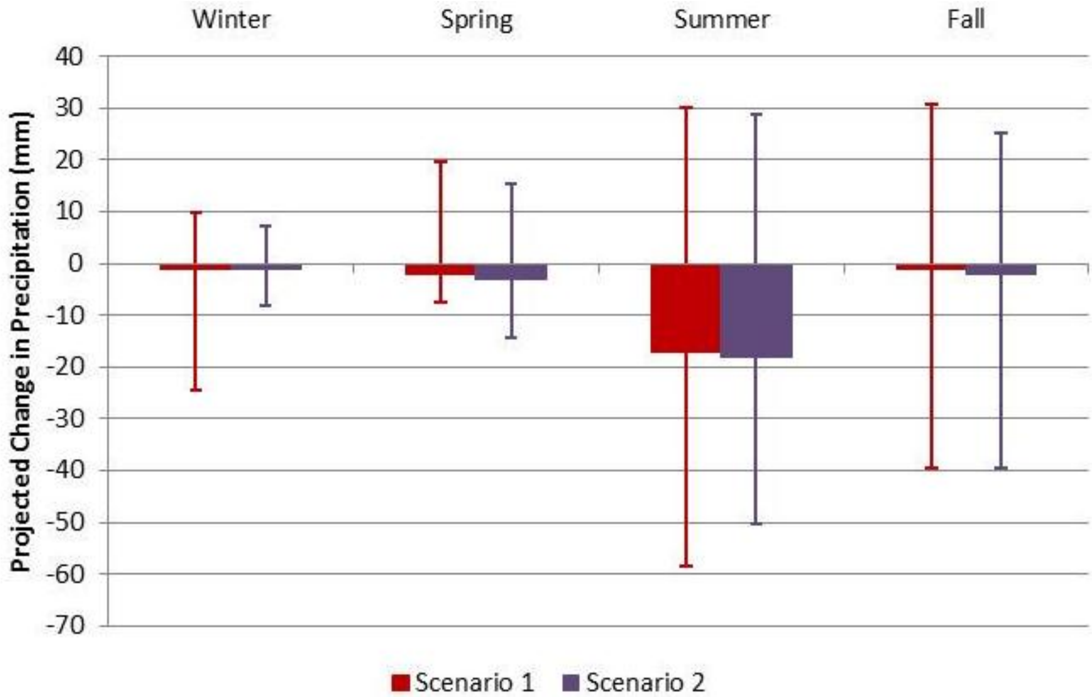

Figure 2.19 Projected change in precipitation (mm) in the 2040s relative to 1970 to 1999 baseline. Source: Based on data collected from McSweeney et al., 2010

Seasonal and monthly change in the 2050s for temperature and precipitation. By the 2050s, the wet season (i.e., May through October) is still projected to become drier and warmer. Relative to a 1961 to 1990 baseline, the seasonal temperature may increase by about 1.6°C to 2.1°C, while seasonal precipitation may reduce by 8 to 9 percent.[6] This would

[6] This suggests temperatures are projected to continue to warm from the 2040s to the 2050s. The comparison between the two decades is not completely consistent as the baseline conditions to which the changes are

lead to an increase in evaporation rates and a decrease in soil moisture. Table 2.3 provides the average across all climate models under a given scenario (labelled "mean", this represents the average of the climate model ensemble) as well as the minimum and maximum projection simulated by a given climate model. Though there is some disagreement amongst the climate models, there is "high" confidence that precipitation is projected to decrease. The difference in the magnitude of precipitation projected by the majority of climate models differs by only 2 to 3 percent for Scenario 1 and 2, respectively. This suggests that the climate model ensemble average is well representative of the potential future for each Scenario.

Table 2.3 Projected temperature and precipitation for the wet season in the Estelí region for the 2050s relative to a 1961 to 1990 baseline. Projected data is shown for the minimum and maximum results from climate models ("min", "max"), the upper and lower values of one standard deviation from the mean ("σ_low" and "σ_high"), and the climate model ensemble mean. Source: based on data collected from Givertz, 2009.

	Obs.	Scenario 1 (2050s)					Scenario 2 (2050s)				
		Min	σ_low	Mean	σ_high	Max	Min	σ_low	Mean	σ_high	Max
Seasonal Temperature (°C)	28.0	28.8	29.2	**29.6**	30.0	30.2	28.2	29.6	**30.1**	30.6	30.7
Seasonal Precipitation (mm)	802	530	722	**740**	757	940	551	713	**733**	753	984

At the monthly scale, the greatest reduction in mid-century monthly precipitation is projected for May and July at approximately 13 to 14 percent relative to 1961 to 1990 baseline under Scenario 1 and Scenario 2, respectively (see Figure 2.19). October is projected to experience a slight increase of 2 to 3 percent for Scenario 1 and 2, respectively.

computed is different (i.e., the 2040s are relative to 1970 to 1999 while the 2050s are relative to 1961 to 1990; hence, the 1961 to 1990 baseline is more apt to provide a greater increase in temperature than the 1970 to 1999 baseline). The difference in seasonal precipitation in the 2040s seems comparable to that provided for the 2050s. The scenarios are the same for the 2040s and 2050s, though there are slight differences in the climate model data used to support these time periods (e.g., the 2040s rely on 15 climate models while the 2050s rely on 16 climate models; and the 2050s projections are based on statistically downscaled data).

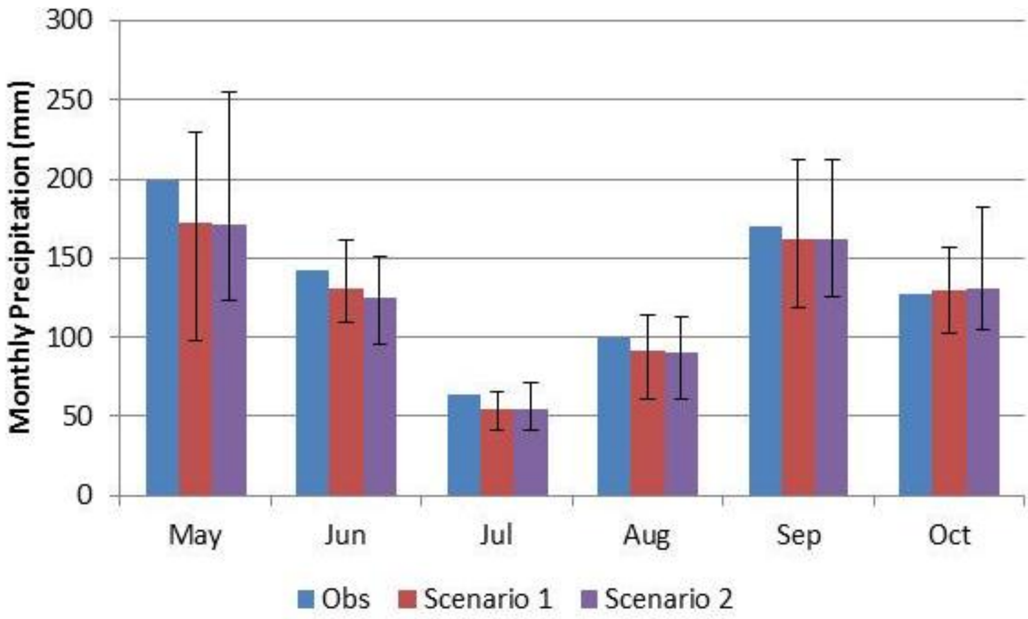

Figure 2.20 Projected change in mid-Century monthly precipitation compared to 1961 to 1990 baseline conditions for the wet season in the Estelí region. The error bars provide the range in projections across climate models. Source: based on data collected from Givertz, 2009.

By the 2050s, the dry season (i.e., November through April) is also projected to become warmer and drier (see Table 2.4). Temperature and precipitation are projected to experience smaller changes compared to the wet season. Temperatures are projected to rise between 1.4°C and 1.9°C under Scenario 1 and Scenario 2, respectively. Rainfall is projected to decrease by 5 to 8 percent under Scenario 1 and Scenario 2, respectively. There is "high" confidence in the direction of change for precipitation. Evident from the spread across the precipitation projections, the majority of climate models suggest a relatively small decrease in precipitation by the 2050s. This suggests that the climate model ensemble average is well representative of the potential future for each Scenario.

Table 2.4 Projected temperature and precipitation for the dry season in the Estelí region for the 2050s relative to1961 to 1990 conditions. Projected data is shown for the minimum and maximum results from climate models, the upper and lower values of one standard deviation from the mean ("σ_low" and "σ_high"), and the climate model ensemble mean. Source: based on data collected from Givertz, 2009.

	Obs	Scenario 1 (2050s)					Scenario 2 (2050s)				
		Min	σ_low	Mean	σ_high	Max	Min	σ_low	Mean	σ_high	Max
Seasonal Temperature (°C)	28.0	28.8	29.1	**29.4**	29.8	29.9	29.1	29.5	**29.9**	30.3	30.7
Seasonal Precipitation (mm)	80	56	73	**76**	79	138	52	72	**74**	77	103

Scenario 1 and Scenario 2 are in general agreement in the projected magnitude and direction of monthly precipitation (see Figure 2.20). However, there are large differences across model simulations for projected monthly changes in precipitation for November, March, and April. For November and March, a small subset of models projects a large increase in precipitation.

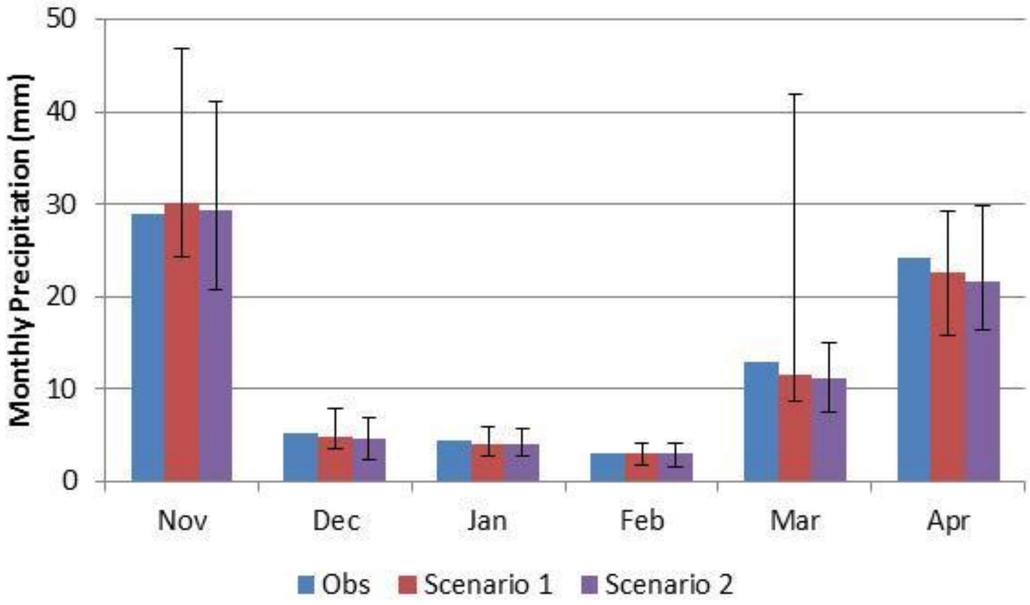

Figure 2.21 Projected change in monthly precipitation in the 2050s compared to a 1961 to 1990 baseline for the wet season in the Estelí region. The error bars provide the range in projections across climate models. Source: based on data collected from Givertz, 2009.

Summary. The projected precipitation and temperature changes associated with each of the two scenarios developed for this analysis are summarized in Table 2.5. While there is considerable uncertainty associated with the available climate projections, this first order approach indicates, that by mid-Century, precipitation may be reduced, potentially decreasing the possibility of floods and landslides..

Both Estelí's dry and wet season are projected to experience an increase in temperature and a relatively modest decrease in precipitation. The combination of these two factors suggests a potential reduction in soil moisture. All scenarios and seasons are projected to experience a reduction in the seasonal precipitation rate.

Table 2.5 Summary of the projected change in seasonal temperature and precipitation for the 2050s (Source: based on data collected from Givertz, 2009).

	Season	Temperature Projected in 2050s	Precipitation Projected in 2050s	Precipitation Rate
Scenario 1	Dry	1.4°C	-5%	-0.1 mm/day
	Wet	1.6°C	-8%	-0.9 mm/day
Scenario 2	Dry	1.9°C	-8%	-0.2 mm/day
	Wet	2.1°C	-9%	-1.2 mm/day

Figure 2.21 qualitatively illustrates today's dry and wet seasons and the associated changes projected for each of the scenarios. Both seasons are projected to become drier and warmer under both scenarios. The difference projected between the two scenarios is small particularly for the wet season; though, Scenario 2 is projected to be somewhat warmer and slightly drier than Scenario 1.

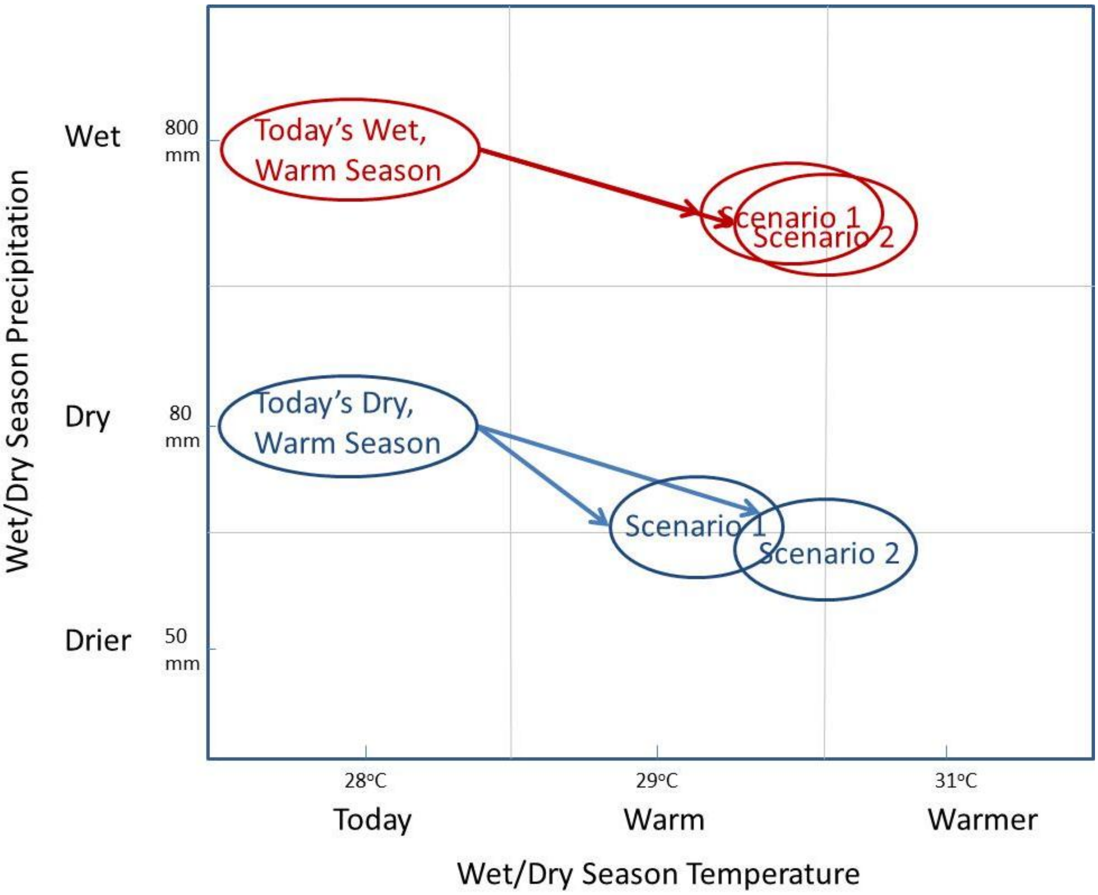

Figure 2.22 Illustrative diagram of the projected mid-Century change of today's dry, warm and wet, warm seasons (not to scale).

2.6.2 Changes in future floods and landslide events

Our assessment uses available information and data to identify areas within the study area that may be vulnerable to future floods and landslides. These first-order results suggest that the current locations prone to landslides and floods described in Figures 2.10, 2.11, 2.12, and 2.16 above may be at less risk. Further analysis of monthly precipitation thresholds associated with landslides and/or floods as well as an analysis at a finer than monthly scale (i.e., event based) would significantly assist in understanding how these hazards may change in the future. Based upon the available data, Table 2.6 provides a summary of the highest-risk locations and how flood and landslide hazards may qualitatively change in the future due to climate changes.

Table 2.6 Qualitative summary of change in areas currently prone to flood and landslide hazards in Estelí by mid-Century.

Hazard	Location	Projection	Projected change in hazard
Floods	Valley of Estelí, including the urban area and the area of Llanos de Colón-Campos Azules have been identified as large flood prone areas	The climate projections suggest that floods may be reduced as seasonal and monthly rainfall are projected to decrease.	
Landslides	No landslides observed in the city; potential vulnerable spot for landslides is Cerro de la Guanabana at the East of the	The climate projections suggest that landslides may be reduced as seasonal and monthly rainfall are projected	

Hazard	Location	Projection	Projected change in hazard
	city	to decrease.	

Additional factors, such as land use and flood management, and system dynamics are not incorporated into Table 2.6. An example of system dynamics could be the following: precipitation reduction may stress forests and reduce forest cover; in response, soils may become more prone to erosion increasing the threat of landslides.

The remainder of this section discusses how floods and landslides may change by mid-Century. The rankings described in Table 2.7 distinguish areas on the hazard maps where the projections suggest a reduction, increase, or no change in flood and landslides. This approach could be broadened and enhanced by engaging local stakeholders to consider how the climate projections presented in this analysis may impact the findings of these maps.

Table 2.7 A ranking system to distinguish areas on the map projected to experience change or no change in landslide and flood hazards.

Ranking	Description of Projected Change in Hazard
	The temperature and/or precipitation projections suggest that an overall reduction in the intensity and/or frequency of the hazard.
	The temperature and/or precipitation projections suggest that areas prone to the hazard will not change in the future.
	The temperature and/or precipitation projections suggest that an overall increase in intensity and/or frequency of the hazard.

Based upon future climate projections, the flood hazard is projected to decrease as indicated by the blue lines surrounding the flood hazard areas (see Figure 2.22). This determination is consistent for both Scenarios 1 and 2, which project reductions in both total precipitation for the dry and wet seasons. This analysis assumes land-use, drainage, and other factors that affect flooding do not change over time.

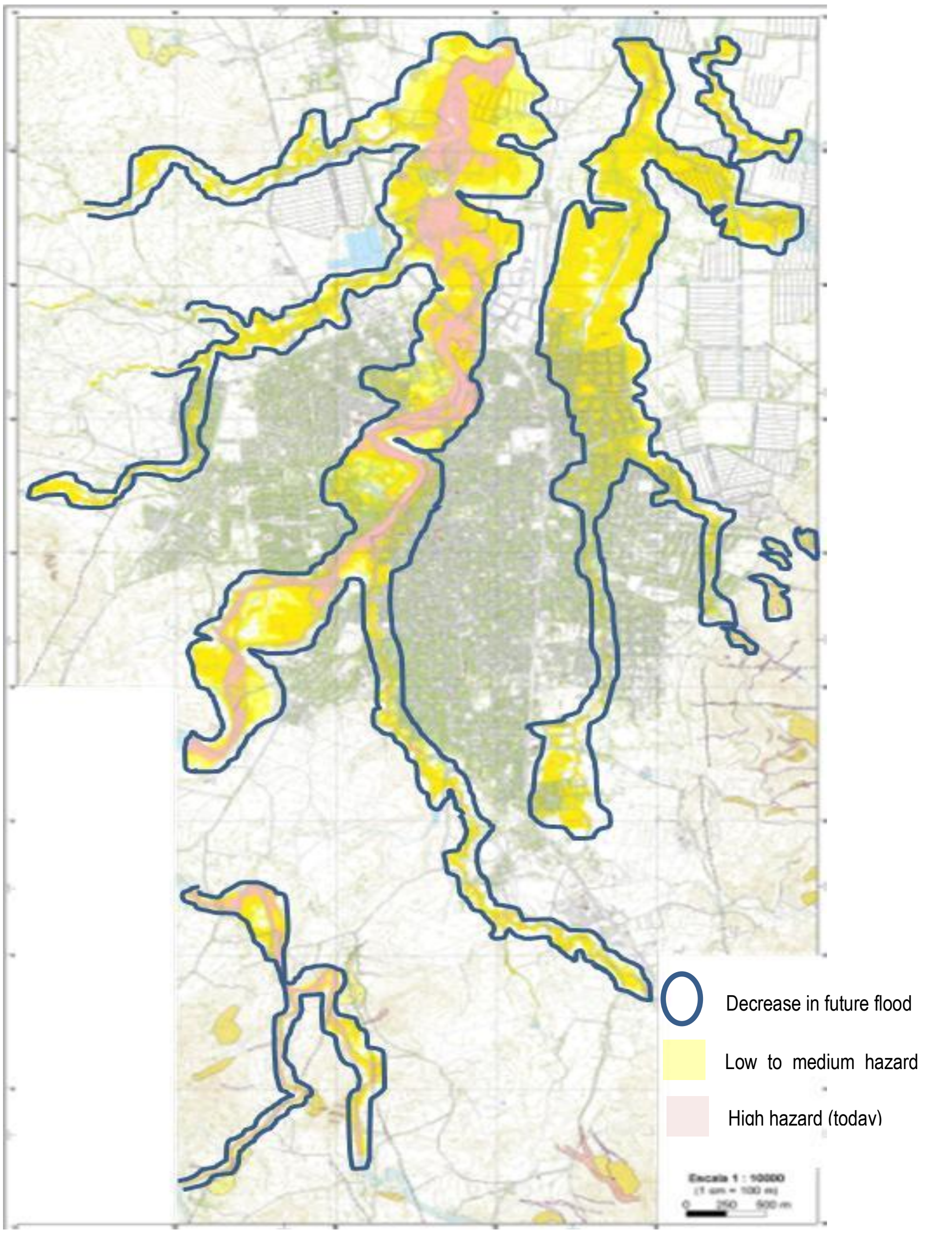

Figure 2.23 Projected change in flood hazard in mid-Century for both Scenario 1 and Scenario 2 where the blue line denotes the general areas that are prone to flood event (i.e., shaded in yellow or pink) and are projected to decrease. Source of hazard map: INETER, 2002.

Landslide hazard is also projected to decrease in response to reduced precipitation. Figure 2.23 illustrates - in blue - the areas considered susceptible to landslides are projected to decrease with time (the other yellow and red shaded areas on the map are relevant to the flood threat). This assumes the current vegetation adapts to future climate variability and that land-use does not change.

Considering future climate variability, the reduction of precipitation will not necessarily result in a reduction in landslide risk. The health of the forests and other vegetation cover in the area will play a key role in preserving the soils properties. Responses of forests or other natural vegetation types to climate change in the region are not investigated in this analysis, but if deforestation or landscape transformation continues in the area, reductions in precipitation and covered soils could exacerbate soil erosion, and lead to a higher overall incidence for landslides.

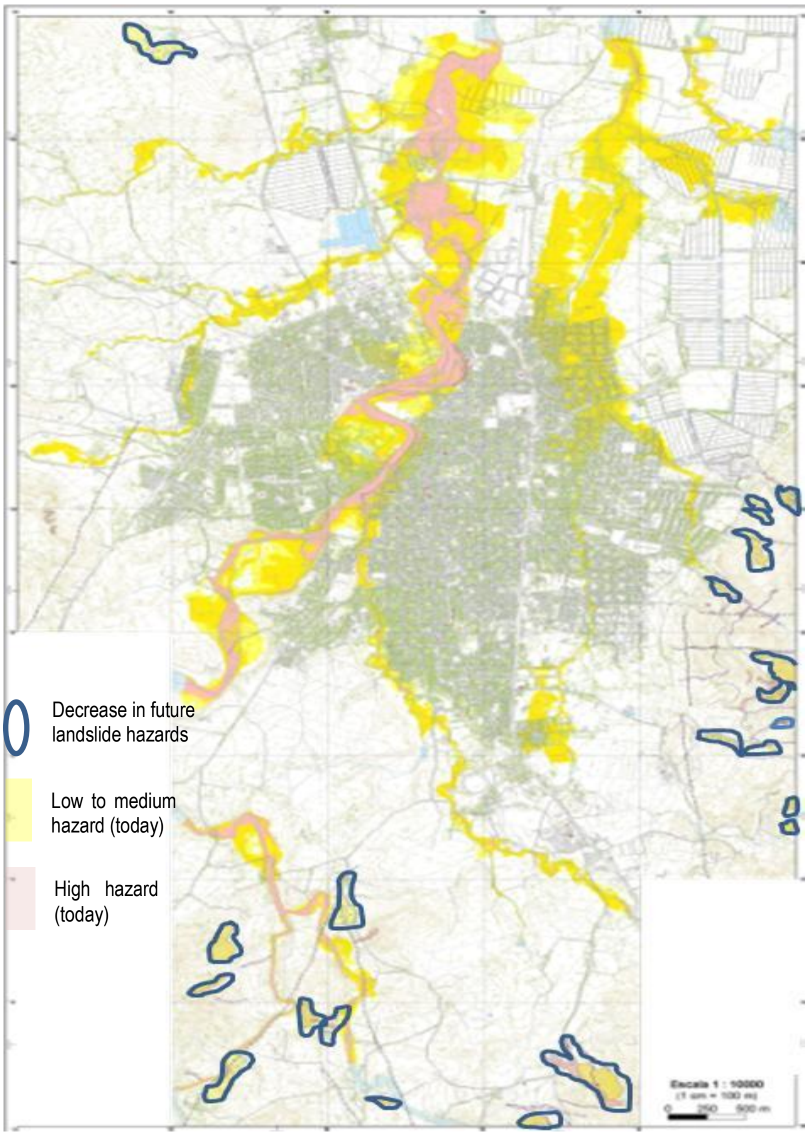

Figure 2.24 Projected change in landslide hazard in mid-Century for both Scenario 1 and Scenario 2 where the blue line denotes the general areas that are currently prone to landslide events and are projected to decrease. Source of hazard map: INETER, 2002

2.6.3 Gaps and limitations

This section provides an overview of the gaps and limitations for each of the two hazard analyses.

The flood hazard assessment is subject to the following data gaps and limitations:

- This analysis used daily precipitation data observed at a single station in the study area, this may mask variability within the study area. Additional daily precipitation data from observation stations with records of 10 year of data or longer would provide a more holistic understanding of risk to the study area. In addition, this analysis would benefit by using a long-term record that extends to 2012.
- More information of the return periods used in the hydrologic and hydraulic modelling of today's flood maps would be beneficial. Running the modelling used to develop today's flood maps with future scenarios could produce a detailed set of future scenario maps that incorporate projected changes in precipitation.
- Future precipitation projections are associated with a high level of uncertainty; models often differ widely in both the magnitude and direction of changes in precipitation. This

affects the application of the findings of future change in landslide and flood hazards presented in this report.

- Additional effort in the development and testing of climate projections specifically developed for the Estelí region is recommended to further enhance our understanding of how total precipitation and precipitation events may change in the future.
- This analysis would benefit from records of flooding events that have already occurred in the area, describing both the meteorological conditions that caused the flooding along with the associated damage.

This landslide hazard assessment is subject to the following data gaps and limitations:

- These projections have focused on changes in annual and monthly precipitation and the impact that these changes could have on landslide hazard in Estelí. Extreme precipitation events will also affect landslide risk, but there is a high level of uncertainty in how this relationship may be influenced by the projected decrease in monthly precipitation. Further examination of specific historical events and landslide hazards may help increase understanding in how individual extreme events contribute to landslide hazard.
- Other factors, such as forest cover loss, urban land use development, and soil erosion will also affect landslide hazard risk. These factors have not been explicitly considered in the hazard analysis.

3 Urban, social and economic adaptive capacity assessment

3.1 Urban, social and economic context

Estelí was founded by the Spanish in the 17th Century. As many other colonial cities in Latin America, Estelí is located in a valley, and its urban layout consists of square blocks, squares and gardens (SINAPRED, 2011). The urban layout is structured according to the grid pattern. The Department of Estelí was established in 1829. However, it was not until 1891 that the *villa* of Estelí was granted city status. In the last decades of the 20th Century, Estelí, as with the rest of Nicaragua, was marked by the civil war, which had a significant economic and social impact to the city (Perez, 2010).

In 2004, the city of Estelí had a population of 93,484 inhabitants (Estelí Municipality, 2006; INEC, 2004). According to our interviews, current socio-economic data may under-estimate the actual characteristics of the city and absolute population is in fact higher, as will be discussed below. Having experienced fast demographic growth in recent decades, Estelí is nowadays an important urban centre in north-western Nicaragua. As a regional centre, it provides economic, social and administrative services to its surrounding hinterland. Urban-rural linkages are of significance.

As the major population and economic centre in northern Nicaragua, Estelí has also gained a specific place in the national urban structure of Nicaragua. In 2002, the establishment of a National Settlement Network was accompanied by the necessity of creating an Urban Centers Development Strategy (Municipality of Estelí, 2004). The strategy seeks to equip each urban center with the necessary physical and social infrastructure to cope with potential natural hazards, water shortages and urban expansion needs. The purpose of the strategy is to assign to each urban center a specific place within the National Settlement Network and equip it with the appropriate infrastructure for its defined functions. As such, Estelí was established as a Large City with departmental and regional functions, and its physical infrastructure is meant to adapt accordingly over time.

The Municipality of Estelí is divided into two administrative areas: urban and rural. These two areas are in turn divided into smaller units. The administrative structure of urban Estelí is characterized by the presence of districts and within these, neighbourhoods. As seen in Figure 3.1 in the next page, the administrative organization of urban Estelí is made up by 3 districts. A total of 59 neighbourhoods are located within these districts (Table 3.1).

Table 3.1 Districts and neighbourhoods in Estelí

District I (23 neighbourhoods)			
Boris Vega	Alfredo Lazo	Justo Flores	William Fonseca
Juan Alberto Blandón	Héroes y Mártires	El Calvario	El Paraíso
Juno Rodríguez	Filemón Rivera	Miguel Alonso	Omar Torrijos
Oscar Benavides	Linda Vista	Igor Ubeda	Rene Barrantes
Virginia Quintero	Milenia Hernández	Hermanos Cárcamo	Elías Moncada
Orlando Ochoa	Paula Ubeda	Jaime Ubeda	
District II (15 neighbourhoods)			
Camilo Segundo	Juana Elena Mendoza	Boanerges López	José Santos Zelaya
Aristeo Benavides	Centenario	Primero de Mayo	Los Ángeles
Oscar Turcios	Michiguiste	José Benito Escobar	Sandino
Villa Esperanza	Santo Domingo	Ronaldo Aráuz	
District III (23 neighbourhoods)			
16 de Julio	Arlen Siu	Carlos Núñez	Dios Proveerá

District I (23 neighbourhoods)			
Aldeas Meaux	Estelí Heroico	Noel Gámez	Belén
Oscar Arnulfo R.	El Rosario	El Jazmín	Ma. Elena Cuadra
14 de Abril	La Comuna	Panamá Soberana	La Unión
Oscar Gámez Nº 2	29 de Octubre	Nuevo Amanecer (La Porra)	Leonel Rugama
Oscar Gámez Nº 1			

Source: Municipality of Estelí, 2004.

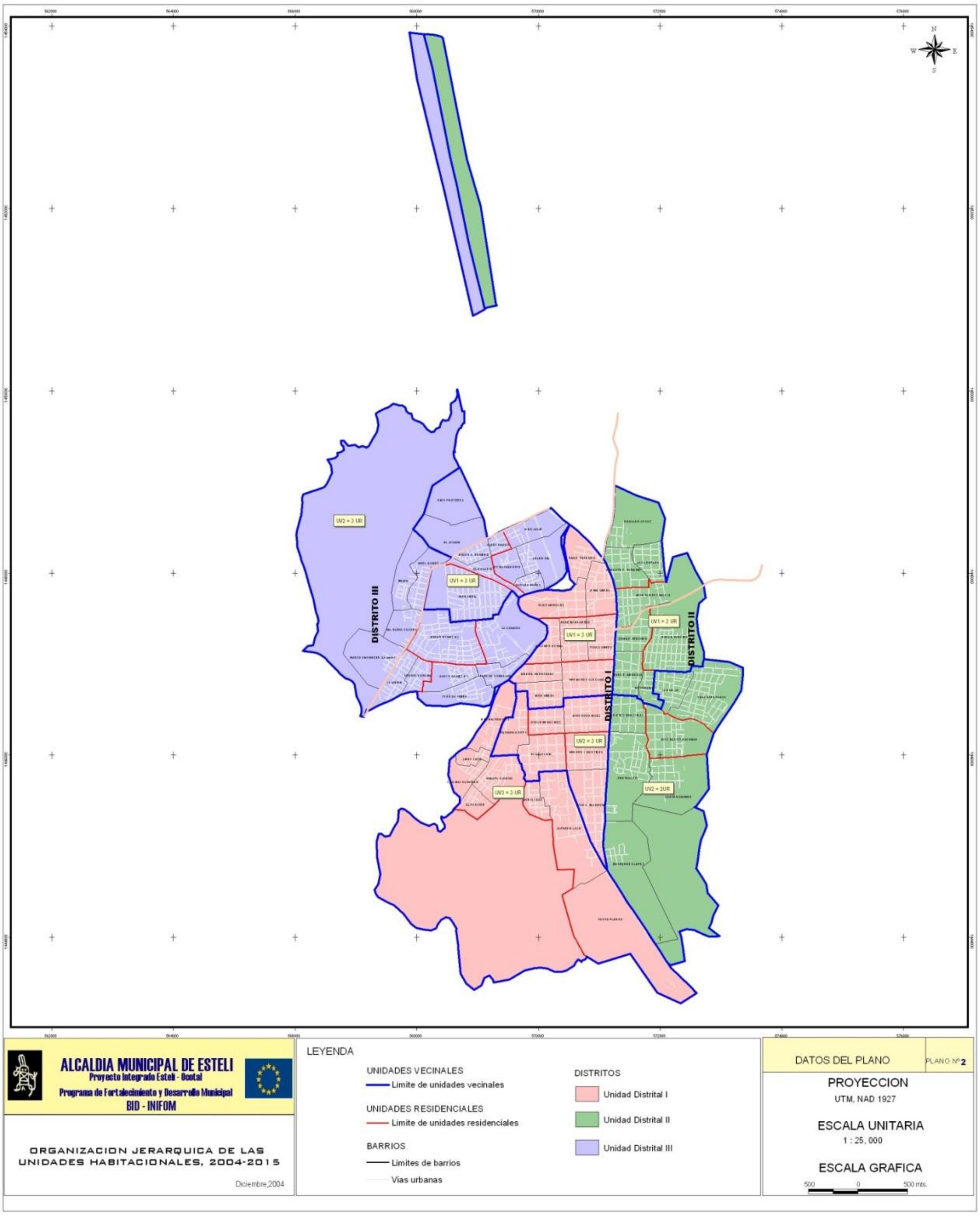

Figure 3.1 The three urban districts of Estelí. Source: Municipality of Estelí, 2004.

3.2 Methodology

For the assessment, qualitative information supported by the quantifiable data which was collected during consultations and from publicly available reports and other material are both used to discuss a number of issues. These include economic and residential land uses, their interplay, and the connectivity provided by infrastructures as well as the distribution and quality of critical infrastructure networks, including those that extend beyond the urban administrative boundaries, and with special focus on water and road infrastructure. This is set within the trajectory of urban expansion and growth as it is currently taking place in Estelí.

Limitations

There is one key limitation associated with the type and format of the information available. Maps showing various socio-economic characteristics and location of critical infrastructure are not available to us. As a result, our methodology had to be adjusted in order to best utilize the existing information and thus a more descriptive and qualitative analysis is employed.

Specific limitations include:

- **Demographic and economic characteristics.** According to our interviews, current economic and demographic data may under-estimate the actual characteristics of the city.
- **Distribution and quality of critical infrastructure.** We present findings for the water and road infrastructure sectors. These sectors were selected because they rely on resources that fall or are inter-connected with systems outside the study area. Further investigation could examine other critical infrastructures located within the study area, such as telecommunications, energy, hospitals, schools, and police and fire stations.

3.3 Economic characteristics

Nicaragua is a predominantly agricultural and forest country with 44% of the employed population working in this sector. Estelí does not deviate from the general national economic activity (UNDP, 2010). Agriculture and farming are the basis of the area's economic structure. Agricultural activity is diversified: it is composed by the crop of beans and corn, the cultivation of milk, the production of non-traditional crops such as chamomile and linseed, and the cultivation of tobacco. Cattle's farming is also a visible economic activity in the area.

In the industrial sector, the tobacco industry has been the main driver of economic growth. The tobacco industry has actually shaped much of Estelí's recent history. The industry took off in the 1960s, following the Cuban experience. The *Joya de Nicaragua* (Jewel of Nicaragua!) is the very first cigar made in Estelí (Perez, 2010).


Figure 3.2 A worker at a tobacco plantation in the province of Estelí and a woman working in a tobacco factory in Estelí, Source: REUTERS/Oswaldo Rivas.

The US embargo on Nicaraguan products in 1984 severely affected the tobacco industry and the Estelí region. Following the end of the civil war in 1990, the tobacco industry regained its place in Estelí's economic structure. There has been significant investment in new plants in the last decade, facilitated by free trade zone incentives. The city benefits from the presence of 33 tobacco factories that mainly manufacture cigars for exportation (10 of which belong to foreign companies). The tobacco industry generates most of the employment in the city nowadays, notably for women (SINAPRED, 2011; European Union et al, 2010). In addition to tobacco, leather and wood are also important industries in Estelí.

Since the 1990s, Estelí has experienced rapid economic growth. The city of Estelí has become the main economic centre of trade of the Department of Estelí. In addition to exports, the city also supplies material goods for the whole department and to the Departments of Matagalpa, Jinotega, Leon and Chinandega. In this sense, the economy of the city revolves around the tertiary sector, namely trade and services (SINAPRED, 2011). Commerce is the main activity in the services sector. Regional markets are particularly important as they are spaces where local agricultural and industrial products are exchanged and sold. It is Estelí's commercial dynamism that has transformed the city into the major economic centre of the Department. In fact, commerce in Estelí provides for 95% of all the good and services of the Department (UNDP, 2010). The city is also a centre for tertiary education, with several universities present, both public and private.

Micro, Small and Medium Enterprises (MSMEs) are of particular relevance for the city (SINAPRED, 2011). MSMEs, such as grocery stores, bakeries, restaurants, bars, clothing shops, pharmacies, real estate agencies, carpentry shops, jewellery, and hotels, account for 65% of the registered establishments in the municipal tax office (Cruz Roja Nicaragüense, 2010). Furthermore, according to the Ministry of Labour, Business and Manufacturing, Trade and Services, the services sector generates employment to a total of 32,486 people (SINAPRED, 2011; European Union et al, 2010).

MSMEs are often located at households, and if a disaster occurs, both the households and businesses can be potentially impacted, thus increasing people's vulnerability to climate-related hazard risks. What is more, according to the Local Economic Development Agency (APROE), it is estimated that approximately 50 per cent of all businesses are informal and are thus particularly sensitive to disaster risk.

According to the Chamber of Commerce there are no businesses (this refers primarily to comparatively larger enterprises and not to household-level businesses) in the urban area that can be potentially directly affected by disasters. In the past, businesses existed along the river but they have now relocated to non-risk areas, taking into consideration problems that may also arise in the distribution of production. On the other hand, plantations in the rural areas are exposed to climate-related hazards, such as floods. The tobacco industry is the main driver of economic growth in Estelí as seen above, and any impact to plantations will likely impact upon city's economy as well. New cigar plants appear to be located away from flood risk areas, but this requires further investigation. The zoning map which identifies areas of economic activity (see Figure 3.3), if combined with a climate-related hazard map, can highlight potential hotspots of vulnerability. The local economy, as seen within the regional context, is thus sensitive to climate change impacts. Yet, there no any detailed studies available on the economic impacts of disasters or climate change.

Estelí has grown in both spatial and economic terms over the past decades. In this sense, there is a clear need to better understand the way the city has expanded (including towards the rural areas) and how this may have (or not) affected urban disaster risk. These issues are now discussed.

3.4 Urban development, spatial expansion and demographic change

3.4.1 A growing city

The Municipality of Estelí concentrates about 54% of the total population of 213,915 inhabitants of the Department of Estelí. According to the 2004 Census report, the population of the Municipality of Estelí is 115,900, of which 93,484 people or 80.6% are concentrated in the urban area reflecting a high percentage of urbanization, influenced largely by in-migration (UNDP, 2010; Municipality of Estelí, 2008).

From the 1950s, Estelí went through a period of very fast demographic growth which led to urban expansion. Following the 1973 earthquake in Managua, thousands of people were displaced, and many of them settled in Estelí (Municipality of Estelí, 2008). In addition, high economic growth has attracted population from the surrounding areas in the north of Nicaragua. As seen in Table 3.2 below, over the period 1950 to 2005, the city of Estelí experienced an almost seventeen-fold population increase. The average annual growth rate has been declining, reflecting maturity of the urbanization process in Estelí (Table 3.2).

Table 3.2 Urban demographic growth

Year	Urban population	Urban population as a percentage of the total population the municipality (%)	Aggregated growth rate (%)	Average annual growth rate (%)
1950	5,557	36.7%	*Base year*	*Base year*
1963	12,742	46.6%		6.6%
1971	19,801	56.8%		3.7%
1980	30,474	N/A%		4.0%
1995	71,861	77.3%		5.9%
2000	82,360	78.6%		2.8%
2004	93,484	80.6%	1,682%	3.2%

Source:Municpality of Estelí n.d.

Given that urban development in Estelí covers an overall area of 32 square kilometres, the density of urban Estelí in 2004 was 2,921 inhabitants per square kilometre (SINAPRED, 2010). District 3 is the most densely populated district, with an average of 10,323 inhabitants per square kilometre.

Through time, Estelí has followed different patterns of urban expansion (Municipality of Estelí, 2006). In the period 1950-1971, the natural limits that constitute the boundaries of the city, such as the Estelí River and the Los Cedros and El Zapote ravines, oriented urban growth in a north-south pattern. The expansion pattern shifted in the period 1971-1980, as the city grew east to west. During that time, urban areas started to reach the natural limits. The city *absorbed* the Pan-American Highway to the east, and expanded beyond the Estelí River to the west.

In the following period, from 1980 to 1995, Estelí went through a period of accelerated urban growth. The city elaborated an Urban Planning Scheme in 1984, which oriented physical growth towards the north-west (Municipality of Estelí, 2004). Despite this instrument, the city kept growing to the east and west, and expanded beyond the Los Cedros ravine to the east and the El Zapote ravine to the south-west.

Since 1984, the city had an Urban Planning Scheme that oriented physical growth to the northwest. In the period 1995-2004, the city's expansion was partially guided by the 1995 Urban Planning Scheme, and reserve and protection areas were established. The 2005-2015 Urban Development Plan makes the attempt to orient urban growth in Estelí following an integrated approach by designating growth areas according to their accessibility, presence of basic infrastructure, transport networks, as well as their natural characteristics. The plan attempts to follow the guidelines established in the 1995 scheme and strengthen the position of the north and south corridors as services and commerce centres. It identifies north-west and the south-west as areas for residential expansion.

Figure 3.3 in the next page shows the current zoning and land use plan for the city (2005-2015 Urban Development Plan). The areas identified for future urban expansion are shaded in orange.

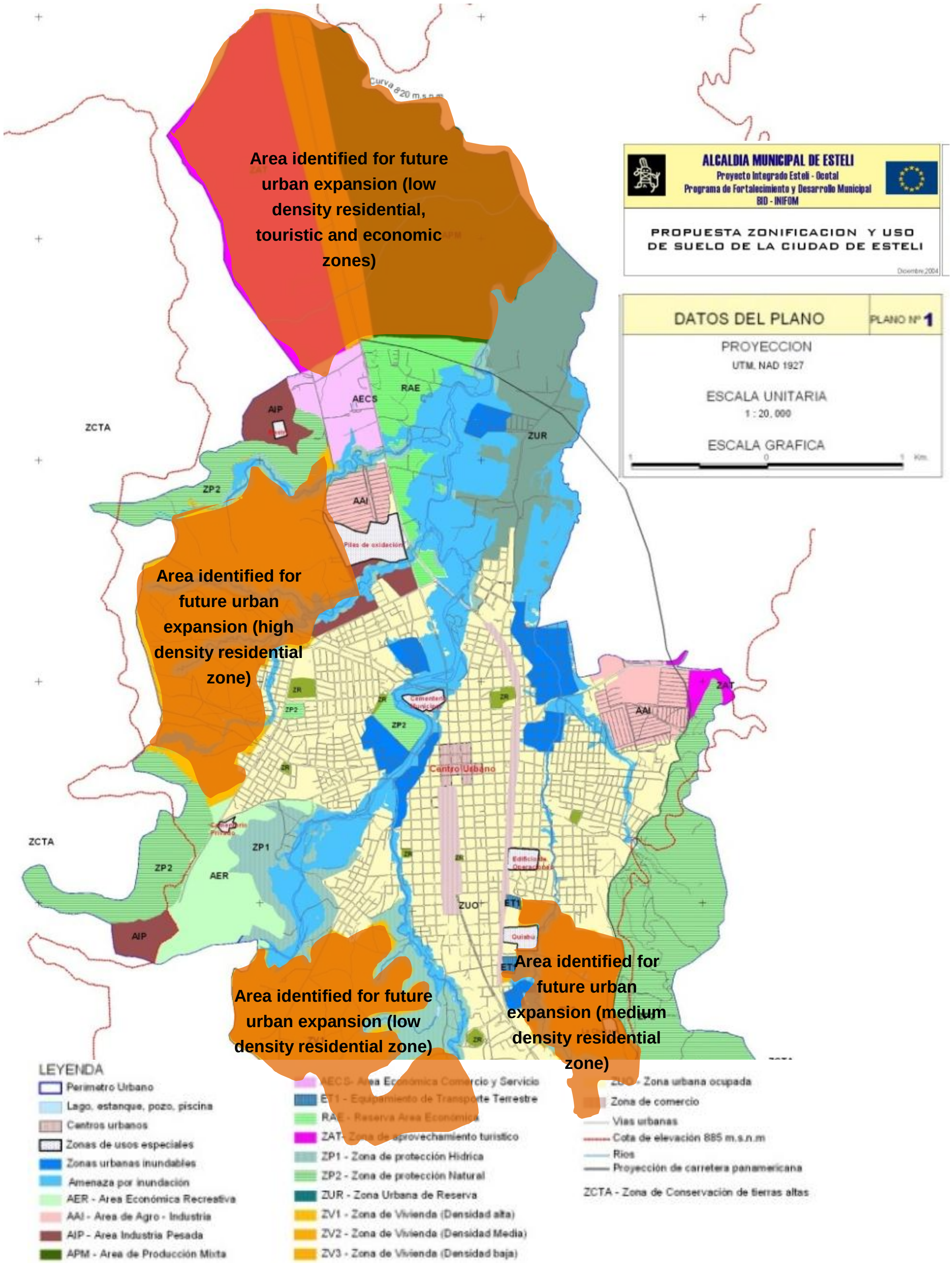

Figure 3.3 Zoning and land use plan for the city of Estelí, Source: adapted from Municipality of Estelí, 2004.

Long-term urban projections predict a consolidation of the north and south corridors, following commerce and services functions. The southwest and northwest corridors are expected to accommodate residential expansion (City of Estelí, 2006). As seen in Table 3.3, the city is thus still expected to grow in the coming years, although at much lower rates than in the past. Assuming that the observed population growth rate in 2000-2005 of 3.2% was maintained until 2010 and then decreased to 2% as a result of natural population growth and of continuing in-migration, one would expect the population of the city of Estelí to reach approximately 137,000 inhabitants in 2020.

Table 3.3 Projected population growth in urban Estelí

Year	Population	Growth rate (%)	Aggregated growth rate (%)
2004	93,484	*Not applicable*	*Base year*
2010	112,934	3.2	
2015	124,688	2	
2020	137,665	2	47.2%

Source: The Authors. The scenario corresponds to the official projected population growth rate of the Municipality for both urban and rural areas. This assumes that the urban population as a percentage of the total population of the municipality will remain the same (around 80%).

With this growth scenario, the main challenge that the Municipality of Estelí will face is responding to the growing demands in basic services and urban infrastructure of the additional population, so that social and economic development of the municipality continues to improve (UNDP, 2010).

The primary reason for expansion in urban Estelí has been a continuous flow of in-migration. It is not only rural-urban migration (although is probably the most important factor) but also migration from other cities and towns of the Department of Estelí and the northern parts of Nicaragua that is contributing to the urban expansion of the city. Populations from other impoverished regions in rural Nicaragua or less developed cities have moved to Estelí attracted by its economic dynamism and prospects (City of Estelí, 2006).

According to our interviews, migration is perceived both as a positive and a negative trend; positive because helps the city to grow, but at the same time negative, because very often people settle in areas not designated for such use, for example, forestry, agricultural and hazard risk areas. This is directly linked to land use policy and land use incompatibility, and is further discussed below.

3.4.2 Land use incompatibility

In effect, urban growth in Estelí has been characterized by incompatibility in land use (CARE et al, 2007). The Municipality of Estelí has made strong efforts in assessing land use in the city: 65% is destined for residential use, 12% for infrastructure, 7.3% for commercial use and 6.2% is identified for expansion (Municipality of Estelí, n.d.). Despite the existence of urban development schemes and land use assessments, urban growth in Estelí has been marked by informal settlement patterns. As urban expansion has mainly resulted from rural-urban migration, newcomers usually settle through spontaneous land invasions, which create land conflicts as well as unstructured urban growth. Many of the new settlements that appeared in the 1990s and 2000s, when Estelí went through a period of accelerated growth, were located in areas not destined for urban expansion as per the 1995 Urban Planning Scheme (Municipality of Estelí, 2008).

Land is usually cheaper in high-risk areas, near to, or along the Estelí and El Zapote Rivers, and is often the preferred choice of marginalized groups. Because of a combination of political and socio-economic factors, informal settlements are often later formalized, although not those located in high risk-prone areas. The new settlements suffer from high environmental problems, notably lack of access to rain sewage, which results in floods. Further, located in areas marked by topographic alterations, such as the Estelí River, or the

El Zapote and the Los Cedros ravines, the new peripheral settlements do not follow the regular urban square grid pattern that is present in the eldest neighbourhoods of the city. Unstable topography makes public service investment more difficult and more expensive in these settlements. As a result, these communities are not equipped with basic infrastructure, such as paved roads and/or sewage.

3.4.3 Neighbourhoods exposed to flooding and landslides

The Municipality of Estelí, supported by the EU-funded Central America Regional Reconstruction Program (PRRAC) and INETER, has developed a Natural Disasters Map for the city of Estelí. Specific neighbourhood plans were also developed, as well as a Municipal Climate Change Adaptation Plan. The Natural Disasters Map, the 2005-2015 Urban Development Plan and the Climate Change Adaptation Plan identify risk areas. The adaptation plan clearly states that in Estelí, floods are largely the result of Estelí River overflows produced by heavy rains.

According to the Estelí Natural Disasters Map, flood exposure is high for neighbourhoods following the Estelí River and the El Zapote ravine, notably in the south-east sector of the Panamá Soberana (District III) neighbourhood and the north-west of the William Fonseca neighbourhood (District I).[7] The south sector of the Carlos Núñez neighbourhood (District III) also presents high exposure to landslide risks. As mentioned previously, after the 1980, the city expanded around the Los Cedros and El Zapote ravines, as well as in areas in proximity to the Estelí River. The neighbourhoods in proximity to these areas present medium to low exposure to flooding. Given its location, the city centre of Estelí is not exposed to any flood and/or landslide hazard risks.

Tables 3.4, 3.5, and 3.6 list the urban districts exposed to flooding as well as their respective population. It is estimated that 9,508 people are exposed to flooding in Estelí. It is important to point out that District II concentrates most of the exposed population, with 5,634 exposed people. Districts I and II concentrate a relatively lower number of exposed populations, with 2,092 and 1,782 exposed people respectively (European Union et al, 2010).

Table 3.4 District I: neighbourhoods exposed to flooding

Neighbourhood	Exposed Population
William Fonseca	115
El Calvario	178
Orlando Ochoa	170
Elías Moncada	197
Milenia Hernández	174
Alfredo Lazo	140
Filemón Rivera	344
Igor Úbeda	524
Miguel Alonso	100
Boris Vega	90
Total	2,092

Source: SINAPRED 2011 & Municipality of Estelí n.d.

[7] Level of exposure is defined as: high: flow intensity above 2 meters; medium: flow intensity between 0.5 and 2 meters; and, low: flow intensity below 0.5 meters.

Table 3.5 District II: neighbourhoods exposed to flooding

Neighbourhood	Exposed Population
José Benito Escobar	860
Michiguiste	80
Aristeo Benavides	600
Camilo Segundo	680
Oscar Turcios	860
Ronaldo Aráuz	160
Augusto Cesar Sandino	605
Los Ángeles	899
José Santos Zelaya	413
Juana Elena Mendoza	459
Centenario	18
Total	5,634

Source: SINAPRED 2011 & City of Estelí n.d.

Table 3.6 District III: neighbourhoods exposed to flooding

Neighbourhood	Exposed Population
Estelí Heróico	650
El Rosario	300
Carlos Núñez	73
Michiguiste	80
29 de Octubre	96
Panamá Soberana	179
La Comuna	124
Arlen Siu	280
Total	1,782

Source: SINAPRED 2011 & Municipality of Estelí n.d.

As mentioned above, the Municipality of Estelí has taken measures to formalize informal settlements in the past. For settlements located in risk areas, a resettlement process is underway with funding by the Central Government and the Municipality. The scheme which was initiated after significant 2010 and 2011 flood events is relocating people living in critical areas along the river (see orange circle in Figure 3.4), to the northwest of the city, within areas identified for future urban expansion.

Resettlements mainly targeted the neighbourhoods of Panamá Soberana, Sandino, 29 de Octubre, William Fonseca and Filemón Ribera (SINAPRED, 2011). Although those settlements that are targeted by the above-mentioned scheme are the most critical, there are more settlements in other locations that are also exposed to flood risk, as seen from the Tables above. For example, those along the river at the east of the city (see red circles in Figures 3.4 and 3.5). For these communities the non-existence of drainage infrastructure is a particularly important problem.

According to the Municipal Climate Change Adaptation Plan, given the city's flat topography, few areas are exposed to landslides. These are the neighbourhoods of Filemón Rivera and Virgina Quintero, both within District I (Table 3.7) (SINAPRED (2011).

Table 3.7 Exposed neighbourhoods to landslides

Neighbourhood	District	Population
Filemón Rivera	I	1,107
Virgina Quintero	I	169
Total		1,276

Source: SINAPRED, 2011 & Municipality of Estelí, n.d.

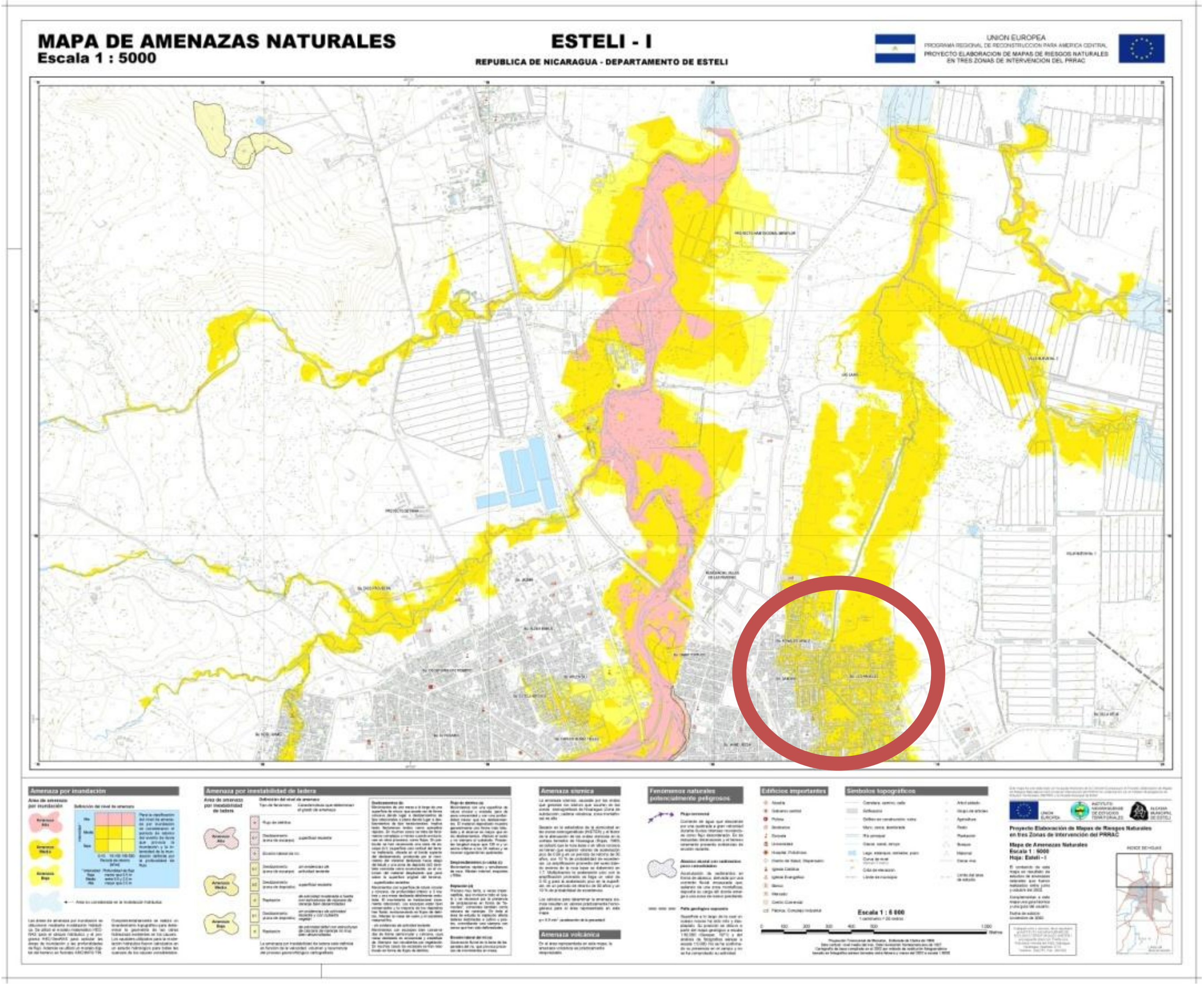

Figure 3.4 Natural hazards map for Estelí (I), Source: INETER 2002.

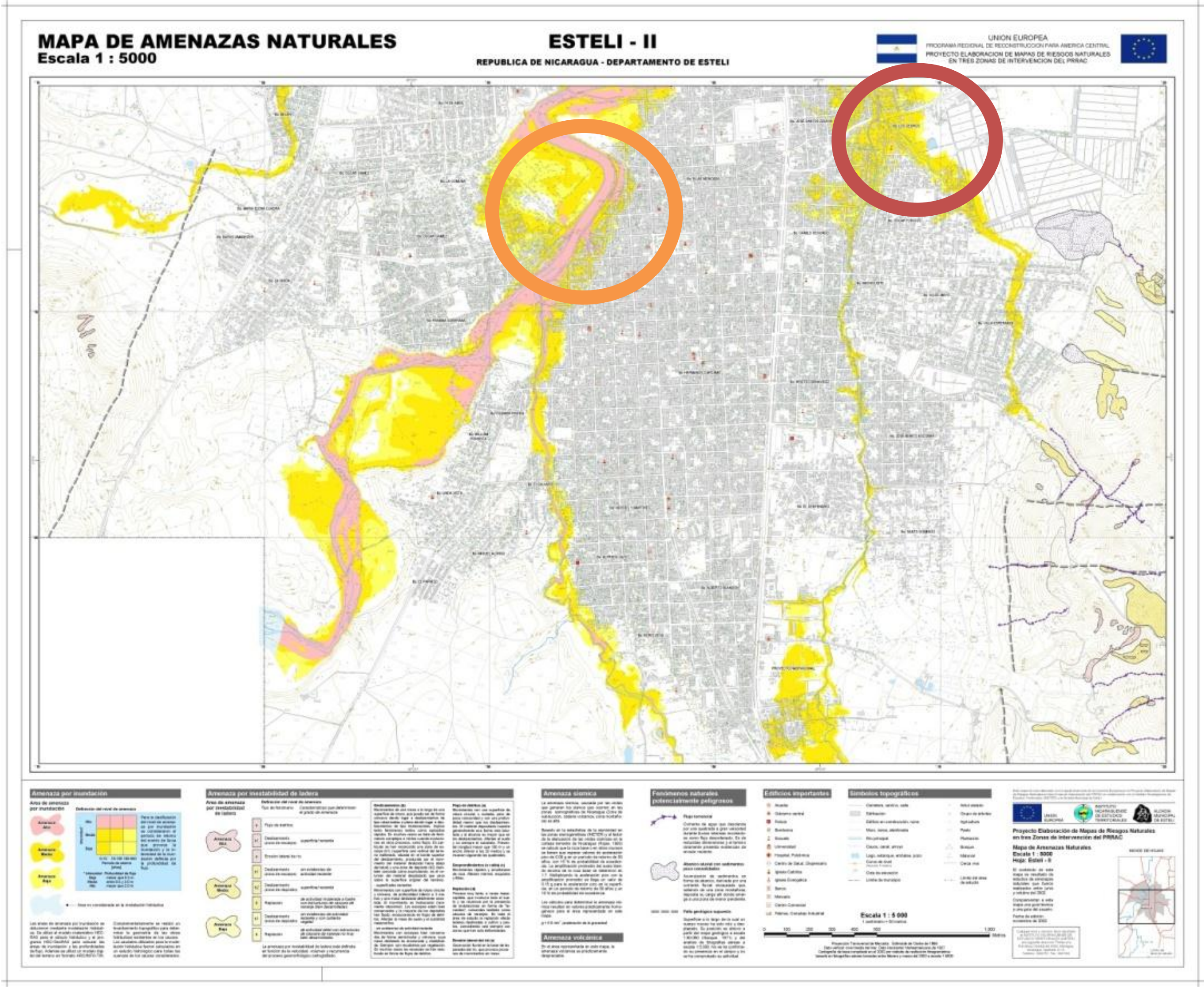

Figure 3.5 Natural hazards map for Estelí (II), Source: INETER, 2002.

3.4.4 Urban poverty

Estelí's urban morphology is characterized by poverty. According to UNDP (2010), 33.6% of urban Estelí lives in poverty.[8] It is important to note that poverty is much higher in rural areas, where 66.4 per cent of the population is considered poor. The Estelí Municipality (2008) also acknowledges that many neighbourhoods are characterized by inadequate urban infrastructure.

Within urban Estelí, poverty is unequally distributed. Table 3.8 shows that District I, which corresponds to the centre of Estelí, has considerably lower poverty rate, comparing to Districts II and III. As a general pattern, better off groups of population are located in the city centre (with the exception of an upper middle-class community that is located at the north-east of the city), while low income groups are located at the periphery. Rural communities are migrating particularly to the south-west part of the city.

Table 3.8 Poverty rates in Estelí Districts

District	Population	Poverty rate (%)
I	39,498	22,7
II	27,510	76,8
III	26,476	75,1

Source: Population data are based on the 2004 Census Report. Poverty rate based on Hacia un Desarrollo bajo en Carbono y Resiliente al Cambio Climático: Municipio de Estelí, Nicaragua. Programa Global de Enfoque Territorial del Cambio Climático-PNUD. 2010 [Unpublished report].

Poverty in Estelí is also reflected by the lack of access of population to basic services. The 2004 figures show that 52% of the city's population lacks access to sewage, while 28% per cent of households lack access to electricity (Municipality of Estelí, n.d.). The lack of sewage infrastructure is a particularly cause of concern, due to the fact that it leads to the accumulation of waste water, which can in turn result in transforming unpaved streets and pathways into lagoons in the rain season (Moser et al, 2010a).

The lack of appropriate sewage infrastructure, combined with unplanned urban expansion, is causing major environmental issues in Estelí. According to the Municipality of Estelí (2006) and SINAPRED (2011), the lack of sewage in approximately 30 neighbourhoods in the city leads to the discharge of untreated water and waste in the Estelí River and other ravines in the city, hence creating serious pollution problems.

Estelí also concentrates a great number of industries that generate pollution. In some cases industries discharge chemical waste products into the water streams (SINAPRED, 2011). The mismanagement of micro-basins thus presents a major environmental challenge in the city (Municipality of Estelí, 2008).

Moser et al (2010a) points out that legal status is a determinant for access to municipal public services in Estelí, and the existence of legal land titles is a requirement for the installation of services. Illegal land invasions not only lead to the settlement of impoverished populations in high risk areas, as it has been seen above, but it also obstructs these populations to access services, such as waste collection, sewage, and drainage that that are important for increasing urban resilience. Tenure rights and inadequate settlement planning are thus closely associated, and may have significant effects when assessing vulnerability.

In understanding socio-economic vulnerability to climate-related hazards, assessing the physical state of dwellings is also important. Estelí is the only municipality in Nicaragua that has developed a housing policy (which was approved in 2000). However, inappropriate

[8] UNDP's methodology to define poverty is based on the capacity of households to satisfy basic per person nutritional needs. The rationale followed by UNDP is to define a basic food basket according to a population's consumption patterns. If a person or household is unable to access the defined basic food basket, then it is considered as poor.

housing conditions are still a reality in the city. As CARE et al. (2007) points out, building code in Estelí is inappropriately implemented.

As Table 3.9 shows, Districts II and III tend to concentrate a higher number of dwellings characterized by bad and very bad physical conditions (56.5% and 43% respectively). In contrast, District I concentrates dwellings marked by relatively better physical conditions. Districts II and III not only concentrate higher number of dwellings in poor conditions than District I, but they are also marked by higher levels of poverty, as seen in the previous section.

Table 3.9 Physical state of dwellings in Estelí (percentage of total dwellings)

District	Excellent/ very good	Good	Average	Bad	Very bad	Other
I	1.1	13.9	53.9	19.9	11	0.2
				30.9		
II	1.9	8.5	33	39.5	17	0.1
				56.5		
III	3.9	14	39	34	9	0.1
				43		

Source: *Elaboración en base a información de la Dirección de Catastro. Alcaldía de Estelí. 26 Agosto 2004.*

Box 6 Urban vulnerability in Estelí

The relationship between the spatial distribution of poverty and exposure to climate-related hazards creates the geography of vulnerability in Estelí. Moser et al (2010b) provides a framework that summarizes the ways in which poverty inter-relates with climate-related vulnerability. They identify three types of vulnerability directly associated with poverty conditions:

- **Physical vulnerability:** refers to inadequate housing conditions as well as the lack of access to basic services, such as sewage, drainage and waste collection.
- **Legal vulnerability:** closely associated with weak land tenure rights, and has consequences in settlement location and planning, and the provision of crucial urban infrastructure for climate-related events.
- **Social vulnerability:** poverty conditions of exposed groups, which undermine their capacity to cope with climate-related extreme weather event and their potential impacts.

Key characteristics under each of the above-mentioned types have all been discussed above.

3.4.5 Perceptions of climate extremes

According to our interviews, although disaster risk may be well understood, there is no general awareness about climate change, let alone climate change adaptation. Local actors have been focusing on disaster risk management, and primarily disaster response, rather than disaster risk reduction or climate change adaptation. Hurricane Mitch is still in people's memory but there have not had any major disaster event since then. In fact, the impacts of the 2010 and 2011 floods did not cause major disruption. The topic of climate change is perceived as very distant from people's daily lives. According to one of our interviewees:

"People started settling in Estelí, when it started becoming safe again, after the 20 years of war. At that time, their only concern was how they could survive day on day, and people thus may not think a lot about the future."

This statement relates to the collective memory of the conflict years and people's perceptions and mind-sets.

In addition, people most often think of mitigation when they hear about climate change, and they are not familiar with the concept of climate change adaptation. Further, very technical (and often academic) analyses are not helping to raise awareness about climate change. People need to be well informed about climate change but it has to be done in a way that can be understood by everyone, according to respondents.

In particular, one interviewee argued that it is thus very important to consider socio-cultural issues on the social adaptive capacity assessment, because this may well illustrate how tradition and history impacts (or has impacted) upon people's understanding of climate-related hazards.

3.5 Distribution and quality of critical infrastructure

The city originally developed on top of a hill. Today, this section houses most of the critical physical and institutional infrastructure, representing the administrative and business city centre, with recent development expanding over to the west side of the river where commerce has become prevalent. Given its location, the city centre of Estelí is thus not exposed to any flood and/or landslide hazard risks.

In 1998, as previously discussed, Estelí was severely affected by Hurricane Mitch. The hurricane essentially destroyed several parts of the city in consequence of extreme floods. Although the most important critical commercial and administrative infrastructure was not located near the river banks at the time, the cemetery which is close to the river was severely damaged, entire neighbourhoods were flooded and destroyed, and bridges toppled. However, while most of the city's critical infrastructure (with the exception of the road network as will be discussed below) was not directly affected by the floods, it was affected by other aspects of the storm, notably high winds.

The connectivity provided by infrastructures as well as the distribution and quality of critical infrastructure networks, including those that extend beyond the urban administrative boundaries and with special focus on water and road infrastructure, are now discussed.

3.5.1 Water

The water services (drinking water and sanitation) are provided by the Nicaraguan Water and Sewerage Enterprise (ENACAL), which offers technical assistance to the Municipality of Estelí from the central level.

There are 21,500 household water connections in the city, representing 95% of the total housing in the urban area. With regards to urban wastewater sanitation, the city of Estelí has a sanitation system that reaches approximately 70% of the urban population. Just less than 30% of the remaining urban population has no access to sanitation services of black and grey water. Sewage is treated usually through sinks and grey water is discharged directly in yards or streets (SINAPRED, 2011).

According to the UNDP (2010) water availability in the Municipality of Estelí is sufficient to meet the current and future demand. However, the water quality is compromised. Climate change through increases in temperature and decrease in the number of days with rain may exacerbate the potential impacts upon the water quality.

3.5.2 Road infrastructure

Flood and landslide impacts to road infrastructure could result in disruption of road networks. The road infrastructure network in Estelí suffered badly from the effects of Hurricane Mitch in 1998 (see Box 6). Landslides and floods can severely affect main access roads of communities, as well as the city's connectivity with the rest of the region.

Estelí has a stretch of 42 kilometers of the Pan-American Highway which serves international ground transportation. The network of streets and avenues within the city is 188.49 kilometers. Generally, the road network has problems of discontinuity of roads (SINAPRED, 2011). Further, their state is not in good condition and they often lack culverts and storm drains (Table 3.10). As a result, areas of the city, or even the city itself, may be isolated during extreme weather events and businesses may be unable to distribute their production.

Table 3.10 State and quality of roads

Status of construction material	Paved		Stone		Unpaved		Total	
	Km	**%**	**Km**	**%**	**Km**	**%**	**Km**	**%**
Good	42	82.4	33.2	15	-	-	75.2	12
Fair	9	17.6	188.49	85	337	100	534.5	88
Total	51	100	221.69	100	337	100	609.7	100

Source: SINAPRED, 2011.

Box 7 The impact of Hurricane Mitch on road infrastructure

Figure 3.6 Isolation of downtown Esteli due to severe damages to a bridge.

Source: Evaluación Indicativa de Peligros y Plan Municipal para la Reducción de Desastres Municipio de Estelí, 2001.

During Hurricane Mitch, the rising waters of the Estelí River reached approximately 6 to 7 meters high in some places. Communities along the banks of the river were directly affected, as was part of the urban infrastructure. The floods caused by Hurricane Mitch severely affected the road network, both in the urban and rural areas. In the urban areas, it affected 30,000 people directly and 33,000 indirectly. This is 63,000 people in total. Further, 139,400 square meters of the urban road network was damaged, including severely damaging four bridges.

3.6 Spatial, social and economic impact upon disaster risks

Overall, the urban social and economic adaptive capacity assessment of Estelí can be summarized in the following table. It describes key characteristics that impact upon climate related disaster risks, such as floods and landslides. A qualitative codification is applied to each characteristic: minimal (it is unlikely that this characteristic will impact upon hazard risk), moderate (it is likely that this characteristic will impact upon hazard risk), and significant (it is highly likely that this characteristic will impact upon hazard risk). Classification follows a subjective, multi-criteria approach. The level of influence assessment is thus based on a combination of stakeholder meetings, secondary literature and the institutional mapping and rapid diagnostic developed in the first phase of the initiative.

Table 3.11 Socio-economic characteristics that impact upon climate related disaster risks

Characteristic	Description	Level of influence
Location of human settlements	Land is usually cheaper in high-risk areas, near to, or along the Estelí and El Zapote Rivers, and is often the preferred choice of marginalized groups.	Significant
Demographic change	From the 1950s, Estelí went through a period of very fast demographic growth which led to fast urban expansion. The city is still expected to grow in the coming years, although at much lower rates than in the past. It is expected that the population will reach approximately 137,000 inhabitants in 2020. With this growth scenario, the main challenge that the Municipality of Estelí will face is responding to the growing demands in basic services and urban infrastructure of the additional population, so that social and economic development of the municipality continues to improve.	Moderate
Economic characteristics	Micro, Small and medium enterprises (MSMEs) are of particular relevance for the city. MSMEs are often located at households, and if a disaster occurs, both the households and businesses can be potentially impacted, thus increasing people's vulnerability to climate-related hazard risks. What is more, it is estimated that approximately 50% of all businesses are informal and are thus particularly sensitive to disaster risk. At the same time, plantations in the rural areas are exposed to climate-related hazards, such as floods. The tobacco industry is the main driver of economic growth in Estelí, and any impact to plantations will likely impact upon the city's economy as well.	Significant
Spatial expansion	Urban growth in Estelí has been marked by informal settlement patterns. As urban expansion has mainly resulted from rural-urban migration, newcomers usually settle through spontaneous land invasions, which create land conflicts as well as unstructured urban growth. Many of the new settlements that appeared in the 1990s and 2000s were located in areas not destined for urban expansion. The Municipality has taken measures to formalize informal settlements in the past. For settlements located in risk areas, a resettlement process is underway.	Moderate
Urban design and characteristics of low-income housing	Districts II and III in Estelí tend to concentrate a higher number of dwellings characterized by bad and very bad physical conditions (56.5% and 43% respectively). In contrast, District I concentrates dwellings marked by relatively better physical conditions.	Moderate
Urban infrastructure	The 2004 figures show that 52% of the city's population lacks access to sewage, while 28% per cent of households lack access to electricity. The lack of sewage infrastructure is a particularly cause of concern, due to the fact that it leads to the accumulation of waste water, which can in turn result in transforming unpaved streets and pathways into lagoons in the rain season. The new peripheral settlements do not follow the regular urban square grid pattern that is	Significant

Characteristic	Description	Level of influence
	present in the eldest neighbourhoods of the city. Unstable topography makes public service investment more difficult and more expensive in these settlements. As a result, these communities are not equipped with basic infrastructure, such as paved roads and/or sewage.	
Critical infrastructure networks	The city originally developed on top of a hill. Today, this section houses most of the critical physical and institutional infrastructure, representing the administrative and business city centre. Given its location, the city centre of Estelí is thus not exposed to any flood and/or landslide hazard risks. According to the UNDP water availability in the Municipality of Estelí is sufficient to meet the current and future demand. However, the water quality is compromised. Climate change through increases in temperature and decrease in the number of days with rain may exacerbate the potential impacts upon the water quality. Flood and landslide impacts to road infrastructure could result in disruption of road networks. Landslides and floods can severely affect main access roads of communities, as well as the city's connectivity with the rest of the region.	Significant
Urban poverty	Estelí's urban morphology is characterized by poverty. 33.6% of urban Estelí lives in poverty. Within urban Estelí, poverty is unequally distributed. District I, which corresponds to the centre of Estelí, has considerably lower poverty rate, comparing to Districts II and III. As a general pattern, better off groups of population are located in the city centre (with the exception of an upper middle-class community that is located at the north-east of the city), while low income groups are located in the periphery.	Significant

4 Institutional adaptive capacity assessment

4.1 Institutional context

Although classified as a small to medium-sized city, Estelí is the largest urban centre in the Department of Estelí and supplies 95% of the goods and services in the region. Its economic and administrative importance gives Estelí a central role in the institutional governance structure of the region, with most risk management functions and facilities located in the city. Like most small and medium cities, development and expansion in Estelí is closely linked with economic and social activity in its surrounding peri-urban and rural areas. The city's rise as the only major urban hub in the region is fuelled by the growth of tobacco farms and industry in free trade zones set up on the outskirts of the city, and a decline in rural conditions in the larger Estelí municipality. Although most of Estelí's residents are employed by these private sector enterprises, the tax free status of this sector means that the city cannot extract much needed revenue for re-investment into the expanding city infrastructure.

The rapid rate of urbanization and expansion of city limits has resulted in a large number of informal settlements and ambiguous development. Although planning laws have been developed to control the direction and form of construction, there is limited implementation and regulation. Much of the city still lacks critical infrastructure, with a pervasive lack of proper drainage, waste removal, and road systems. Although the municipal government is adopting relocation as a risk management strategy, with many families being moved from illegal settlements in high risk areas to alternative locations, lack of basic infrastructure acts as an impediment to any meaningful long term planning for flood risk management. The influence of rapidly increasing regional socio-economic pressures on a relatively small city with traditionally weak infrastructure is a familiar story for many emerging urban centres in developing regions that must balance economic growth with social development. The management of current and future risks in the city of Estelí offer interesting insights into some of the challenges encountered in adapting to climate change in small and medium sized cities

4.2 Methodology

Data collection for the institutional assessment was based on three phases. The first phase utilized background data provided in the local consultant's report from the initial rapid diagnostic, along with other relevant secondary data and reports. The second phase was undertaken during the preparatory scoping visit, where interviews with key informants were used to characterize the background institutional architecture and culture of decision-making for risk management in Estelí, verify the appropriateness of the overall framework, and identify any remaining written data sources. Additionally, the visit was used to contact a wider range of stakeholders from government agencies, civil society and the private sector that were willing to complete the questionnaire survey. In the third phase, the questionnaire survey was circulated to these respondents, and the results collated with all other collected data.

4.2.1 Background data

For Nicaragua and Estelí, a good proportion of the required data was available through documentary evidence – dates and extent of legislation, urban planning guidelines, etc. The primary source for this type of information was the report prepared by the local consultant. Using desk based research and interviews with key stakeholders, the report provided a brief diagnostic of the relevant institutions and policy frameworks for climate change adaptation and risk management in Nicaragua. A list of available documents, reports and policy resources was also provided. Although the report provides data for the mapping of risk institutions for Nicaragua and Estelí, further data was required in order to assess the efficacy and robustness of risk management structures, and their potential to adapt in the context of increasing climate change risk. Interviews using the Adaptive Capacity Index were conducted during the preparatory scoping visit to provide this information.

4.2.2 Adaptive Capacity Tool

The institutional assessment focussed on the risk management and planning structures and capacities of city governments in each urban location, since adaptation is a planning challenge that must be incorporated into most areas of government activity in order to shape local changes; as well as positively influence the relationships between municipal authorities and local level organizations working to adapt to climate change.

For the analysis of the institutional context and capacity for adaptation building, the consultants deployed the Adaptive Capacity Index (ACI) developed for the EC FP7 project MOVE, which assesses institutional adaptive capacity for climate change and multi-hazard disaster risk at the local and national levels. The ACI seeks to measure disaster risk management in terms of the perceived performance of public policy and adaptive capacity for four fields: risk identification, risk reduction, disaster management, and adaptive governance. Each policy field is evaluated using the benchmarking of a set of sub-indicators that reflect performance targets associated with the effectiveness of disaster management activities. The participation of external experts as well as disaster managers in validating the quality of specific activities and capacities is incorporated to minimise bias. Each of the four elements of the framework identified above is populated by four sub-indicators. A detailed list of the variables can be found at http://www.move-fp7.eu/. The table below illustrates the framework structure of the ACI.

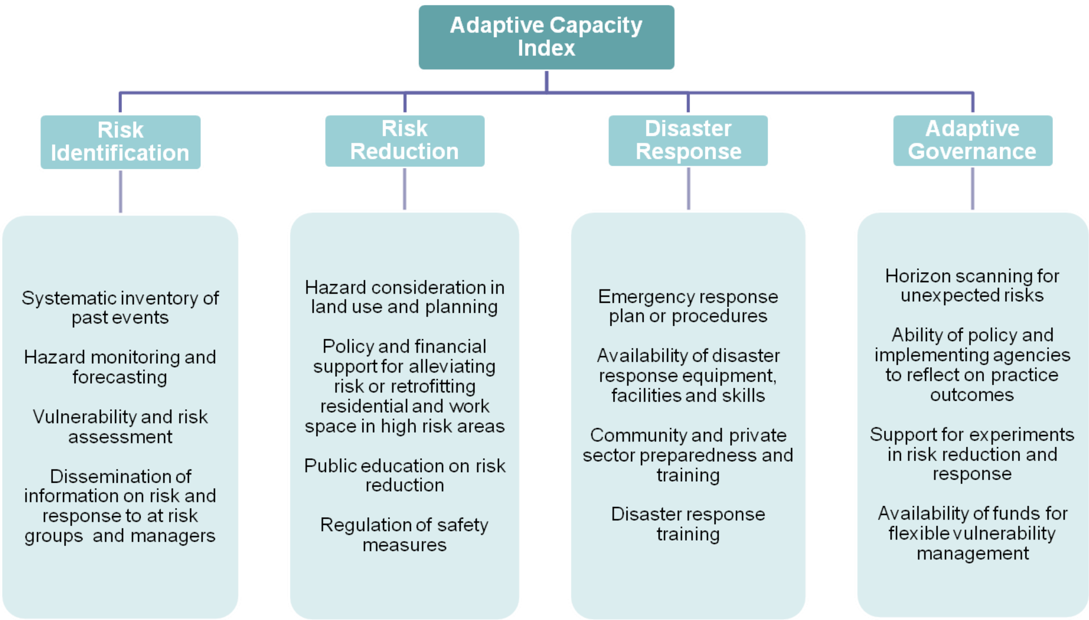

Figure 4.1 Framework structure of the ACI

The ACI was presented in questionnaire form to match the data collection needs of this project. The questionnaire survey is a single tool with different methods of data collection. In Estelí, it was used by the team as a framework for discussion on the institutional risk management system with key respondents during the scoping visit. Some sections were be filled out by the consultant and others by the respondent as part of a detailed conversation about risk management and adaptation practices and policies. In addition to one-on-one interviews, a shortened version of the survey was emailed to a larger group of respondents identified during the initial visit. The combination of the two types of survey responses allowed for a wider sample of stakeholder groups, as well as providing a detailed discussion of risk management mechanisms in Estelí.

A quantitative (though relativistic) assessment of each of the four topic areas in the ACI questionnaire was developed using the following performance levels:

- Limited (No formalized capacity; Activity is ad hoc, very infrequent and not planned or captured by strategy)

- Basic (A low level of formal capacity. Activity is planned. Action is infrequent and superficial, below the levels or intensity required to make a concrete difference to outcomes)
- Appreciable (A modest level of formal capacity. Activity is planned and strategic. Action is regular and outcomes can be identified but are limited in the depth of impact)
- Outstanding (Strong formal capacity. Activity is planned, strategic and integrated into all major sectors. Action is frequent, outcomes have made a clear difference to risk and its management), and
- Optimal (Very strong formal capacity. Activity is planned, strategic, integrated and a part of everyday practice. Action is constant, and outcomes have reshaped risk and its management and continue to do so in continuous cycles of activity).

Assessment of each topic area was also differentiated across prescribed time periods to generate a trajectory of capacity over time and assess how these trajectories are changing for different sample groups (e.g., public or private sector). The years 1995, 2005 and 2010 were selected as benchmark years, with a total time span of 15 years regarded by stakeholders as sufficient for capturing recent hazard events and for demonstrating trends in disaster risk management (while recognizing the limitations of institutional memory in each organization). The benchmark dates successfully reflected transformations in policy and capacity that occurred after important disaster events such as Hurricane Mitch in 1998.

There were an insufficient number of completed questionnaire surveys to attribute a numerical value to each performance level in order to derive a quantitative representation of management performance. However, the qualitative data generated using performance indicators was adequate in allowing for a direct comparison of performance across organizations and time. In addition, interviewed respondents were also asked for statements describing examples of capacity or of capacity changing tools or events. This discussion-review process served as a verification tool for the qualitative performance assessments, and was an important way of revealing cross-cutting and influential practices that could be transferred to other participating cities in a process of horizontal learning.

A final stage of the methodology will be local verification of findings. A draft assessment report will be circulated to respondents to provide scope for additional input and as a verification exercise.

4.2.3 Methodological Challenges

Many of the meetings with stakeholders were organized as group sessions, making it difficult to use the survey to assess individual evaluations of risk management practices in the city. Most respondents were supplied a questionnaire to fill in and return at a later date. This resulted in a small degree of inconsistency between responses since respondents did not always complete the questionnaire fully or consistently, or they did not provide sufficient detail in their answers. A number of respondents failed to return the surveys even though several reminders were issued.

However, the information provided in the local consultant’s report was a very good guide on the institutional framework for risk management in the country and helped in the quick identification of key stakeholders and issues. The response rate was lower than in other study sites but the gap was bridged by data and observations made during the field visit. Triangulation of information from several different sources was used to construct a generally accurate picture of adaptation planning and risk management in Estelí.

4.3 Policy instruments

4.3.1 National

The Climate Change Directorate within the Ministry for Environment and Natural Resources (MARENA) delivered Nicaragua’s First National Communication to the United Nations

Framework Convention on Climate Change (UNFCCC) in 2001. It identifies agriculture and livestock, energy, ecosystems, human health and water as priority sectors (Government of Nicaragua, 2001). In the water sector, the government emphasizes the importance of water conservation, watershed management, infrastructure for water deviation, avoidance of deforestation, land planning measures, solid and liquid waste management, improving the country's legal framework, implementation of water action plan, and decentralization and promotion of integrated use of watersheds as part of the national climate strategy. A second National Communication was published in 2011. This document contains, among other things, adaptation strategies for several key agricultural sectors such as tobacco and coffee production.

At a regional level, Nicaragua is a member of the Central American Integration System (SICA). This framework coordinates the institutional actions of Central American states, along with the Central American Commission for Environment and Development (CCAD), a committee which brings together the environmental ministries of SICA member states. A regional climate change strategy was developed under SICA and CCAD in 2010 (CCAD and SICA, 2010). The strategy summarizes climate information and sector vulnerabilities of member states and proposes six strategic areas, one of which is 'vulnerability and adaptation to climate variability and change, and risk management.' Other strategic areas are: mitigation; capacity building; education, awareness raising, communication and participation; technology transfer; and international negotiations and management.

Nicaragua developed a National Action Plan on Climate Change in 2003 (MARENA, 2003). Although the plan takes into consideration land use, forestry, agriculture, energy and water, adaptation is addressed only in the context of agriculture and water. This plan does not appear to have been implemented. In 2010, the government put forward the National Strategy and Action Plan on Environment and Climate Change. It describes key environmental challenges and sets out an agenda of actions for the period of 2010 to 2015 in climate information, agriculture, forestry, conservation, water resource management, and sustainable land use. Specifically, the plan proposes priority adaptation actions related to strengthening monitoring and collection of climate information, development of early warning and response capacity, and adaptation strategies for the water and agriculture sectors (Government of Nicaragua, 2010). It sets priorities for strengthening national and local capacity to incorporate climate change into policies and land management, and promotes public decision-making for vulnerability and risk reduction, poverty reduction, and sustainable development.

Similarly, a general governmental document on climate change discusses water, agriculture, forests, energy and coastal and marine resources as affected sectors (MARENA 2008). Priorities identified in this document are, among other issues: integrated watershed management, conservation of protected areas, biodiversity conservation, reduction of environmental contamination, reforestation (with specified national targets), integrated marine and coastal ecosystems management, sustainable land use and citizen participation as key actions that help to adapt to a changing climate.

Other sector specific strategies for adaptation include guidelines for the development of an adaptation strategy for forest ecosystems, and the National Plan of Human Development, where adaptation to climate change is mentioned under three of eight strategic programs: Productive and Commercial Strategy; Environmental Sustainability and Forest Development; and Disaster Risk Management. Although climate change planning is not the central issue in any of these programs, it is referenced as a key factor to be taken into account in the development and execution of strategies and policies related to agriculture, environment, forestry and disaster management. Climate change is also mentioned in the country's National Human Development Plan.

There is a clearly observable prioritization of the water and agriculture sectors in most climate change strategies and adaptation policies in Nicaragua. This theme continues in climate change adaptation programming in the country, which largely focuses on research and capacity building at the national and sub-national levels. Nicaragua is currently experiencing a high level of activity in adaptation projects and planning relative to other

Central American countries. This includes a UNDP led capacity building initiative that involved vulnerability assessments for water, health and coasts. The Adjustment Measures Program in MARENA created both the Strategy for Adaptation to Climate Change of Water Resources and Agriculture Systems in Basin No. 64, and a Vulnerability Analysis System for Coffee Production and Food Security in specific regions, with a view to informing policy decisions on adaptation to climate change in other regions. There is also a vulnerability assessment for the Región Autónoma Atlántico Norte (RAAN; North Atlantic Autonomous Region) that discusses impacts on water, agriculture, fisheries, natural resources and biodiversity, human systems, coasts and health. Two important projects involving more specific measures, including infrastructure investments, have been approved recently. They are financed by the Inter-American Development Bank (IADB) and the Adaptation Fund and will be implemented over the next five years. As with previous initiatives, they tend to focus on agriculture and water.

In the context of disaster risk management, in 1998 Hurricane Mitch became a catalyst for the transformation of disaster response planning in Nicaragua. Mitch exposed the necessity for a legal framework for coordination of national and local emergencies and disasters and the National System for Prevention, Mitigation and Attention to Disasters (SINAPRED) or Law 337 was created two years later in 2000. Before Act 337, disaster response in the country was centralized and reactive, based on the actions of a few specialized institutions such as the Fire Brigade and Army. The creation of SINAPRED shifted the focus of disaster response to risk prevention in a proactive, decentralized manner.

The National Plan for Risk Management (2004) builds on law 337 and sets national objectives for risk management. The plan advocates a system-wide approach to addressing risk, with an emphasis on prevention, citizen participation, attention to risk creating factors, and socioeconomic development to reduce vulnerability. The National Response Plan was created in 2008 as a national guide to planning for disaster response. This plan sets out strategies for various sectors and scales of administration in order to limit the negative impact of disasters. It provides basic information on different risk scenarios that need to be considered in the development of response plans by different sectors and regions.

4.3.2 City level

There are a variety of policy instruments available to the Municipality of Estelí for the administration and regulation of its environment. These include the Urban Development Plan 2005-2015, the Town Planning Regulations, the Institutional Strategic Plan, the Annual Investment Plan, the Municipal Environmental Plan Estelí, Estelí Environmental Policy and the Regulation of Water for Irrigation, among others. It is important to note, however, that none of these policy tools or regulatory instruments incorporates a long-term vision that takes into account the impact of climate change.

The municipality has made considerable efforts in establishing disaster risk management planning initiatives. In 2001, with support from international organizations, the first Municipal Plan focusing on floods was elaborated. It did not act specifically as a disaster management plan, but it did identify the main risk areas of the city. It was not until 2003 that a response plan, including an early warning system, was established. Despite the existence of DRM planning instruments, it is important to point out that these mainly address flood hazard. There is relatively little attention given to landslides (since urban Estelí, as demonstrated earlier, is not susceptible to landslides) and climate change is a fairly recent policy topic. The Estelí Municipal Council approved a Municipal Climate Change Adaptation Plan in 2011. Despite its presence, the plan remains unknown to most direct local stakeholders and to residents at large.

4.4 Institutional mapping

4.4.1 National

In Nicaragua, the Ministry of Environment and Natural Resources (MARENA) houses the national institutions responsible for addressing climate change and the environment. The Climate Change Directorate within MARENA is the focal point of the UNFCCC, and all climate change related work of the government appears to be concentrated in this relatively small team. Initiatives to support the identification and implementation of mitigation and adaptation measures, such as the National Environmental Strategy and Climate Change, are developed and implemented through this national agency. In addition, the National Clean Development Office (ONDL) in MARENA provides technical support for mitigation, adaptation and vulnerability actions, and has conducted studies and developed localized adaptation strategies. Despite advancements made in adaptation measures, Nicaragua's national government experiences weak capacities; MARENA, for example, has few permanent staff.

The Institute of Territorial Studies (INETER) is the coordinating body of the national meteorological network. This network contains several public and private sector organizations that have installed measuring stations (for eg. the National Weather Service (NWS), the Ministry of Agricultural Development and Agrarian Reform (MIDINRA), and multinational organizations such as the Standard Fruit Co. and Nicaragua State Sugar). The INETER provides weather forecasts, briefs and warnings, as well as macro-level models, water levels and flood hazard maps.

Law 337 defines the creation of a disaster response structure composed of a National Committee (SINAPRED), Departmental Committees and Municipal Committees (COMUPRED). SINAPRED, the National System for Prevention, Mitigation and Attention to Disasters, consists of public institutions, civil society organizations, and local and regional authorities that work in coordination to reduce risks and protect the physical and social assets of individuals and the state. Its main aim is to coordinate disaster risk management actions. The Committee is comprised of eight sector working committees: Health, Natural Resources, Security, Education, Supplies, Infrastructure, Environment, and Special Operations.

COMUPREDs, the municipal level committees, are designed to respond to all incidents within the territory of a particular municipality. However, not all municipalities across Nicaragua have municipal commissions. This is due to institutional strength and capacity problems, but also due to the fact that not all municipalities face the same level of threat and vulnerability.

There are other institutions that have historically been linked to emergencies and disasters at the national level, such as the Nicaraguan Red Cross and the Fire Department (state and voluntary). These are represented in SINAPRED within the Special Operations group, which is coordinated by Army of Nicaragua. Both the Red Cross and Fire Department are only represented in the major cities of each department or municipality, so their role at the municipal level is of variable significance.

Law 337 states that civil society institutions (NGOs and other civil bodies) may join SINAPRED and other working committees by signing a protocol of accession. This protocol allows committees to support humanitarian and voluntary risk management in the country, while maintaining a system that is organized and coordinated by the state. These organizations have traditionally included NGOs such as SDC, CARE International, Humboldt Center, Action Against Hunger, World Vision and German Agro Action. SINAPRED has worked with several of these groups for improved training, equipment and drills, as well as on Early Warning Systems (EWS) for floods, landslides, fires and volcanic eruptions.

It is important to note that the policies and procedures of SINAPRED do not as yet reflect the long-term threat of climate change, or how this will alter the magnitude and frequency of natural hazards affecting Nicaragua.

4.4.2 City level

In addition to COMUPREDs, local level disaster management organizations include the community level COLOPRED (Local Committees for Prevention, Mitigation and Attention to Disasters) and COCOPRED (Local Community Committees for Prevention, Mitigation and Attention to Disasters). The National Executive Secretary of SINAPRED monitors the actions of all these organizations on the issue of Prevention, Mitigation and Attention Disaster in Nicaragua. The city of Estelí operates on the same national model. The municipal COMUPRED of Estelí has existed since 2011 and is coordinated by the Mayor of Estelí. It consists of eight sector working committees, of which seven are chaired by government agencies, and one by the Institute for Lifelong Learning (INSFOP), a local NGO established in 1978 and renowned for its social and educational work.

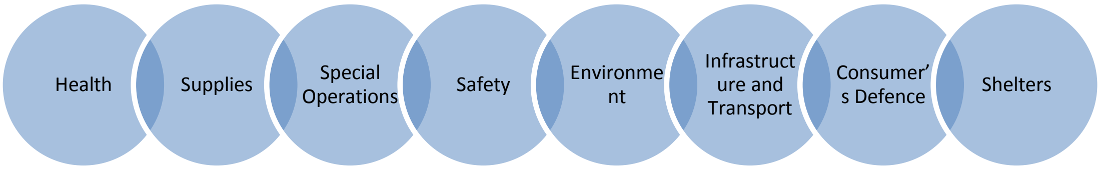

Figure 4.2 COMUPRED sector commissions

The COMUPRED operates under an annual work plan and other contingency plans with the support of Civil Defense. The Army of Nicaragua also has a physical presence in the Municipality of Estelí building. COMUPRED meetings take place regularly every month, and are attended by representatives from each of the eight sector working committees, as well as Police, Fire and other departments in town hall. According to the Municipal Response Plan updated in June 2011, COMUPRED has 267 individuals assigned to special teams for search and rescue, 1,689 individuals acting as support staff, 89 light vehicles, 16 trucks, and radio and mobile communication equipment. It has also established 13 sites as temporary shelters, including 9 evangelical churches, with capacity for 900 people.

Faced with a sudden or progressive threat, the COMUPRED activates a warning plan and immediately notifies all member institutions to coordinate action amongst their sector working committees in response the emergency. The Civil Defense coordinated all action and communication in this phase of response. It is also responsible for monitoring the situation and supporting the initial and final damage assessment. It coordinates search, rescue and recovery operations, provides medical assistance, conducts quick repairs of damage of essential services, and keeps the public informed of the status of the emergency.

The figure below shows two main rings separating the municipal level, the departmental level and the national level (Figure 4.3).

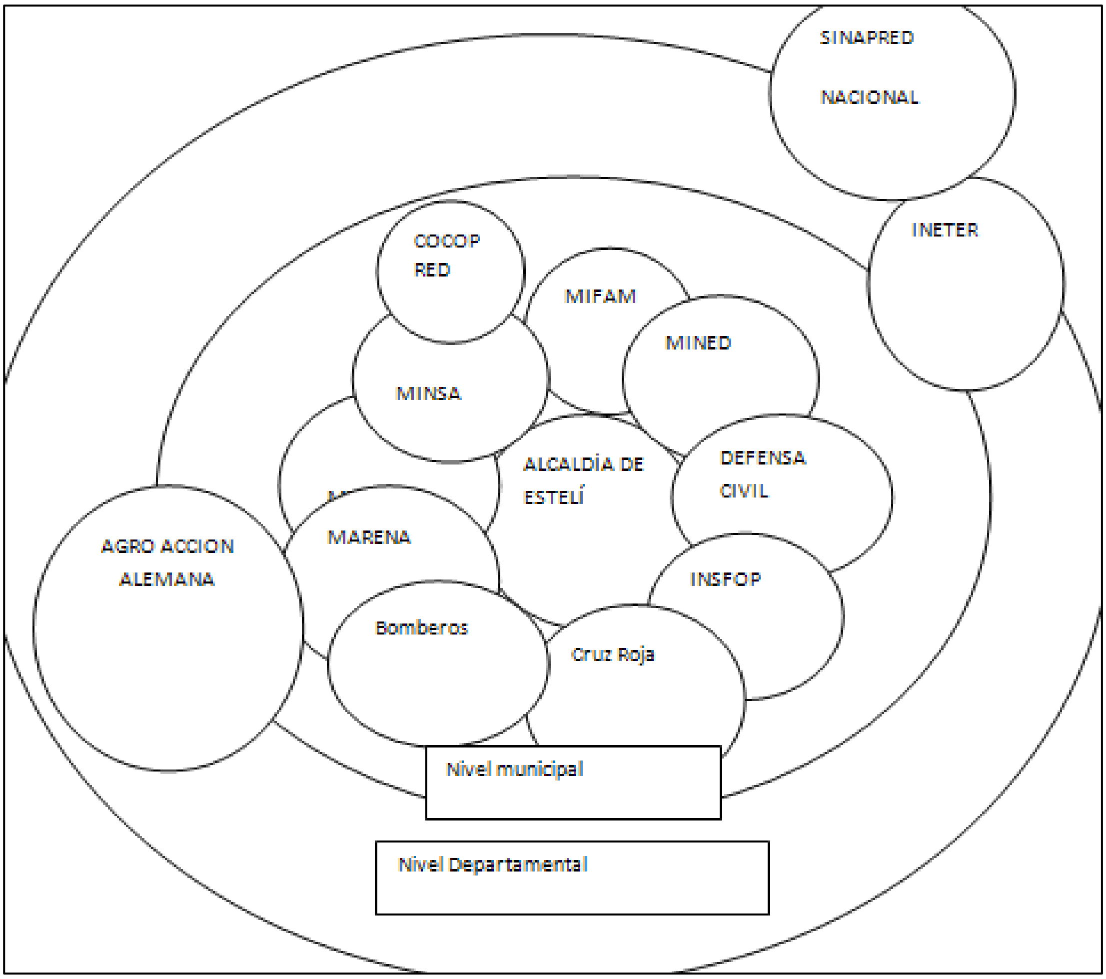

Figure 4.3 Organizational map of disaster risk management in Estelí, The Authors.

Urban planning is the responsibility of the Municipality of Estelí. Within the municipal structure the Department of Planning and Urban Development makes rules for land use, zoning, housing and public infrastructure development proposals. Its planning tools incorporate natural hazard and risk management. In 2002, it produced a detailed map (1:5000) showing the location and level of flood risk in the town of Estelí, along with a zoning proposal accounting for this flood risk. The department has its own staff, including a chief architect and four technicians responsible for the preparation of plans, maps and field inspections.

The two COCOPREDs operational in Estelí are located in the headwaters of Estelí river, about 10 km south of the city. They were created to manage local flood emergencies, and for playing a role in the early warning system for potential downstream flood risk in the city. They monitor and provide information on river flows during rainfall events to the city of Estelí.

Several other actors and groups play an important role in supporting risk management practices for the city. These include the Catholic Church and various Protestant congregations. During the last two flood events in urban Estelí (2010 and 2011) both churches initiated food collection and clothing drives among their parishioners to support affected families. In particular Protestant Christian congregations have made available nine church buildings that serve as temporary COMUPRED shelters for homeless families in case of evacuation.

Another important actor is the National Autonomous University of Nicaragua (Unite) that, through the Regional Multidisciplinary Faculty Estelí (FAREM-Estelí), provides training in risk management and climate change adaptation to secondary school teachers, college students, and technical staff from the municipal authority (including the Mayor of Estelí). FAREM has also organized forums and discussions on risk management in Estelí and northern Nicaragua with organizations involved in risk management such as SINAPRED, Civil Defence, UNDP, mayors, local NGOs, government ministries and international development organizations.

The international NGO Welthungerhilfe has also provided technical, financial, and advisory support for disaster risk management in the city. Its "Strengthening emergency response capabilities in Estelí River Basin" project (2008-2009) provided the city of Estelí and the institutions that make up the COMUPRED (Police, Civil Defence, Fire Brigade and local communities) the equipment and training necessary to install an early warning system (EWS) for floods. A second project "Municipal Response Plan Risk Management Approach of Estelí" (2011) improved the Municipal Response Plan, which had not been updated since 2003.

There is currently no local level organization active in climate change planning and adaptation at the city level. An effort to develop adaptation action in the city resulted in the formulation of a local committee to create a "Strategy for climate change adaptation for Estelí" but this never became operational. Organizations part of the COMUPRED demonstrate an awareness of the effects of climate change on the environment and people but lack clarity on how this can be integrated into planning and daily operations of the institutions. An Adaptation Plan for Climate Change was approved by the City Council of Estelí in September 2011, but it is still largely unknown within city level government agencies.

Although most risk management action remains focused on the disaster response system in Estelí, a few projects are being undertaken by NGOs and some government entities to implement measures for adapting to climate change. This includes a project by the National Red Cross, supported by the Netherlands Red Cross, aimed at consolidating a strategy and development plan with measures to adapt to climate change for Estelí. It focuses on improving awareness through education on climate change and its effects, construction of mitigation works in water and sanitation and improving the capabilities of the COMUPRED, and strengthening the capacity of the local government to integrate climate change in their projects, strategies and plans. Other organizations, like Oxfam, are involved in community-level initiatives that are helping to build adaptive capacity.

4.5 Gaps in existing capacity and opportunities for adaptation

An examination of policy and institutional structures reveals that Nicaragua has developed an integrated and proactive system for disaster risk management since its experience of Hurricane Mitch in 1998. At the policy level, its legal framework allows for a comprehensive and multi-sector approach to disaster risk management, and the country has its own National Disaster Prevention and Attention Plan, as well as a National System for Disaster Management and Prevention (SINAPRED).

More recently, the government has increasingly engaged with climate change planning at the national level, with adaption strategies and projects featuring especially strongly in the policy planning for the two priority sectors of water and agriculture. The scope of these strategies is limited by a lack of institutional infrastructure both at the national and local level. MARENA has limited capacity and resources to implement plans down to the local scale, and no local level institution has climate change and adaptation planning as part of its direct mandate or budgetary allocation. For example, in accordance with the national climate change strategy, and with assistance from MARENA, the Estelí Municipal Council approved a Municipal Climate Change Adaptation Plan in 2011. However, the strategies identified in the plan have not been implemented to date due to a lack of resources, funding and clarity of organizational responsibility. To date, most stakeholders in the city are unaware of its existence.

In contrast, systems for disaster risk management have been successfully decentralised and decision-making devolved to local administrative government structures. However, despite a strong national policy framework, limited availability of financial resources has resulted in a low level of preparedness and long-term risk reduction planning at the sub-national level. The government has yet to develop a financial strategy to support the mainstreaming and implementation of risk management planning in the country. Limited financial resources have been made available to support local institutions for responding to and preparing for disaster risk. Any existing investment is largely aimed at disaster management, not climate change adaptation.

Most risk management organizations in Estelí are therefore primarily focused on disaster mitigation and response, with little awareness or prioritization of climate change planning and adaptation across the city. Risk management, in both policy and practice, is reactive and response-led. Although coordination and logistical planning for disaster management through the COMUPRED and the two Community Committees for Disaster Prevention and Attention (COCOPRED) is very strong, the city has to rely on national and military resources for infrastructure and equipment for response during emergencies. Good organizational links and communication with communities have resulted in a strong early warning system, relying on input and participation of community members both in the risk assessment and risk communication phases of the system. Financial investment in infrastructure, logistical resources, training and capacity building for adaptation is needed to support such actions and improve risk reduction and adaptation capacity across the city.

The uneven focus on response versus planning, and operational limitations induced by a shortage of financial resources are reflected in the results of the ACI. The figures below provide the values derived for the indicators of Risk Reduction and Disaster Response in Estelí (Figure 4.4 and Figure 4.5). It is easy to visualise the sharp increase in disaster response capacity after Hurricane Mitch in 1998. All sub-indicators for Disaster Response increased to outstanding or appreciable levels except for response equipment and skills. This can be attributed to the resource intensive nature of procuring and maintaining response equipment. In contrast, sub-indicators for Risk Reduction in Estelí remained flat or experienced only slight improvement over the years. Even though vulnerability and hazard risk are considered in land-use and planning, respondents suggested that weak implementation resulted in only a basic level of hazard consideration in practice. Similarly, there is a high level of awareness in the population of Estelí city on climate risks to life and the economy. This is because the city is frequently affected by climate events, especially flooding. However institutional capacity for public education on risk, including information of risk prevention and preparedness, remains very limited according to respondent evaluation.

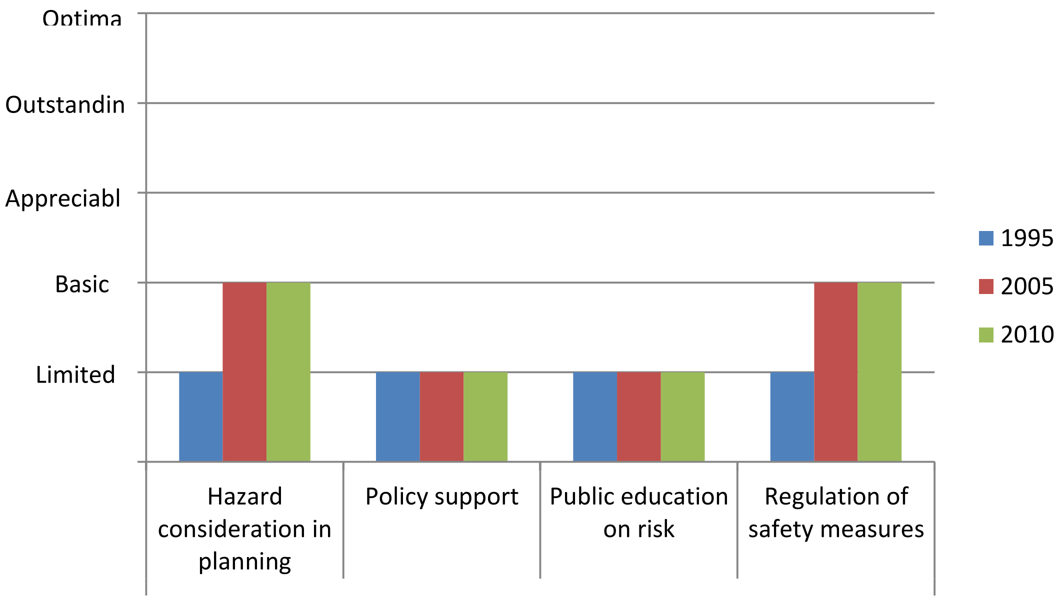

Figure 4.4 Risk reduction in Estelí, Source: The Authors.

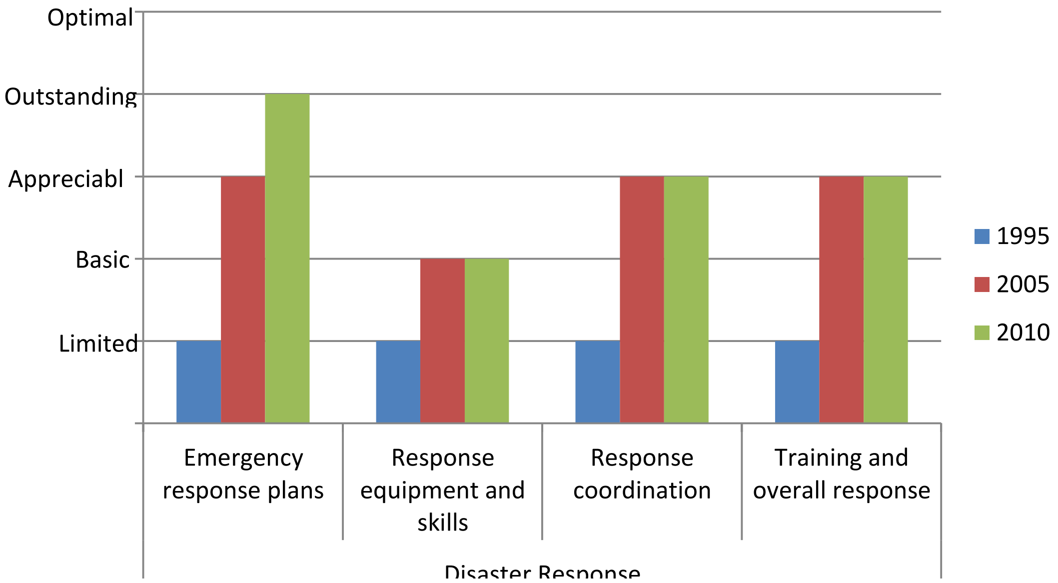

Figure 4.5 Disaster response in Estelí, Source: The Authors.

A similar picture emerges in land use and urban planning. Although the city has developed an Urban Development Plan for 2005-2015, it does not have the human capacity or financial resources to implement it. Urban growth in Estelí is dominated by the spread of informal settlements. Even though several of these sites have been formalised and land titles granted to residents, over half (52%) of the city does not have access to proper sewage disposal or basic services. This indicates the limited infrastructural and financial capacity of municipal institutions, with climate change vulnerability configured as an output of hazard exposure.

Although agriculture and the tobacco industry located in the outskirts of the city are the main drivers of economic growth in Estelí, very few private sector organizations have engaged with climate change adaptation as part of their business continuity plans and strategies. Since these industries are located in Free Trade Zones, the municipality does not hold the right to draw taxation revenue in these areas. No insurance instruments are available to the predominantly small and medium sized businesses that operate within city limits. The integration of private sector interests and the development of a more comprehensive plan that considers regional watershed management rather than urban boundaries could provide a more effective strategy for municipal authorities.

A regional plan would also be useful for addressing larger pressures of migration and rural vulnerability. Estelí is affected by economic, social and environmental processes occurring in its surrounding areas. Development in these rural areas is weak, as evidenced by the steady migration to urban areas. The impact of climate variability on these regions will have a direct impact on risk management and vulnerability in the city of Estelí. An assessment of vulnerability and climate change risk in these areas, combined with a more integrated approach to regional risk management could provide the basis for a forward looking approach to adaption planning.

Although there is good availability of meteorological data and cartographic information for Estelí, this information is scattered and not accessible in useful formats for risk planning and response organizations. Estelí has a weather station, but this only measures precipitation, not temperature or wind. There is also no central database for information on past disaster events and losses. Also, the University and FAREM Estelí have undertaken provisional assessments of vulnerable neighbourhoods for academic purposes, but the information is not readily available to risk management organizations. Investment towards the improvement, consolidation and accessibility of climate and disaster risk data in a format that is relevant to local stakeholders and policy-makers is necessary for informed decision-making and policy formulation.

It is important to note the central role of radio and television communication in Estelí. The three local television channels (Channel 8, Channel 9 and Channel 35) and several local radio stations have demonstrated a high degree of willingness to attend, participate in, and report on various events held for disaster preparedness and training, and during disaster events as well. A regional Network of Environmental Journalists has also been involved in different training events that allow journalists to correctly use terminology and convey disaster risk more appropriately to the public. .A survey conducted in urban neighbourhoods of Estelí found that 85% of the population prefers television as the primary source of information communication (Barriga 2005). The municipal authority can partner with local media to improve public education on not only disaster management but also climate change risk and adaptation.

Overall, the city of Estelí has a high coordination capacity for organizing logistics and response procedures in an emergency. This high capacity emerges out of its organization of personnel from 17 government institutions, NGOs and relief agencies, and media agencies in a system in which each of the parts provides expertise and resources. In turn all parties respond to a single response plan under coordination led by the Mayor and Civil Defense. There is accurate local knowledge of vulnerable populations and infrastructure. However, the system is limited by a lack of resources, primarily financial but also human and physical, as well as weak infrastructure and essential services in the city

5 Climate-related vulnerability and risk assessment

5.1 City profile

Estelí is a city located in North-Western Nicaragua, about 150 kilometres North of Managua. Estelí is thus centrally located within Nicaragua with a heterogeneous topography of hills and plains ranging from approximately 1,000 to 1,600 meters above sea level. The Municipality of Estelí is one of the six municipalities of the Department of Estelí. Estelí acts as both the seat of the Estelí Municipal government and of the Estelí Department. It is connected with the rest of the country through the Pan-American Highway.

The Estelí River runs along the city for six kilometres and divides it from Northeast to Southwest. The El Zapote ravine also runs through the city, while the El Zanjón de los Cedros ravine runs through the South, following the Pan-American Highway until finally joining the Estelí River. These water streams are responsible for the floods occurring within the urban core of Estelí.

The purpose of the climate-related vulnerability assessment is to identify flood and landslide hazards that may be caused or exacerbated by climate change in Estelí, and to assess the likelihood and relative consequence of these hazards in order to prioritize responses and mitigate risks.

The Municipality of Estelí is divided into two administrative areas: urban and rural. The administrative boundaries of urban Estelí will be the basis for the area of study. The administrative structure of urban Estelí is characterized by the presence of districts and within these, neighbourhoods. The administrative organization of urban Estelí is made up by 3 districts. A total of 59 neighbourhoods are located within these districts.

Having experienced fast demographic growth in recent decades, Estelí is nowadays an important urban centre in north-western Nicaragua. As a regional centre, it provides economic, social and administrative services to its surrounding hinterland. Urban-rural linkages are of significance. In the industrial sector, the tobacco industry has been the main driver of economic growth. Micro, Small and medium enterprises (MSMEs) are of particular relevance for the city.

Estelí has thus grown in both spatial and economic terms over the past decades. Although Estelí did not experience high growth in most of the second half of the 20th Century, it went through a period of accelerated urban expansion from the 1980s. High economic growth attracted population from the surrounding areas in the north of Nicaragua. The population jumped from 30,000 inhabitants in 1980 to 70,000 in 1995, to reach more than 90,000 in 2004.

According to the 2004 Census report, the population of the Municipality of Estelí is 115,900, of which 93,484 people or 80.6% are concentrated in the urban area reflecting a high percentage of urbanization. The average annual growth rate has been declining, reflecting maturity of the urbanization process in Estelí. Nonetheless, as a result of natural population growth and of continuing in-migration, one would expect the population of the city of Estelí to reach approximately 137,000 inhabitants in 2020.

The 2005-2015 Urban Development Plan makes the attempt to orient urban growth in Estelí following an integrated approach by designating growth areas according to their accessibility, presence of basic infrastructure, transport networks, as well as their natural characteristics. The plan attempts to follow the guidelines established in the 1995 scheme and strengthen the position of the north and south corridors as services and commerce centres. It identifies north-west and the south-west as areas for residential expansion.

In effect, urban growth in Estelí has been characterized by incompatibility in land use. Despite the existence of urban development schemes and land use assessments, urban growth in Estelí has been marked by informal settlement patterns. As urban expansion has mainly resulted from rural-urban migration, newcomers usually settle through spontaneous land invasions, which create land conflicts as well as unstructured urban growth. Land is usually cheaper in high-risk areas, near to, or along the Estelí and El Zapote Rivers, and is often the preferred choice of marginalized groups. The new settlements suffer from high environmental problems, notably lack of access to rain sewage, which results in floods.

Predominant features of the built environment and urban population that impact upon flood and landslide hazard risks are summarized in Figure 5.1.

In the sections that follow, available information is compiled into a profile of vulnerability and risk for Estelí. This is based on the evidence discussed in the *Climate-related hazard assessment*, the *Urban, social and economic adaptive capacity assessment*, and the *Institutional adaptive capacity assessment*.

Figure 5.1 Predominant features of the built environment in Estelí that impact upon flood and landslide hazard risks.

5.2 Institutional vulnerability in Estelí

The institutional architecture of a city plays a central role in shaping the risk and vulnerability experienced by urban populations to natural hazards. It determines the distribution, accessibility and quality of critical services and physical infrastructure available to residents, and the provision of a safe and healthy environment. The institutional architecture refers to formal structures of government management such as legislation, planning guidance, and public organizations, as well as the more informal aspects of governance such as transparency and accountability, which characterise the social contract between citizens and the state. In small and medium sized cities, the capacity of urban management and governance institutions to identify and respond to current and future climate vulnerability defines not only the resilience of the urban system, but also its potential for future growth and sustainable expansion.

Institutional capacity for adaptation

An examination of policy and institutional structures reveals that Nicaragua has developed an integrated and proactive system for disaster risk management since its experience of Hurricane Mitch in 1998. At the policy level, its legal framework allows for a comprehensive and multi-sector approach to disaster risk management, and the country has its own National Disaster Prevention and Attention Plan, as well as a National System for Disaster Management and Prevention (SINAPRED).

More recently, the government has increasingly engaged with climate change planning at the national level, with adaption strategies and projects featuring especially strongly in the policy planning for the two priority sectors of water and agriculture. The scope of these strategies is limited by a shortage of institutional capacity both at the national and local level. MARENA has limited capacity and resources to implement plans down to the local scale, and no local level institution has climate change and adaptation planning as part of its direct mandate or budgetary allocation. For example, in accordance with the national climate change strategy, and with assistance from MARENA, the Estelí Municipal Council approved a Municipal Climate Change Adaptation Plan in 2011. However, the strategies identified in the plan have not as yet been implemented due to a lack of resources, funding and clarity of organizational responsibility. To date, most stakeholders in the city are unaware of its existence.

In contrast, systems for disaster risk management have been successfully decentralised and decision-making devolved to local administrative government structures. Despite a strong national policy framework, limited availability of financial resources has resulted in a low level of preparedness and long-term risk reduction planning at the sub-national level. The government has yet to develop a financial strategy to support the mainstreaming and implementation of risk management planning in the country. Limited financial resources have been made available to support local institutions for responding to and preparing for disaster risk. Any existing investment is largely aimed at disaster management, not climate change adaptation.

Most risk management organizations in Estelí are therefore primarily focused on disaster mitigation and response, with limited awareness or prioritization of climate change planning and adaptation across the city. Risk management, in both policy and practice, is reactive and response-led. Although coordination and logistical planning for disaster management through the COMUPRED and the two Community Committees for Disaster Prevention and Attention (COCOPRED) is very strong, the city has to rely on national and military resources for infrastructure and equipment for response during emergencies. Good organizational links and communication with communities have resulted in a strong early warning system, relying on input and participation of community members both in the risk assessment and risk communication phases of the system. Financial investment in infrastructure, logistical resources, training and capacity building for adaptation is needed to support such actions and improve risk reduction and adaptation capacity across the city.

The uneven focus on response versus planning, and operational limitations induced by a shortage of financial resources are reflected in the sharp increase in disaster response capacity after Hurricane Mitch in 1998 In contrast, sub-indicators for Risk Reduction in Estelí remained flat or experienced only slight improvement over the years. Even though vulnerability and hazard risk are considered in land-use and planning, respondents suggested that weak implementation resulted in only a basic level of hazard consideration in practice. Similarly, there is a high level of awareness in the population of Estelí city on climate risks to life and the economy. This is because the city is frequently affected by climate events, especially flooding. However institutional capacity for public education on risk, including information of risk prevention and preparedness, remains limited according to respondent evaluation.

A similar picture emerged in land use and urban planning. Although the city has developed an Urban Development Plan for 2003-2015, it does not have the human capacity or financial resources to implement it. Urban growth in Estelí is dominated by the spread of informal settlements. Although several of these sites have been formalised and land titles granted to residents, over half (52%) of the city does not have access to proper sewage disposal or basic services. This indicates the limited infrastructural and financial capacity of municipal institutions, with climate change vulnerability configured as an output of hazard exposure.

Although agriculture and the tobacco industry located in the outskirts of the city are the main drivers of economic growth in Estelí, very few private sector organizations have engaged with climate change adaptation as part of their business continuity plans and strategies. Since these industries are located in Free Trade Zones, the municipality does not hold the right to draw taxation revenue in these areas. No insurance instruments are available to the predominantly small and medium sized businesses that operate within city limits. The integration of private sector interests and the development of a more comprehensive plan that considers regional watershed management rather than urban boundaries could provide a more effective strategy for municipal authorities.

A regional plan would also be useful for addressing larger pressures of migration and rural vulnerability. Estelí is affected by economic, social and environmental changes taking place in its surrounding areas. Development in these rural areas is weak, as evidenced by the steady migration to urban areas. The impact of climate variability on these regions will have a direct impact on risk management and vulnerability in Estelí city. An assessment of vulnerability and climate change risk in these areas, combined with a more integrated approach to regional risk management could provide the basis for a forward looking approach to adaption planning.

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Overall institutional assessment

Overall, the city of Estelí has a high coordination capacity for organizing logistics and response procedures in an emergency. This high capacity emerges out of its organization of personnel from 17 government institutions, NGOs and relief agencies, and media agencies in a system in which each of the parts provides expertise and resources. In turn all parties respond to a single response plan under coordination led by the Mayor and Civil Defense. There is accurate local knowledge of vulnerable populations and infrastructure. However, the system is limited by a lack of resources, primarily financial but also human and physical, as well as weak infrastructure and essential services in the city. Future efforts to promote climate change adaptation and planning will need to build on the strong local coordination networks in Estelí by providing financial and technical support for increased institutional capacity.

5.3 Flooding and landslide vulnerability in Estelí

Estelí is susceptible to floods while landslides do not pose a significant risk (landslides are isolated to the neighbourhoods of Filemón Rivera and Virgina Quintero within District I). Weather records over the last 40 years (1960-2003) suggest an increase in temperature and a decrease in total rainfall, though there has been an increase in the proportion of rainfall that occurs in heavy events[9] (McSweeney et al., 2010). Temperature is projected to continue to increase in the future, while both the total precipitation and the rate of precipitation for the dry and wet seasons are projected to decrease. The decrease in precipitation can reduce threats of floods and landslides. However, the uncertainty in precipitation projections and other, non-climate factors that affect flood and landslide risks need to be considered in applying these conclusions. Additional factors such as the health of the forests and other vegetation cover in the area could affect the occurrence of landslides. If the vegetation is unaltered, then the reduction in soil moisture may reduce the threat of landslides. On the other hand, if deforestation or landscape transformation continues in the area, the drying soils could exacerbate soil erosion and increase the threat of landslides.

5.3.1 Approach

This section synthesizes information on Estelí's landslide and flood vulnerabilities, focusing on the current physical risk, urban social and economic conditions, and institutional arrangements. This is done by conducting a vulnerability analysis for each of the three districts in the study area. Due to the lack of available data, the results of this analysis should be viewed as an informative screening of which districts are more likely to be affected by landslides and floods by mid-century.

A vulnerability analysis of critical infrastructure is not possible as this would require an analysis by infrastructure category (e.g., inspection of building codes, damages associated with past events, and other indicators to determine how sensitive the infrastructure is when exposed to the hazard). This analysis does, however, overlay the critical infrastructure with the districts that are exposed to the hazards. This vulnerability analysis can then inform decision makers as they consider climate adaptation options and provide recommendations regarding the combination of hazards, districts, and facilities that would benefit from a more intensive risk analysis.

A vulnerability analysis considers the exposure, sensitivity, and adaptive capacity of the settlement to the hazard (see Figure 5.2). Each of these components is discussed in more detail below.

[9] A heavy event is defined as a daily rainfall total that exceeds the amount of precipitation associated with the top 5% of daily precipitation of the record.

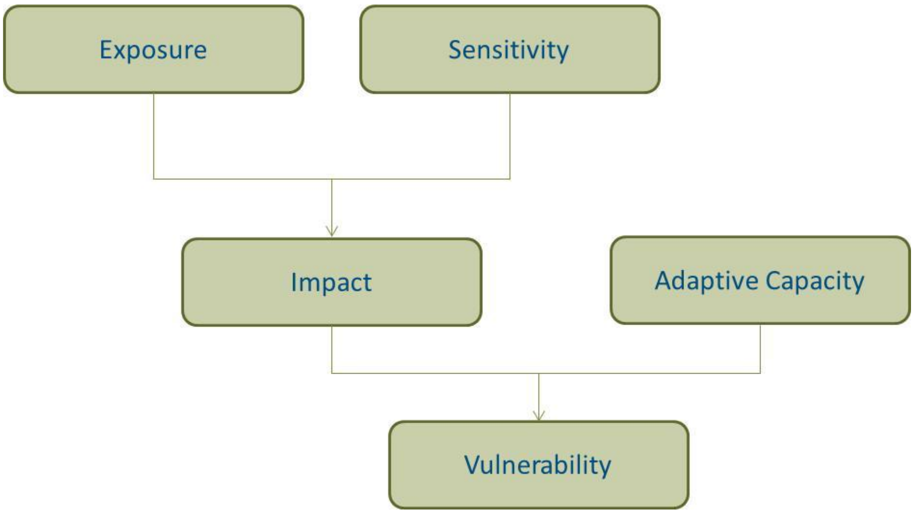

Figure 5.2 Schematic of the vulnerability analysis for landslides and floods.

- ***Exposure.*** Exposure considers whether a settlement and/or facility is located in an area that is considered susceptible to the hazard. For this analysis, this is simply a "yes/no" determination based on the findings in the hazard analysis. The hazard analysis identified the districts that were exposed to a landslide and/or flood hazard and considered through the use of climate projections whether the exposure may increase or decrease by mid-century (see Box 8).

Box 8 Projected changes in hazards

Due to climate change, Estelí's exposure to floods and landslides during the wet season is projected to slightly decrease by mid-century.

Given the hazard analysis does not include a more intensive modelling effort (e.g., new hydrologic and hydraulic modelling driven with projections of precipitation to investigate how exposure may change or drilled-down analysis of changes by precipitation event), this analysis is constrained to simply considering whether the existing hazard will worsen or reduce in areas already exposed to the hazard. Because of this, this analysis cannot provide a quantitative number describing the change in flooding or landslide exposure. However, it can provide a high-level description of which settlements are exposed to the hazard and a qualitative description based on quantitative data as to how climate change may impact future exposure. Climate projections were developed to reduce various components of uncertainty (e.g., an average from an ensemble of climate models was developed for two plausible socioeconomic futures). As with any projection, there is inherent uncertainty. In addition, new climate data that is shown to produce more rigorous results should be considered to augment the results presented in this report.

- ***Sensitivity.*** Sensitivity describes the degree to which a settlement that is exposed to the hazard might be affected. This step can rely on design standards, historical and geographic analogues, and/or expert opinion. The sensitivity of the settlement structure in each district was ranked based upon the percentage of dwellings that are in "bad" or "very bad" conditions. The physical state of dwellings was used as a proxy to suggest the proportion of housing that are less able to withstand landslides and may suffer more damage during a flood.
- ***Adaptive capacity*****.** Adaptive capacity considers how an impacted district (i.e., a district that is exposed to and potentially harmed by the hazard) may be able to cope or adapt. This may include considering what technological, economic, and social means are available to help the settlement deal with the hazard. The adaptive capacity of the settlements is based upon the poverty levels. This metrics was used with the assumption

that settlements with higher poverty rates will be less capable of responding to and/or protecting against the hazard.

This analysis assumes that a district's poverty rates and percentage of housing in poor conditions are applicable to all neighbourhoods in that district as provided in the *Urban, social and economic assessment* and summarized here. In reality, one neighbourhood may be worse off than another within the same district; however, the data are not available at the neighbourhood level. The metrics included in this analysis were used based on the best available information; however, this analyses would have benefited from additional data such as the height of doorways and the materials used for housing construction.

The percent of dwellings in each district that is in "bad" or "very bad" physical state is considered for each District (see Table 5.1). Districts II and III have a higher number of dwellings characterized by poor conditions, while District I has relatively better housing conditions.

Table 5.1 Physical state of dwellings in Estelí (percentage of total dwellings)

Settlement	% of dwellings that is in bad or very bad condition
District I	30.9%
District II	56.5%
District III	43%

The percentage of poverty in each district of Estelí was considered (see Table 5.2). District I has a considerably lower poverty rate compared to Districts II and III. The distribution of the population in Estelí follows a general pattern with more affluent populations are located in the city center (with the exception of an upper middle-class community located at the northeast of the city, within District III), while lower income groups are located along the periphery.

Table 5.2 Poverty rates in Estelí Districts.

Settlement	Poverty rate (%)
District I	22.7%
District II	76.8%
District III	75.1%

Table 5.3 details the rankings used for sensitivity and adaptive capacity. The two metrics for sensitivity and adaptive capacity are ranked from 0 to 4.

Table 5.3 The rankings of sensitivity and adaptive capacity.

Rank	Sensitivity	Adaptive Capacity
0	0 to 20% of dwellings is in bad or very bad condition	Poverty level less than 8%
1	20 to 40% of dwellings is in bad or very bad condition	Poverty level less than 15%
2	40 to 60% of dwellings is in bad or very bad condition	Poverty level less than 20%
3	60 to 80% of dwellings is in bad or very bad condition	Poverty level less than 30%

Rank	Sensitivity	Adaptive Capacity
4	80 to 100% of dwellings is in bad or very bad condition	Poverty level greater than 30%

- ***Vulnerability.*** The vulnerability analysis applies the rankings of sensitivity and adaptive capacity from low (i.e., least vulnerable) to high (i.e., most vulnerable) for the settlements located in each district that are located in flood- and/or landslide-prone areas.

The rankings of sensitivity and adaptive capacity are then used to assess potential vulnerability, as shown in Table 5.4. The suggested responses to the potential vulnerabilities are as follows:

- Low (“L”): Stay attentive to the hazard but not necessarily change current planning and management
- Medium (“M”): Consider developing strategies to curtail impacts and consider enhancing warning systems
- High (“H”): Develop strategies to curtail impact and consider hazard vulnerability in planning.

This evaluation is representative of both the landslide and flood vulnerability analyses.

Table 5.4 Index of potential vulnerability for hazards based upon the rankings of sensitivity and adaptive capacity.

Sensitivity						
	4	M	M	H	H	H
	3	M	M	M	H	H
	2	L	M	M	M	H
	1	L	L	M	M	M
	0	L	L	L	M	M
		0	1	2	3	4
		Adaptive Capacity				

In addition to sensitivity and adaptive capacity, the percentage of population exposed to flooding and landslides in each district is considered. This metrics is presented in Table 5.5 and can be helpful in determining the priority of adaptation actions needed among the three districts. A break-down of the data by neighborhoods within each district is provided in the socioeconomic analysis.

Table 5.5 Percentage of population exposed to flooding and landslides.

Settlement	Number of people exposed to flooding	% of population exposed to flooding	Number of people exposed landslides	% of population exposed to landslide
District I	2,092	5%	1,276	3%
District II	5.634	20%	0	0%
District III	1,782	7%	0	0%

5.3.2 Vulnerability Results

This project focuses on floods and landslides which can be triggered by rainfall. Table 5.6 provides an overview of anthropogenic and climatic impacts that affect floods and landslides. This section investigates the (1) settlements, and the (2) facilities and critical infrastructure that may be vulnerable to these hazards in each district.

Table 5.6 Summary of anthropogenic and climatic stressors of landslides and floods, and a description of the projected change in climate by mid-Century.

	Stressors		Projected climate change
	Anthropogenic Activities	Climatic	
Floods	■ Poor drainage infrastructure. ■ Deforestation of upstream areas in a watershed. ■ Lack of waste and wastewater infrastructure. ■ Paving, construction, and activities which minimize the absorptive capacity of the soil.	■ Prolonged periods of rain ■ Intense rainfall	By mid-Century, both the wet and dry seasons are projected to become drier. Overall, the projected reduction in precipitation may decrease the possibility of flooding. This projection assumes no change in land-use, drainage, and other factors that affect flooding.
Landslides	■ Deforestation and land clearing for urban expansion. ■ Excavation and other activities that remove earth materials from slope-ward areas	■ Slope saturation from intense or prolonged rainfall. ■ Prolonged intense precipitation ■ Flooding	By mid-Century, both the wet and dry seasons are projected to become drier. Overall, the projected reduction in precipitation may decrease the possibility of landslides. The reduced soil moisture due to precipitation decreases may reduce the threat of landslides for unaltered vegetation. However, drying soils may increase the threat of landslides where vegetation has been removed and/or covered by impermeable surfaces.

The future exposure to floods and landslides may decrease as precipitation decreases; however, it is not clear the degree of decrease and how that will impact the exposure (see Tables 5.7 and 5.8).

Districts II and III have the highest vulnerability to the potential decrease in future exposure (see Table 5.7). Additionally, it is important to note that District II has the largest percentage of population exposed to flooding (20 percent). District II also concentrates the largest proportion of dwellings in poor conditions and the highest poverty rate. District I, on the other hand, has the lowest percentage of population exposed to flooding (5 percent) as well as the lowest proportion of dwellings in poor conditions and poverty rate. This suggests a relatively higher urgency of addressing flood risks in District II and lower urgency in District I.

Table 5.7 Summary of districts that are potentially vulnerable to floods.

Settlement	Population	Potential Vulnerability					
		Exposure Today	% of pop exposed	Future Exposure	Sensitivity	Adaptive Capacity	Vulnerability Score
District I	39,498	Y	5%	↓	1	3	**M**
District II	27,510	Y	20%	↓	2	4	**H**
District III	26,476	Y	7%	↓	2	4	**H**

Only a small number of the population in District I is currently exposed to landslide risks, which are projected to decrease in the future (see Table 5.8). The vulnerability of Districts II and III is not presented as they are not currently exposed to landslides.

Table 5.8 Summary of districts that are potentially vulnerable to landslides.

Settlement	Population	Potential Vulnerability					
		Exposure Today	% of pop exposed	Future Exposure	Sensitivity	Adaptive Capacity	Vulnerability Score
District I	39,498	Y	3%	↓	1	3	**M**
District II	27,510	N	0%				
District III	26,476	N	0%				

Figure 5.9 provides an indication of flood and landslide exposure overlaid with the results of the vulnerability analysis by district. All three districts in Estelí are considered moderate to highly vulnerable to floods and landslides.

It is important to note that the city of Estelí has experienced significant urban growth and will continue to expand in the future. The 2005-2015 Urban Development Plan identified four areas for urban expansion in the north, west, southwest, and southeast of the current city boundary. Considering the urban expansion plan with the current flood hazard map, areas to the:

- North are designated for low density residential and economic zones and are at a medium to high threat to flooding.
- West within District III are targeted for high density residential zone and are considered to be at a low threat to flooding.
- Southwest within District I are targeted for low density residential zone and are considered to be at a low threat to flooding.
- Southeast within District II are targeted for medium density residential zone and are considered to be at a medium threat to flooding.

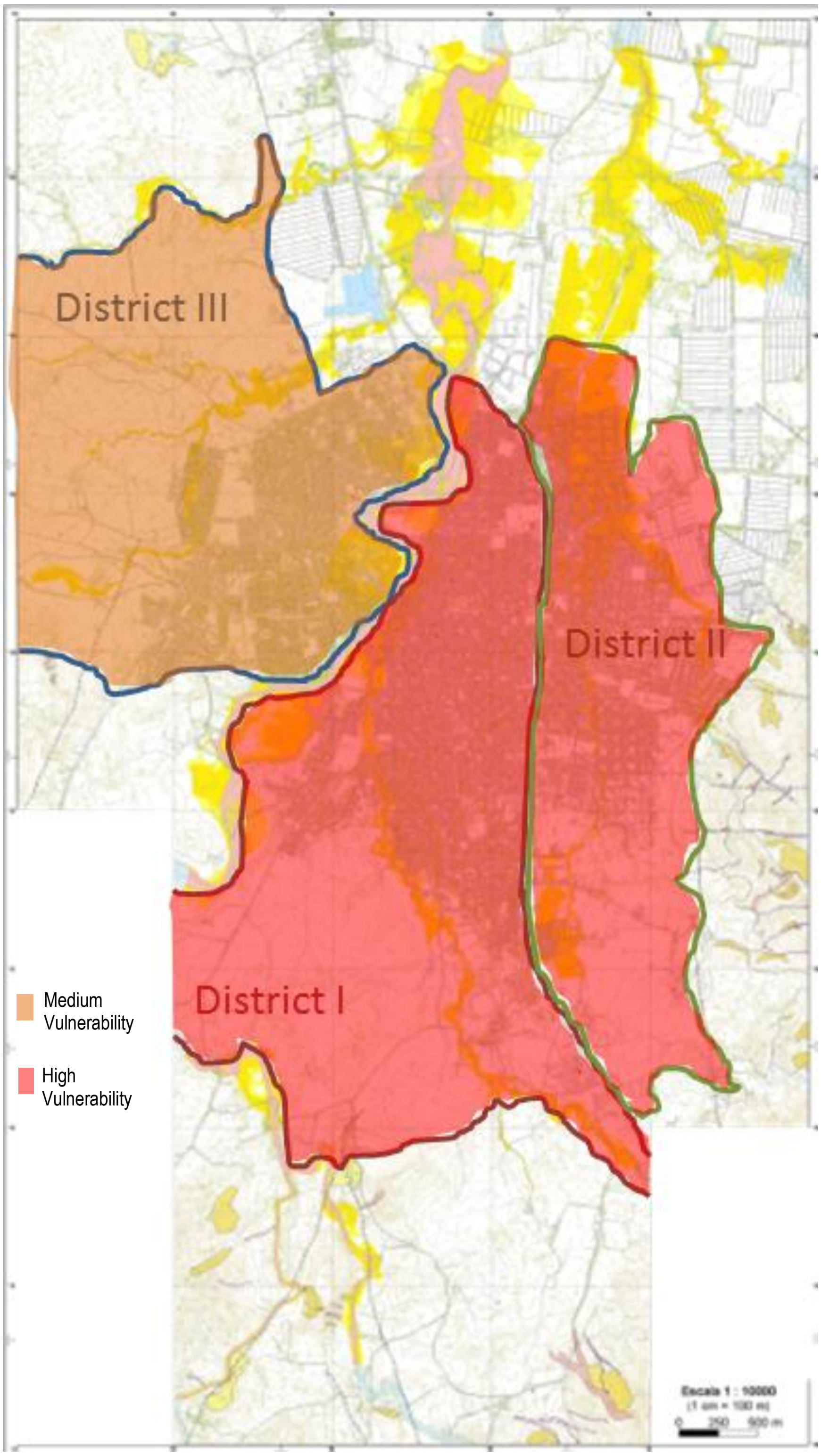

Table 5.9 **Potential vulnerability of settlements within each district prone to flood and landslide hazards. Red shading suggests high vulnerability (District II and District III) and orange shading suggests medium vulnerability (District I).**

5.3.2.2 Facilities and Critical Infrastructure

Though GIS-data of facilities and infrastructure in Estelí was not available, a few considerations regarding infrastructure exposure to floods and landslides can be discussed. Estelí's administrative and business center, which houses most of the city's critical physical and institutional infrastructure, is located on top of a hill. As a result, the city center together with its critical infrastructure is not exposed to any flood and/or landslide hazard risks. The road network, however, is susceptible to floods and landslides. Estelí's roads are not in good condition and lack culverts and storm drains. Flooding and landslide impacts could therefore disrupt the road network and isolate areas of the city or the entire city from the rest of the region. Additionally, lack of sewage infrastructure is a significant concern in Estelí, with more than half of the city's population without access to sewage. The discharge of untreated waste and wastewater into the Estelí River and other ravines in the city has caused serious water pollution and increased the health impacts of flooding.

5.3.2.3 Conclusions

This first-order analysis considered whether areas within the city that are prone to landslides and/or floods are projected to experience worsening conditions by mid-Century. Further, it considered settlement vulnerability within the city to these hazards. This study suggests two findings: (1) exposure to floods and landslides may decrease in the future based upon monthly and seasonal rainfall projections, and (2) settlements located in Districts II and III are the most vulnerable areas to floods. This analysis provides an efficient means to arm decision makers with useful and high-level information to consider whether a more thorough vulnerability and/or risk analysis is warranted. That said, it is recommended additional data be collected and analyses conducted to further explore this important topic.

5.3.3 Considering risk

A risk assessment considers the likelihood of a hazard event occurring (typically expressed in terms of probability) and the magnitude of the consequence if the hazard event occurs. Some studies define likelihood use the probability of the occurrence of a climate hazard (NYCPCC 2009). Our vulnerability analysis incorporated limited primary and secondary data. In order to expand this analysis to consider risk, additional data is needed to develop a quantifiable baseline understanding of the frequency, severity, and triggers of landslides and floods and how these hazards may change over time. In addition, no information was available to consider the impact of these hazards on specific critical infrastructure.

The following studies are suggested for the city of Estelí to continue its development of pertinent risk information:

- This analysis was largely limited by not having the capacity to re-run the hydrologic and hydraulic modelling used to inform the flood maps for the city of Estelí with future climate projections. Future work in this arena is recommended. Though future climate projections cannot reasonably provide estimates of how rainfall may change at temporal scales less than 1 day (e.g., rainfall rate of mm per hour), changes in daily rainfall can generally be useful for these studies along with potential changes in other environmental conditions such as changes in soil moisture.
- Enhance the vulnerability assessment by determining important precipitation thresholds (e.g., an intense rain event following an unseasonably wet season) that are statistically correlated with landslides and/or flood events. These thresholds would need to be at no finer a spatial resolution than daily in order to develop consistent climate projections of how these thresholds may change in the future. Using these climate projections, changes in exposure to landslides/floods may be considered. In addition, the models used to develop today's flood maps could be used to simulate future floods by driving the models with the climate model ensemble future return periods. However, the findings of such a study can be insightful but are hampered by the greater uncertainty associated with projecting extreme events compared to projecting monthly and annual changes in rainfall.
- The vulnerability assessment could be enhanced by incorporating additional metrics describing sensitivity and adaptive capacity. For example, the height of the doorway floorboard may be useful in determining susceptibility to floods. In addition, considering how the values of these metrics changed with future time would create a more dynamic analysis.

- Developing GIS-data of infrastructure would help identify which infrastructure are located in flood and landslide prone areas, likely focusing on the sewer system and roadways. Next, selection criteria could be developed to determine which of the infrastructure that is exposed to the hazards is critical (e.g., is the roadway an emergency evacuation route). Of the critical infrastructure, a drilled-down vulnerability analysis specific to that infrastructure could be developed.

The choice of which activities to undertake depends on the concerns and stakeholder understanding of the hazards within the city of Estelí.

6 Strategic climate adaptation investment and institutional strengthening plan

6.1 Introduction

Estelí is susceptible to floods but landslides do not represent a big threat in the city. During the rainy season, flooding results from the overflow of the Estelí River and its tributaries that run through the city. The climate assessment analysis illustrates that temperature is projected to increase in the future, while both the total precipitation and the rate of precipitation for the dry and wet seasons are projected to decrease. The decrease in precipitation can reduce threats of floods and landslides. However, the uncertainty in precipitation projections, particularly associated with extreme events, and other non-climate factors that affect flood and landslide risks need to be considered in applying these conclusions. Linking the potential climate projections to the way urban development is taking place is essential in understanding the possible effects that climate change could have in Estelí. Although climate projections do show a potential decrease in precipitation and a rise in temperature, which might result in a decrease in flood and landslide risk, the trends in urban development could actually lead to risk remaining constant or increasing.

Estelí is experiencing strong demographic growth and urban expansion. Poverty has gone hand in hand with growth in the city. This has affected the level of exposure to climate change hazards: urban development has often occurred in an unplanned manner, with low-income populations settling in risk areas, notably in proximity to water streams. The way in which urban development takes place thus constitutes a major challenge for Estelí. Guiding urban growth, controlling settlement in risk areas as well as the provision of basic urban services are essential in establishing a pattern of resilient and sustainable urbanization in the city.

The purpose of the *Estelí strategic climate adaptation investment and institutional strengthening plan* is to identify and then to prioritize short-, medium- and long-term adaptation interventions aimed at enhancing resilience to flooding and landslides in Estelí.

6.2 Approach and tools for adaptation planning

The preceding *Climate-related vulnerability assessment* provides the basis from which to identify and prioritize a set of strategic climate adaptation investments and institutional strengthening interventions that can be linked or incorporated into existing priorities, sector plans and planning instruments in Estelí.

Engagement with national and local level stakeholders and decision-makers during the execution of the assignment was a very important feature which helps ensure coherence with national and local priorities and to tailor measures to fit needs. A strategic, longer term view is proposed, coupled with action planning on a shorter time horizon in the short and medium term.

The plan draws accordingly on the conclusions and the feedback obtained during a workshop held in Estelí in March 2013. The feedback served to validate assessment findings, update or readjust them and establish a set of specific actions to be proposed based on the needs and major issues identified by stakeholders. This process helps ensure that the proposed climate change adaptation measures can be mainstreamed within the policy and institutional framework, and form part of an overall climate change adaptation strategy for Estelí.

Climate change adaptation planning is a key element of urban planning since it sets out a range of responses that can be implemented to enable communities to ‘adapt’ and become more resilient to climate-related change. Resilience is broadly defined as the ‘ability to absorb or off-set damage and so avoid lasting harm and recover to pre-disaster status.’ (da Silva et al., 2012) In the context of climate change, a more resilient system (i.e., a city) has the ability to withstand higher threshold limits in specific events, such as floods and landslides.

The steps taken to develop the *Strategic climate adaptation investment and institutional strengthening plan* for Estelí were:

1. Identification of urban planning, physical, socio-economic and institutional challenges and shortcomings related to flooding and landslides, drawing from the four assessments carried out under the project.
2. Definition of planning themes that create the foundation for a climate change adaptation strategy.
3. The planning themes lead to specific structural and non-structural measures which can be implemented in Estelí to manage and reduce flooding and landslide vulnerability and risk. These measures are presented in Table 6.1 and Table 6.2. Table 6.3 positions the measures within the disaster risk management (DRM) cycle.
4. Finally, a set of specific actions that can be undertaken to implement adaptation measures are proposed. These actions are presented in Table 6.4, which specifies:
   - The targeted area in the city: the area/s where the action can be enacted.
   - The institution responsible for enacting the action: this identifies the institution or institutions that have a responsibility for the proposed action.
   - The timeframe for its implementation: this allows providing a prioritization spectrum. Short-term actions are the issues with the highest priority; long-term actions are the issues with lower priority, or with high priority but with longer-roll out times.
   - An estimation of its relative cost: this is meant to give estimation on the resources to be allocated for the implementation of the action.

In the process of planning and implementation, the uncertainty associated with climate projections and its implications requires addressing, as Box 9 below describes

Box 9 Dealing with uncertainty: addressing the risk of maladaptation

Ranger et al (2011) point out that as a degree of uncertainty is incorporated in climate projections, uncertainty is also embedded within the climate change adaptation process.

If policy-makers need to make investment decisions that will have a direct impact in the future capacity of a city to adapt to climate change, and uncertainty is embedded within the decision-making process, policy-makers face a significant challenge: *How to plan and decide on what will best help in constructing the city's resilience to climate change when the information available to advise on decision-making is limited and/or unclear?*

The major risk of not taking uncertainty into account is to take decisions that expose a society to maladaptation. This occurs when unsuitable investments are made for addressing the climate changes that actually do happen.

There are two forms:

- Under-adaptation: when the actions and adjustments made are not enough to deal with the climatic changes that do occur. For example, needing significant financial resources for replacing infrastructure built prematurely and found unsuitable to address climatic changes can be regarded as under-adaptation.
- Over-adaptation: when the adjustments made initially prove to be unnecessary, but later on they are either not adaptive or counter-adaptive. For example, when considerable financial resources are put into building a sea defense meant to withstand a sea level rise of 4 meters, but this change does not happen and the infrastructure is found unsuitable.

In dealing with maladaptation, the integration of adaptation considerations into existing planning and policy priorities can be seen as a major asset. Incorporating adaptation into the overall development process can allow the proper addressing of the existing needs of a city. The rationale is to focus on principles rather than projections. If adaptation is integrated not as an independent characteristic but as a constitutive element spanning across an integrated development strategy, the possibility of delivering an appropriate strategy taking into account present uncertainties is increased.

Furthermore, a core feature of integrated planning is to build flexibility into adaptation strategies by prioritizing long-term adaptive capacity while avoiding inflexible decisions: here, the need to have a decision support tool allowing stakeholders to make "robust" investment choices in a context of uncertainty has been advanced (Lempert et al., 2010).

"Optimal" solutions stand in contrast to "robust" ones. An "optimal" solution is only adapted for an expected future, but might be inappropriate if conditions change. "Robust" solutions might not be optimal, but they are appropriate no matter the conditions that are encountered in the future. Allowing the incorporation of new information to guide decision-making allows the effective design of an adaptation strategy in which flexibility and robustness are embedded as core elements.

6.3 Strategy and adaptation measures

Overall goal

The overreaching goal of the strategic plan is to increase resilience to floods and landslides in Estelí. On the basis of planning themes, specific measures to address particular urban development challenges as well as institutional shortcomings are identified. These measures also promote a more sustainable and resilient urban development process.

From goal to planning themes

The potential planning themes that create the foundation for a climate change adaptation strategy to help Estelí build its resilience against floods and landslides, both now and in the future, can be outlined as follows:

- **Investment in drainage, sanitation and waste removal services, and improved implementation of land use and urban planning laws:**
  - Improvement of access to public basic services and of municipal functions in Esteli.
  - Identification and incorporation of urban vulnerability and demographic groups at risk from climate-related hazards in planning strategies
  - Consideration of urban expansion and future demographic trends, as well as physical and climate vulnerabilities in land use management.
- **Capacity building in city level government institutions engaged in climate change planning and risk management:**
  - Improvement of human resources capacity and infrastructure for the successful implementation of climate adaptation practices and policies.
- **Mechanisms for data collection, storage and dissemination to be created and/or improved for better climate monitoring, risk planning, and information sharing:**
  - Improvement of information, communication and policy relevant technical knowledge for assisting local actors to identify and understand impact, vulnerability and adaptation responses in order to effectively select and implement practical and high priority adaptation measures.
- **Improved budgetary resources and climate financing for long-term recovery and building resilience against climate change hazards:**
  - Improved funding capacity and financial resources to enable strengthening of the institutional capacity of risk management organizations.
  - Formalized structures of cooperation with the private sector in planning and risk reduction phases for sustained and meaningful engagement.

- **Cross-scale integration of risk management practices:**
  - Promotion of local level participation in climate change adaptation and risk reduction.
  - Initiatives to engage the public and local stakeholders in adaptive actions and to improve citizen awareness regarding floods and landslides to consolidate institutional and local adaptation and provide a more holistic approach to climate change planning.
- **A shift from disaster management to long term risk reduction and climate change adaptation to ensure a proactive and forward-looking system of risk governance:**
  - Supporting efforts towards mainstreaming climate change adaptation from policy into development practice and programmes.

From planning themes to measures

An integrated strategy requires the use of both structural and non-structural measures for “getting the balance right” (Jha et al., 2012).

Flood and landslide risk management measures can be either structural or non-structural. In broad terms, structural measures aim to reduce risk by controlling physical processes – such as the flow of water – both outside and within urban settlements. They are complementary to non-structural measures which aim at keeping people safe from flooding or landslides through better planning and management of – in this case, urban – development. More narrowly:

- **Structural measures:** refer to physical investments that a city can institute in order to prepare its built environment for the expected effects of climate change. Structural measures are often costly investments in hard-engineered infrastructures.
- **Non-structural measures:** refer to investments other than the improvement of physical infrastructure. These measures are often less costly than structural measures, and span a wider spectrum, covering urban (for example, planning), socio-economic (for example, poverty reduction) and institutional (for example, educational campaigns) dimensions.

Tables 6.1 and 6.2 which follow present a series of disaster and climate change-related adaptation measures which can be implemented in Estelí to manage and reduce flooding and landslide risk and vulnerability to these hazards – and, in so doing, enhance overall urban resilience.

Each measure is briefly described and the anticipated co-benefits over and above their flood and landslide management role are sketched.

In order to present a forward-looking view and allow the prioritization of adaptation options, two ratios are also considered:

- **Benefits relative to costs:** to allow an understanding of how the costs inherent to the measure compare with the expected benefits.
- **Robustness to uncertainties:** robustness refers to the way in which the benefits of an adaptation measure might vary with climate projections. It can be regarded as the risk of maladaptation. For example, on the left hand-side of Figure 6.2 are found “no-regret measures” (measures that will have a positive effect on adaptation, no matter the accuracy of climate projections, as for example, with awareness campaigns). On the right hand-side are located “higher-regret” measures, whose benefits are dependent on the accuracy of climate projections (for example, drainage systems or flood defences).

It is important to highlight that the robustness and cost-benefit ratios of measures are established on a case-by-case basis. It is also acknowledged that costly, long-term projects should seek “no-regret” ways to build in flexibility in order to address potential uncertainty.

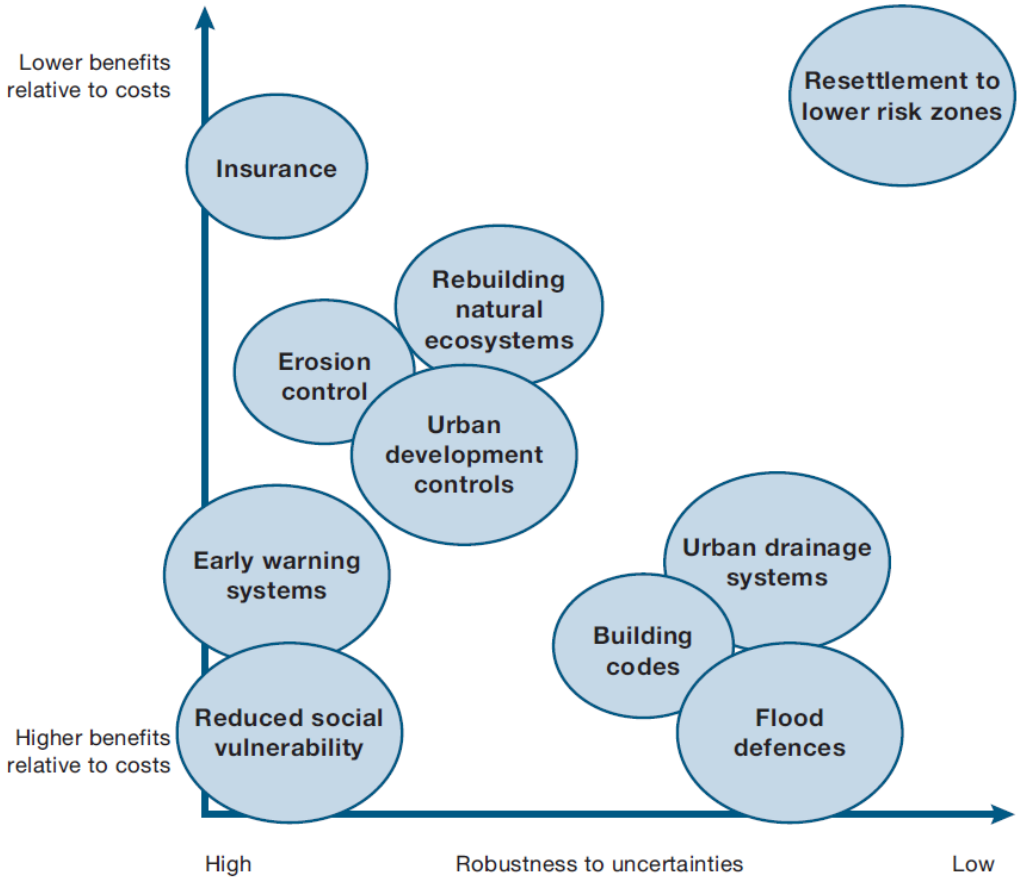

Figure 6.1 Relative costs and benefits of flood management options (based on findings for Guyana, Mozambique and UK). Source: Adapted from Ranger and Garbett-Shields 2011, in Jha, A., Bloch, R., and Lamond, J. (2012).

Table 6.1 Structural measures

Climate changes	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
■ Temperature is projected to increase ■ Total precipitation and rate of precipitation for the dry and wet seasons are projected to decrease	■ Flooding due to precipitation ■	**Investment in the city's rain water treatment infrastructure**	Stakeholders acknowledged that the city's lack of a rain water treatment system was a major challenge in flood risk management. The concentration of rain water can lead to flooding in streets, resulting in major devastation. A better connectivity with the sewage infrastructure was advanced as a possible solution: increasing water captivity, and improving its guidance and storage could improve flood risk management. Stakeholders mentioned that a rain water treatment masterplan was developed. However, they recognized that there is a lack of financial resources for its implementation. Investment is needed to improve the city's rain treatment infrastructure.	■ Improved connectivity with the sewage system ■ Increased flood-risk management capabilities	Moderate	Low

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Table 6.2 Non-structural measures

Cali	Potential impact	Measure	Challenge – and solution	Co-benefits	Benefits relative to costs	Robustness to uncertainties
■ Temperature is projected to increase ■ Total precipitation and rate of precipitation for the dry and wet seasons are projected to decrease	■ Flooding due to precipitation	**Enhance the implementation of zoning and land use planning instruments**	Zoning is defined as land use regulations and planning. As a planning instrument, zoning is meant to guide urban expansion: it can orient urban development away from high-risk areas. In Estelí, urban growth is the result of rural-urban migration: low-income newcomers often settle in high-risk areas through spontaneous land invasions. Unplanned growth and incompatibility in land use are acknowledged as major urban development issues influencing exposure to climate change hazards. These issues are all the more worrisome as growth is expected to continue in the city, and the remaining available land for expansion is limited. Thus, there is a recognized need of enhancing the implementation capabilities of zoning and land use planning instruments. This would enable the establishment of a more sustainable pattern of urban development, ultimately resulting in improved urban resilience. During the workshop, three main points were raised in this: **Implement a resettlement process:** there is a need to legalize informal dwellings located in areas where risk can be managed and resettle populations living in zones where risk cannot be managed. **Avoid expansion in risk areas:** in order to contain unplanned urban growth which exacerbates hazard exposure, measures need to be taken in order to avoid the settlement of population in risk areas. As an example of measures to be implemented, stakeholders mentioned planting trees along river banks. This would avoid dwellings to appear and enhance the environmental protection of rivers as well as create new green areas in the city. **Enhance planning regulations:** currently, all planned settlements are approved by the Municipality. There was consensus that efforts should be put into guaranteeing that this becomes the norm for all new settlements. This would help ensure sustainable expansion and the provision of basic urban services.	■ Liveability of cities ■ Structured urban growth ■ Enhancement of the physical conditions of urban dwellings ■ Better provision of urban services ■ Increased resilience	High	High

	Prioritize and enhance civil society's awareness to risk	Stakeholders recognized the need to improve civil society's awareness of risk. It was acknowledged that education was the first step for a better understanding of risk, the possible consequences it can have, and the deployment of attached prevention and mitigation strategies. Various measures were advanced to launch a risk awareness: Stakeholders mentioned the possibility of **using means of communications, notably the radio**: radio shows specifically targeting risk could be accessed by a large proportion of the population and thus expand public awareness of risk. Stakeholders also focused on the need of **enhancing environmental awareness campaigns**, such as "Vivir Limpio". Estelí suffers from severe pollution issues: waste management is not addressed appropriately, which creates the accumulation of waste in streets and rivers. This can result in an exacerbation of flooding, when such events do occur, as the over-accumulation of waste impedes the appropriate flow of water. As such, improving education and allowing the population to be aware and the actions they can take for better managing waste could prove essential in reducing risk**.**	■ Better understanding of risk ■ ■ Increased environmental conditions ■ ■ Increased deployment of risk prevention and mitigation measures	High	High
	Enhance institutional capabilities through the establishment of COCPREDs in each neighborhood	Although Estelí has high DRM response capabilities, stakeholders acknowledged that the city would benefit from expanding the COMUPRED's network through establishing COCOPREDs (Community Committees for Disaster Prevention and Attention) in each neighbourhood (currently two are in operation in the city). It is believed that this would not only contribute to the aforementioned need of enhancing the population's awareness on risk; it would also engage local communities in preparedness and action while strengthening institutional aptitudes in dealing with disasters. Various benefits are perceived: **Improve the local presence of the DRM system:** engaging local communities in the preparation and implementation of DRM strategies can enhance the knowledge and needs of potentially affected populations. This would help design more appropriate measures, while engaging the local population and making it play a more central role in the system. **Enhanced access to information and a better understanding of how the DRM system operates:** there is an acknowledged need to make the population aware of COMUPRED's structure and operational plan, as well as the location of both the risk areas in the city and the location of shelters.	■ Enhance the population's engagement in the DRM system ■ Increased assessment of local needs and problems ■ Improved access to information and better understanding of the operation of the DRM system ■ Increased institutional capabilities: institutional strengthening.	Moderate	High

	A shift from disaster management to long term risk reduction and climate change adaptation	Stakeholders mentioned that in people's minds, climate change is not perceived in everyday life. Rather, it is only perceived in major meteorological events and their devastating effects. The current DRM system is designed following the aforementioned logic. **The DRM system in Estelí is reactive and response-led**: the focus is on the coordination of actions and the elaboration of strategies when a disaster does occur. A shift from disaster management to long term risk reduction and climate change adaptation would address the roots in climate change hazards: if climate change is framed as an issue occurring and having possible consequences every day, this would also call for immediate and daily action. The system would no longer be **reactive but proactive**: it would act in such a way as to target the causes that create exposure to climate hazards in Estelí. Strategies that would lead to a long-term reduction of risk could then be properly developed. In this, a **reconfiguration of the political structures** dealing with climate change might prove useful. Currently, there is not a structure having climate change planning as a single mandate: climate change action is jointly undertaken by Civil Defense and the Environment Department at the Municipality. **Establishing an institution whose main objective would be to deal with climate change** would not only render this more visible within DRM; it would also allow a better implementation of climate change adaptation strategies.	■ Change the local population's perception of climate change: climate change as a daily process with consequences occurring every day. ■ Shift from a reactive and response-led system to a proactive system. ■ Creation of a political structure with a mandate in climate change: increased visibility of climate change as an issue in the DRM system. ■ Institutional strengthening	High	High
	Improved budgetary resources and climate financing	Stakeholders recognized that the city's limited financial capabilities are a major challenge in any possible actions to be undertaken in climate change adaptation. Whether it is for financing new infrastructure, expanding the local DRM system, or engaging new actors in it, Estelí is confronted with a lack of resources. This is not to be underestimated, as it could hinder the potential long-term capacity to address climate hazards. Increased resources for climate finance could thus help the city expand its capabilities in coping with climate change hazards. Specific municipal budget allocations in climate change would enhance the city's capacity in designing strategies targeting a particular output in climate change adaptation action. The underlying question is to figure out where the new resources could come from. Innovative solutions involving different scales in government, including local and national authorities, might be necessary to ensure that possible increased budgetary allocations are at disposal.	■ Enhanced capabilities in designing climate change adaptation actions ■ Capacity-building ■	Moderate	High

	Increased involvement of civil society actors (universities and private sector) in climate change adaptation strategies	Stakeholders acknowledged that the involvement of various civil society actors could be improved. This would allow the establishment of a more integrated and participatory strategy in climate change adaptation and the DRM system overall. Stakeholders specifically targeted: **Universities:** Estelí benefits from the presence of five universities. Nevertheless, the institutions don't often run programs and research in climate change. There could be a **potential added value from encouraging research in climate change and incorporation the lessons and conclusions from already existing programs.** The private sector: engaging private sector stakeholders in climate change adaptation through a Corporate Social Responsibility (CSR) scheme. Stakeholders acknowledged that private companies, notably in the tobacco industry, undertook innovative measures in climate change adaptation and mitigation. Lessons could be drawn from this and applied to create a stronger, more integrated climate change adaptation action.	■ Moderate	Moderate

Proposed measures and the disaster risk management (DRM) cycle

Under the disaster risk management (DRM) cycle, the structural and non-structural measures above can also usefully be classified as: (i) risk reduction, (ii) risk transfer or share, (iii) preparedness, and, (iv) response and recovery (Mitchell and Harris, 2012). Table 6.3 below locates the proposed structural and non-structural measures in the DRM cycle.

Table 6.3 Risk management options

Risk reduction (preventing hazard/shock, reducing exposure and vulnerability)	Risk transfer or share	Disaster preparedness	Disaster response and recovery
Investment in the city's rain water treatment infrastructure		Prioritize and enhance civil society's awareness to risk	
Enhance the implementation of zoning and land use planning instruments		Enhance institutional capabilities through the establishment of COCPREDs	
		Increased involvement of civil society actors (universities and private sector) in climate change adaptation strategies	
	Improved budgetary resources and climate financing		

6.4 Action plan

Table 6.4 presents a set of specific actions that can be undertaken to implement climate change adaptation measures. It illustrates the areas targeted by the action, the institution responsible for putting it in place and give it life, the expected time-frame (short, medium, or long-term), as well as the relative costs. The purpose of this is to present strategic planning initiatives that the city could consider and how these could be implemented.

Table 6.4 Estelí action plan

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
Enhance the implementation of zoning and land use planning instruments	Implement a resettlement process in areas where risk cannot be mitigated and legalize informal dwellings in areas where risk can be managed	■ City-wide; particularly: ■ Esteí river river banks ■ El Zapote river river banks ■ El Zanjón de los Cedros river banks	■ Urban Planning Department ■ Environment Department ■ Civil Defense				Moderate to high
	Avoid expansion in risk areas: contain unplanned urban growth in zones with strong risk hazard						
	Enhance planning regulations: put efforts into making sure that all new settlements go through municipal monitoring and approval						
Prioritize and enhance civil society's awareness to risk	Launch radio programs on risk: the radio is the most accessible means of communication and could be used as an instrument to reach out to vulnerable and marginalize populations and inform them on risk and the actions they could take	■ City-wide	■ Environment Department ■ Civil Defense				Low
	Enhance environmental awareness campaigns: improving education and allowing the population to be aware of the actions they can take for better managing the natural environment, notably solid waste, could prove essential in reducing risk						
Enhance institutional capabilities in the DRM system	Establish COCOPREDs in each neighborhood: engage local communities in the preparation and implementation of DRM strategies	■ City-wide: prioritize neighborhoods	■ COMUPRED				Moderate

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
	Improve access to information: better inform the population on the COMUPRED's structure and the location of shelters	with non-existing COCOPREDs.					
Investment in the city's rain water treatment infrastructure	Work on enhancing the connectivity with the city's sewage infrastructure	■ City-wide. Focus on at-risk neighbourhoods with non-existence or low rain drainage capabilities.	■ Public works department ■ Urban Planning Department				Very high
	Prioritize the maintenance of the existing sewage system						
A shift from disaster management to long term risk reduction and climate change adaptation	Work towards changing the DRM system from a response-led approach to a proactive approach	■ City-wide	■ COMUPRED				Moderate
	Establishing an institution whose main objective would be to deal with climate change						
Increased involvement of civil society actors (universities and private sector) in climate change adaptation strategies	Encourage university research in climate change and incorporate lessons and conclusions from already existing programs into planning strategies	■ City-wide	■ COMUPRED				Moderate
	Engage private sector stakeholders in climate change adaptation through a Corporate Social Responsibility (CSR) scheme						

Measure	Action	Targeted neighbourhoods (or broader locations)	Institutional responsibility	Schedule			Relative costs
				Short-term (1-5 years)	Medium-term (5-10 years)	Long-term (10-20 years)	
Improve budgetary resources for climate financing	Enhance the allocation of resources in municipal budgets for climate change action	■ City-wide	**City level** ■ COMUPRED ■ Urban Planning Department ■ Environment Department ■ Civil Defense **National level** ■ MARENA ■ SINAPRED				Moderate
	Work across municipal departments and collaborate with national level institutions to find new ways of financing climate action						

6.5 Conclusion

Climate change adaptation is a continuous process: the adaptive capacity of a city can be constructed and enhanced over time, through various measures in different time-scales (short-term, medium-term, long-term). The *Estelí Strategic Climate Adaptation Investment and Institutional Strengthening Plan* presented an overview of the strategies that the city can adopt to strengthen its capabilities in climate change adaptation planning.

Given past catastrophes, notably Hurricane Mitch in 1998, Estelí has already taken significant steps in enhancing its capabilities in disaster risk management. The city of Estelí has a high coordination capacity for organizing logistics and response procedures in a disaster emergency. There is also accurate local knowledge of vulnerable populations and infrastructure.

In addition, Estelí has made progress in establishing planning instruments attempting to control urban expansion and guide urbanization processes. However, although there is awareness regarding the at-risk areas in the city, risk hasn't been fully integrated into land use planning. At the same time, the disaster risk management system is limited by a lack of resources, primarily financial but also human and physical, as well as weak infrastructure and essential services in the city. Future efforts to promote climate change adaptation and planning will need to build on the strong local coordination networks in Estelí by providing financial and technical support for increased institutional capacity.

As part of the adaptation planning process, it was attempted to frame adaptation within overall development priorities. This was largely conducted by paying strong attention to the way in which urban expansion is taking place. Studying the drivers of urbanization in Estelí helps to better understand the linkages between urbanization, economic growth and poverty. As seen in this report, Estelí has become a major industrial hub in northern Nicaragua and it is this strong economic dynamism that triggers urban-rural migration. However, given the lack of planning instruments and persistent poverty, populations often locate in risk areas. Vulnerability to climate-related hazards, such as floods and landslides can be significantly reduced if climate change adaptation is linked or incorporated into existing priorities, sector plans and planning instruments in Estelí.

The main challenge for policy- and decision-makers is to implement a climate change adaptation process that considers the trade-offs between current development priorities and long-term climate risks and embraces uncertainty, as the timing and scale of local climate change impacts affects the types of measures to be adopted and prioritization of investments and action. In the end, the ability and willingness of key actors to address climate change impacts will be of utmost importance.

7 References

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ANNEXES

Annex 1 Methodology of hazard assessment

This analysis utilized existing resources used by Estelí government to consider how flood and landslide hazards may change by mid-century (2040s and 2050s). To effectively inform future urban planning, it was important that this approach be appropriately aligned with the available local data and tools. The steps taken to consider how climate changes by the 2040s may impact the timing and frequency of future landslide and flood events included:

1. Review available information describing the physical system such as hydrology and geomorphology to understand the drivers that affect landslides and floods.
2. Collect and investigate data on past landslide and flood events in Estelí to assess the degree of impact per event and the conditions that precipitate events.
3. Assess available resources used by the municipality to describe zones susceptible to landslides and floods, and to inform emergency planning.
4. Assess and process available future precipitation and temperature data for mid-century.
5. Assess and perform the application of three distinct approaches that consider how climate change may impact the resources examined in Step 3.

Each step is discussed in greater detail below.

Step 1: Review the physical system. It is important to first understand the physical system specific to Estelí that affects the nature and location of landslides and floods. To do this, the thematic maps of local terrain, geology, and hydrology developed by the Estelí government were reviewed.

To investigate local climate, two data sources were analysed:

- Monthly temperature and precipitation data from 1970 to 1988 for the Estelí station summarized in Corrales (2005) were used to present averages of monthly precipitation and temperature.[10]
- Literature review summarizing observed trends for Nicaragua.

The lack of meteorological data limits this analysis. Given that no contemporary observational data are available for Estelí, it is not possible to investigate the meteorological conditions that have triggered floods in the past to expose relevant environmental thresholds.

The results of this step are presented in Section 2.3.

Step 2: Catalogue past events. A collage of past flood and landslide events was compiled based on: (1) discussions with stakeholders during the field visit; (2) government reports; and (3) online material including local newspaper reports. This information was collected to explore answers to these specific questions: Do floods and/or landslides occur concurrently? Have floods and landslides occurred in the recent history? Is the hazard more apt to occur during specific times of year? Is there regularity to the occurrence of the events or is the time series of events punctuated by a few events over a long time period? Answers to these questions helped illuminate the flood and landslide trends in Estelí. This step was limited based on the minimal information available.

The results of this step are presented in Sections 2.4 and 2.5.

Step 3: Review flood and landslide resources. As this analysis is to inform planners, planning and emergency management resources were collected which are used by the local stakeholders to gage landslide and flood hazards. Using these resources allowed this analysis to be developed drawing from sources of information that local planners are intimately knowledgeable with. The tools collected for Estelí include flood and landslide maps (there were no recorded and available information linking emergency response to meteorological conditions). The methodology supporting these maps was reviewed with particular attention to how (and if) precipitation was used. For example: Is the flood and/or landslide early warning system triggered by a specific precipitation threshold? Were the flood and/or landslide hazard maps developed based on precipitation metrics?

[10] The exact location of this station within Esteli is not provided.

Discussion of the findings of this step is presented in Sections 2.4 and 2.5.

Step 4. Assess climate projections. Sources that provide precipitation and temperature projections were reviewed. For replicability across other cities and as no locally tailored data was available, data sources that provide global projections of climate were considered.

Considerations in identifying and developing appropriate projections. The following approach was adopted to develop robust projections from the available projections to inform this analysis (see Box 10 for term definitions and additional discussion of uncertainty in climate projections):

- **Time period:** This analysis required mid-century data, preferable centered around the 2040s.
- **Spatial scale:** The data sources of climate projections available included global climate model projections with and without the application of statistical downscaling (i.e., the 2040s projections were constructed from the global climate models, while the 2050s projections use global climate models that have been statistically downscaled to the Estelí region).
- **Natural Variability:** To reduce this uncertainty, 30-year averages are preferred centered at the 2040s; however, only 10-year averages were readily available for the 2040s. To address natural variability, 30-year averages were also provided centered at mid-century (2050s).
- **Model uncertainty:** To reduce the contribution associated with model uncertainty, projected change was calculated as an average for the climate model ensemble (i.e., the average values across all climate model results for a given emission scenario). This is consistent with the approach recommended by the broader community of climate scientists as the most robust indication of how climate may change in the future when considering adaptation responses (Knutti et al., 2010). To illustrate the range of values projected across the climate models, additional analysis as described in the paragraphs below were also undertaken.
- **Scenario uncertainty:** Given it is unclear how global society may evolve over the coming decades, this analysis considered low (B1) and moderately-high (A2) greenhouse gas emission scenarios for developing potential futures.

To assess the disparity in the magnitude across the suite of climate model projections, additional information is provided including: the maximum and minimum projections and the values at one standard deviation from the climate model ensemble average. When possible, the lower and upper values associated with one standard deviation from the climate model ensemble average represent approximately 68 percent of the projections simulated across the climate models. If the lower and upper values are far from the climate model ensemble average, then there is a large spread across the projections.

Box 10 Uncertainty in climate projections

There is considerable confidence in the capability of climate models to simulate temperature projections[1] particularly at the continental scale, but less confidence in climate models ability to project precipitation. This difference in confidence should be qualitatively considered when incorporating risk and vulnerability assessment results into future planning.

There are three main sources of uncertainty in climate model simulations:

1. Natural variability (the unpredictable nature of the climate system)
2. Model uncertainty (the ability to accurately model the Earth's many complex processes)
3. Scenario uncertainty (the ability to project future societal choices such as energy use)

The relative contribution of each uncertainty component to the climate model simulation's overall uncertainty varies with time. In the near term, Hawkins and Sutton (2009) suggest scenario uncertainty is relatively minimal while model uncertainty and natural variability are dominant contributors by near-term and mid-century. These uncertainties also change relative to each other for projections on different spatial scales. Natural variability becomes a greater source of uncertainty at finer scales. This is one reason why incorporating downscaled projections expands the potential uncertainty in climate projections.

There are a few methods adopted within the climate modelling and impact science community to capture the breadth of uncertainty associated with each of the three main sources. To understand the uncertainty associated with natural variability, climate model results may be averaged over long-term periods of time (e.g., 30 years) or driven with variations in input data to simulate various sources of natural variability differently. A collection of results across climate models that rely on variations in parameterizations and other components within climate models can provide some breadth of the uncertainty component associated with climate models. And considering various emission scenarios reflecting differences in how our society may change in the future provide some degree of quantification of the scenario uncertainty.

Climate datasets used in the analysis. Two scenarios were developed for this analysis. For simplicity, this analysis refers to the climate model ensemble mean under the B1 emission scenario as Scenario 1 and the climate model ensemble mean under the A2 emission scenario as Scenario 2 (see Box 11).[11] These emission scenarios were chosen as they provided projections for low and moderately-high emission scenarios and were readily available from a number of sources across a number of climate models. For this analysis, all projections are considered equally plausible.

Box 11 Scenarios for this analysis

Scenario 1: The climate model ensemble average under the low (B1) emission scenario.

Scenario 2: The climate model ensemble average under the moderately-high (A2) emission scenario.

For this analysis, we collected two sets of projection data:

- Annual and seasonal projections of precipitation and temperature for the two Scenarios were gathered from the website managed by United Nations Environment Program (UNEP) and United Nations Development Program (UNDP) for the 2040s relative to a 1970 to 1999 baseline (McSweeney et al., 2010). This data provides projections of 15 global climate models under two emission scenarios (see Table A1.1).[12]
- Monthly precipitation and temperature projections for mid-century for 16 global climate models were collected from climate wizard for the two Scenarios (Givertz, 2009) (see Table A1.1).[13]

Table A1.1 Catalogue of climate projections used in this analysis.

Dataset / Report	Precipitation Projections	Downscaled?	Spatial Resolution	Emission Scenarios	Climate Models
				■	
Climate wizard[14]	Monthly (2050s)	Yes	50 km	■ B1 ■ A2	Statistically downscaled 16 global

[11] The A2 emission scenario family has population that continuously increases and regional economic development with technology change more fragmented than other scenarios. The B1 emission scenario describes a global population that peaks in mid-century and declines thereafter, and an emphasis on global solutions to economic, social, and environmental sustainability. The A1B emission scenario describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies without relying too heavily on one particular emission scenario (IPCC, 2007).

[12] As recommended by the scientific community, this analysis considers the average across model grid cells around the Esteli study area (i.e., not just at the grid cell that overlays Esteli). This increases the statistical confidence of the results (Girvertz, 2009).

[13] Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (Meehl et al., 2007), were downscaled as described by Maurer et al. (2009) using the bias-correction/spatial downscaling method (Wood et al., 2004) to a 0.5 degree grid, based on the 1950-1999 gridded observations of Adam and Lettenmaier (2003). This dataset is for the 2050s (averaged from 2040 to 2069) compared to a 1961 to 1990 baseline. The 2040s datasets were not available.

Dataset / Report	Precipitation Projections	Downscaled?	Spatial Resolution	Emission Scenarios	Climate Models
(Girvetz, 2009)					climate models used to inform the IPCC Fourth Assessment
UNDP[15] (McSweeney et al,. 2010)	Annual, Seasonal, Extreme Events (2040s)	No	250 km	■ B1 ■ A2	15 global climate models used to inform the IPCC Fourth Assessment

The projected changes in climate based upon these datasets for the two scenarios are provided in Section 2.6.

Step 5. Assess approaches to consider climate change impacts on floods and landslides. As described below, three approaches were considered and the viability of implementing each one based on available information was tested:

- **Approach 1.** This approach identifies and investigates the development of flood and landslide hazard maps used by local stakeholders in planning and emergency management. Any precipitation metrics used to develop the flood and landslide maps are identified. An analysis is done to quantify how these precipitation metrics may change in the future and a discussion of the implications of these changes on the frequency and/or intensity of future flood and landslide events is provided. This effort is not able to re-run hydrologic/hydraulic modelling with the future projection but can provide some indication of how the modelling results based on today's conditions might be affected by future changes in climate.
- **Approach 2.** Using regional meteorological events that have caused floods and/or landslides can be a useful approach in developing precipitation event thresholds. How floods and/or landslides may change in the future can then be investigated by looking at future daily precipitation projections to see how often these thresholds might be crossed in the future. For example, for a series of storm events that caused significant flooding, the daily precipitation associated with each event and the precipitation totals for five days leading up the event can be collected from the observational data. This data can then compared to the historical average to consider if these precipitation metrics are good indicators of a potential flood and/or landslide. If so, then projecting how these precipitation metrics may change in the future may give some rough estimate as to whether floods and/or landslide may worsen (assuming all other stressors are held constant).
- **Approach 3.** When observational data and/or records are very limited, global datasets of precipitation projections can provide insight as to how changes in the nature of precipitation may impact future floods and landslides in Estelí. Precipitation can be investigated on a number of scales, such as annual, seasonal, monthly, and daily changes. Considering how precipitation indicators such as the 5-day maximum per year, the 95-percentile, the number of days above 10 millimeters of rain per year may change can provide some indication of how the frequency, duration, and intensity of events may change on a daily scale. Though these indicators are not tailored to be site-specific (i.e., precipitation metrics that have been shown to be a good indicator of landslides in Estelí), they do provide information regarding future changes in storm events that can be useful when considering how climate change may affect hazard events.

Table A1.2 provides a succinct discussion of each approach along with a description of the data requirements, the assumptions and limitations for applying the approach in the Estelí study area. The level of detail in the findings for use by the municipality reduces from the first approach to the third approach, moving from a more quantitative analysis to one that is more qualitative. Given the constraints on the available information, we largely adopted Approach 3 to investigate how landslides and floods may change in the future.

[14] http://www.climatewizard.org
[15] http://country-profiles.geog.ox.ac.uk

As this study was not intended as an intensive vulnerability and risk analysis, we did not consider a sophisticated and time-consuming model-intensive approach for Estelí. This would include conducting hydrologic and hydraulic modelling driven by projected changes in precipitation to consider changes in the flood hazard. Additionally, analysis to better understand today's relationships between storm events and hazards could also be conducted over time through the collection of important storm event data. This, for example, could potentially provide a robust statistical relationship between storm events and landslides that could be used to tailor future precipitation projections to consider changes in future landslide hazards. The findings of our analysis based on the more simpler approaches, however, can provide guidance regarding the best use of funds for conducting such a vulnerability and risk analysis (e.g., which hazards are likely to worsen, are there potential hotspots where hazards may get worse, etc.) for Estelí.

Table A1.2 Description and considerations of approaches to investigate how changes in precipitation may impact floods and landslides in Estelí.

Approaches to Investigate Future Changes in Floods and Landslides				
Approach	**Description**	**Requirements**	**Assumptions**	**Discussion/Limitations**
1. Identify precipitation metrics used in developing local flood and landslide hazard maps for local planners. Consider how these precipitation metrics may change in the future.	Investigate the methodology used to develop local flood and landslide hazard maps that inform local planners (e.g., 100 year flood, maps that identify areas that are prone to flooding, etc.). Determine what precipitation metrics were used in the map development. Identify appropriate source(s) for the projections of the precipitation metrics within the temporal and spatial resolution required and use these data to consider future change in hazard. In addition, through stakeholder discussions determine if additional anecdotal information or emergency flood and/or landslide warning systems are used and tied to precipitation thresholds.	■ Local flood hazard maps ■ Local landslide hazard maps ■ Emergency flood warning systems ■ Emergency landslide warning system ■ Local expertise in flood events ■ Local expertise in landslide events ■ Projections of identified precipitation metrics	The findings of this approach describing future conditions would not create new flood and landslide hazard locations. This method is constrained to consider whether the flood and landslide hazard locations identified by the flood and landslide maps are projected to intensify or lessen; though qualitative reasoning can be applied to broaden the identified future hot spots. As this analysis is intended to separate the climate change component from other influencing factors to consider how climate change may affect future hazard levels, it is assumed other future changes across the city remain static such as changes in land use, construction and maintenance in sewage/drainage systems, and housing.	Local stakeholders use flood and landslide maps as described in Sections 2.4 and 2.5 to identify areas prone to floods and landslides. The flood maps are based on sophisticated hydraulic and hydrologic modelling. It was not possible to reproduce these maps associated with future climate (i.e., drive the hydraulic and hydrologic models with climate projection data).
2. Identify precipitation thresholds.	Use past events described in research/academic/government literature and local newspapers to	■ Collection of past flood events	This approach assumes that the identified precipitation thresholds	Government and international reports along with local newspaper articles provide a small collection of

Approaches to Investigate Future Changes in Floods and Landslides

Approach	Description	Requirements	Assumptions	Discussion/Limitations
Consider how these precipitation thresholds may change in the future.	identify the dates of past flood and/or landslide events. Using these identified dates, construct a table with the daily precipitation observed at a local weather station. If there are enough events to consider, investigate the strength of the precipitation threshold(s) in predicting flood events (e.g., construct a scatterplot between precipitation and flood, investigate whether there were other days that crossed a specific precipitation thresholds but did not lead to flooding); similarly for landslide events. Use daily downscaled precipitation projections to consider how the frequency of the precipitation threshold(s) may change in the future.	▪ Collection of past landslide events ▪ Local meteorological data ▪ Daily downscaled precipitation projections	represent a consistent indicator for floods and landslides. For example, if cumulative rainfall over a 5-day period is considered a reasonable indicator for a given hazard in today's climate, it is assumed it will still be a reasonable indicator under a potentially changed climate (i.e., the future stressor/impact relationships remain constant). As this analysis is intended to separate the climate change component from the other influencing factors to consider how climate change may affect future hazard levels, it is assumed other future changes across the city remain static such as changes in land use, construction and maintenance in sewage/drainage systems, and housing.	flood events in Estelí. However, these information do not provide the precipitation rates and environmental conditions that led to the flooding. In addition, Estelí does not collect daily precipitation data that could be linked to the flood event. Local stakeholders and a literature review were able to provide some insight into the locations of past flood events and the associated damage.
3. Construct / leverage future precipitation projections and qualitatively	Identify sources of recent precipitation projections for Estelí (i.e., projections developed ideally using modelling of IPCC AR4 or later) and the associated metrics (e.g., time	▪ Precipitation projections	As this analysis is intended to separate the climate change component from the other influencing factors	Precipitation and temperature projections provide some indication of how landslides and floods may change in the future, but are not developed specifically focusing on

Approaches to Investigate Future Changes in Floods and Landslides

Approach	Description	Requirements	Assumptions	Discussion/Limitations
consider the impact on local flood hazard maps.	periods, emission scenarios, climate models). Construct a catalogue of precipitation projections and determine the best projections to use for the flood and landslide analysis. Ideally, the data would include changes in annual, monthly, and daily precipitation. If daily is not available, then 'processed' projections that are available should be considered (e.g., changes in the 5-percentile of precipitation; changes in the 100 year precipitation return period).		to consider how climate change may affect future hazard levels, it is assumed other future changes across the city remain static, including: land use, construction and maintenance in sewage/drainage systems, and housing.	tailored precipitation flood and landslide drivers in Estelí. Hence, the resulting assessment has a large degree of uncertainty related to the downscaling and homogenization of information and environmental variables.

Annex 2 Floods database

Table A2.1 Distribution of reports originating floods across the city. Source: DesInventar Database (Version 9.5.12-201).

	Flood	Flashflood	Storms	Total
Entire city	4		1	5
Lon Angeles	3	1		4
Jose Santos Zelaya	2	1		3
Belen	1	1		2
Filemon Rivera	2			2
Igor Ubeda	2			2
Melania Hernández	2			2
Oscar Turcios	1	1		2
Rolando Arauz	1	1		2
Sandino	1	1		2
Aristeo Benavides	1			1
Betania		1		1
Boenerges Lopez		1		1
Camilo Segundo	1			1
Centeno		1		1
El Calvario	1			1
El Rosario	1			1
Emmanuel Mongalo	1			1
Jose Benito Escobar		1		1
Los Cedros		1		1
Panamá Soberana	1			1
Quebrada Grande		1		1
Santo Domingo		1		1
William Fonseca	1			1

Annex 3 Climate change projections

Table A3.1 The projected climate model ensemble mean (labelled "mean"), the minimum projection simulated by a single climate model (labelled "min"), and the maximum projection simulated by a single climate model (labelled "max") for both Scenarios.

	Obs	Scenario 1 (2040s)			Scenario 2 (2040s)		
		Min	**Mean**	Max	Min	**Mean**	Max
Temperature (^oC)							
Winter		0.6	**1.1**	1.5	0.9	**1.4**	1.8
Spring		0.6	**1.5**	1.1	0.9	**1.4**	1.8
Summer		0.7	**1.1**	1.7	1.1	**1.5**	2.2
Fall		0.7	**1.2**	1.5	0.9	**1.4**	2.0
Precipitation (mm)							
Winter		-9	**-1**	15	-8	**-1**	7
Spring		-8	**-2**	20	-14	**-3**	16
Summer		-58	**-17**	30	-50	**-18**	29
Fall		-40	**-1.2**	31	-40	**-2**	25

Clerkenwell House ▪ 67 Clerkenwell Road ▪ London EC1R 5BL UK ▪ +44 (0) 20 7611 1100 ▪ +44 (0) 20 3368 6960 fax ▪ icfi.com ▪ ghkint.com