Climate Change Adaptation Planning in Latin American and Caribbean Cities

FINAL REPORT: EL PROGRESO, HONDURAS

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Climate Change Adaptation Planning in Latin American and Caribbean Cities

A report submitted by ICF GHK
in association with

King's College London and Grupo Laera

Job Number: J40252837

Cover photo: The Ulúa River in flood on the left, and the levee and Colonia 2 de Julio of El Progreso on the right.

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Document Control

Document Title	Climate Change Adaptation Planning in Latin American and Caribbean Cities *Complete Report: El Progreso, Honduras*
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Abbreviations

ACI ..... *Adaptive Capacity Index*

ASIDE ..... *Research Association for Ecological and Socioeconomic Development*
Asociación de Investigación para el Desarrollo Ecológico y Socioeconómico

CAPRA ..... *Probabilistic Risk Assessment Initiative*
Plataforma de Información sobre Riesgos de Desastres

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

CODED ..... *Departmental Emergency Comittee*
Comité Departamental de Emergencia

CODEL ..... *Local Emergency Committee*
Comité de Emergencia Local

CODEM ..... *Municipal Emergency Committee*
Comité de Emergencia Municipal

COEN………...*National Emergency Committee*
Comité de Emergencia Nacional

CONOT…... *National Council of Territorial Zoning*
Consejo Nacional de Ordenación Territorial

COPECO..*Permanent Contingencies Committee*
Comisión Permanente de Contingencias

CTICC...Inter-institutional Technical Committee for Climate Change

DIM………………………….…………………………………….*Integral Multidimensional Diagnosis*
Diagnóstico Integral Multidimensional

DGOT …..*National Directorate of Territorial Zoning*
Dirección General de Ordenación Territorial

DRM……….……………………..………………………..………………………*Disaster Risk Management*

ENSO…………………………………………..………………………..…*El Nino Southern Oscillation*

ESNACIFOR...*National Forestry Academy*
Escuela Nacional de Ciencias Forestales

FONAPRE...*National Fund for Emergency Preparation and Response*
Fondo Nacional de Preparación y Respuesta a Emergencias

GDP..*Gross Domestic Product*

IADB……………………………………..*Inter-American Development Bank*

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

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

MHDI…………………………………………………………………..*Municipal Human Development Index*

MSMEs………………………………………………………………...Micro, small and medium enterprises

PATH II.………………………..Honduras Land Management Program
Programa de Administración de Tierras de Honduras

PMDN…….…………………………………...............……………….*Natural Disasters Mitigation Program*
Programa de Mitigación de Desastres Naturales

SANAA..*National Aqueducts and Sewage Service*
Servicio Autonómo Nacional de Acueductos y Alcantarillados

SERNA...*Secretariat of Natural Resources and Environment*
Secretaría de Recursos Naturales y Ambiente

SICA.…………………...Central American Integration System
Sistema de Integración Centro Americano

SINAGER…..…………………………………..…..............….*National Disaster Risk Management System*
Sistema Nacional de Gestión de Riesgos

UBN...*Unsatisfied Basic Needs*

UNFCCC...United Nations Framework Convention on Climate Change

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

ZMVS...*Sula Valley Metropolitan Area*
Zona Metropolitana del Valle de Sula

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 is designed 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 selected for involvement: Castries, Saint Lucia; Cusco, Peru; El Progreso, Honduras; Esteli, Nicaragua and Santos, Brazil. For each city, five main activities were carried out:

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; and
5. Based on the findings of the four assessments, a combined strategic climate adaptation institutional strengthening and investment plan, intended to 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.

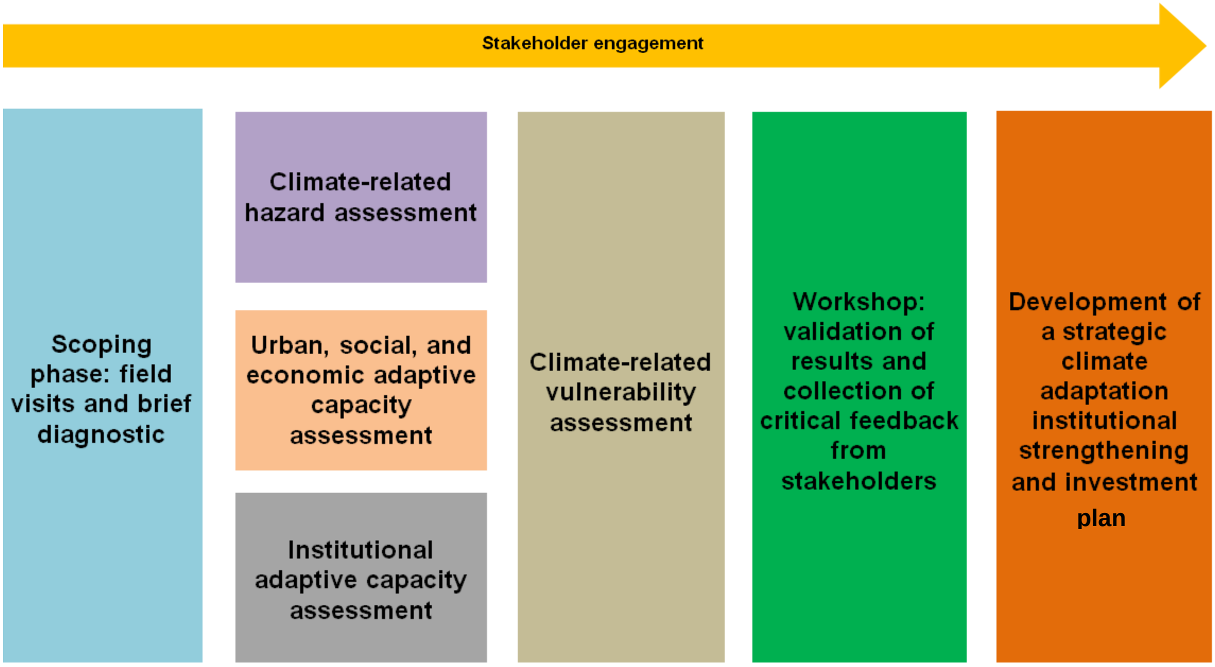


Figure 0.1: The process and main activities of the project

A summary of key findings of this report now follows.

Understanding the problem of flooding and landslides

Climate related flood and landslide hazard risks

El Progreso is susceptible to floods but landslides do not pose a significant threat to the city. Reported landslides are unusual and have occurred only in rural areas of the wider Municipality of El Progreso. However given the city's location in northwest Honduras, in proximity to the Caribbean and at the confluence of the Pelo and Ulúa Rivers, exposure to floods is significant in El Progreso: during extreme or prolonged rainfall in the rainy season or during hurricanes and tropical storms, runoff from the mountains causes the overflow of the Ulúa River and its tributaries, resulting in major flooding events in the city.

The city has been historically hit by a series of hurricanes and tropical storms and accompanying severe floods: Hurricane No 5 in 1935, Tropical storm Gilda in 1954, Hurricane Francelia in 1969, Hurricane Fifi in 1974, Hurricane Joan in 1988, Tropical Storm Gert in 1993 and Hurricane Marcos in 1996. However, the most significant recent catastrophe was Hurricane Mitch in 1998, which caused major devastation. Storms and floods are responsible for considerable human and economic impact in Honduras. During 1997 to 2006, four storm events caused damages of $127 million (U.S. dollars), and three flood events affected 15,000 people and caused damages of $128 million (U.S. dollars) (World Bank, 2009).

By the 2040s, temperatures in El Progreso are projected to increase. Seasonal and annual precipitation is projected to decrease (though it is not clear how the intensity, frequency, and/or duration of rainfall events may change). This suggests areas prone to floods and landslides may be at slightly less risk. 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. 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 El Progreso. 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 even increasing.

Urban development and exposure to disaster risk and climate change

In El Progreso, urban development has gone hand in hand with economic expansion. In the 1970s, the Honduras central government established the Cortés Free Trade Zone, followed by other trade zones in the Sula Valley. This gave rise to the creation of an industrial corridor in the region, which in turn fostered population in-flows. Urban demographic growth nurtured a conurbation process, which ultimately resulted in the emergence of the Sula Valley Metropolitan Region in 1993, integrating 20 municipalities for the coordination of strategic regional planning.

Nowadays, the Sula Valley is the main driver of economic activity in Honduras, and generates the majority of the country Gross Domestic Product (GDP). El Progreso has directly benefited from this economic dynamism: the municipality's economic structure is diverse, as it consists of agricultural, industrial and commercial production. In recent years El Progreso has experienced an increase of industrial activity due to the establishment of maquiladoras.

Catalysed by rapid economic growth, urban expansion in the region occurred following spontaneous and disordered patterns, often lacking urban planning guidance. Each municipality responded to the new challenges in an isolated manner. Regional economic development and the subsequent conurbation process it brought have created high pressures on land use in the territory. Furthermore, in El Progreso urban growth often took place in an unplanned manner, resulting in misuse of land and the emergence of settlements in inappropriate areas, including the banks of rivers, watersheds and ravines, as well as steep areas. This has exacerbated exposure to floods in the city.

The city has recently developed planning strategies to address unplanned urban expansion and exposure to risk. Local authorities formulated a Municipal Development Plan (PDM-OT) in 2012, which incorporates land use studies as a core element. The municipality elaborated a land assessment study that forms the basis for a Municipal Zoning Proposal. The proposal identifies different potentialities for the spatial configuration of the municipality. It creates a scenario of spatial organization by evaluating current levels of production and protection, and by associating them with possible risks and threats (PDM-OT, 2012). El Progreso is thus taking the first steps in integrating risk when formulating municipal planning strategies.

Economic expansion has allowed El Progreso to have better social indicators than the Honduras national average. Nonetheless, the analysis undertaken in the assessment phase illustrated that there is a real geography of vulnerability in El Progreso. Combining the sensitivity of settlements (based upon the percentage of households that use cement for the exterior walls) with the adaptive capacity of dwellings (based upon the household with unsatisfied basic needs – UBN[1] index) allowed identifying what are the most vulnerable areas within El Progreso's urban core.

[1] UBN is an indicator of measuring poverty and is calculated based upon the following basic needs: drinking water, sanitation, education, subsistence capacity, overcrowding, and state housing.

The socio-economic assessment concluded that 33 neighbourhoods out of 111 are exposed to floods in El Progreso. Most of them are located in the northwest and southwest areas, thus establishing an east-west divide to flooding exposure in El Progreso. However, because of data limitations, the vulnerability assessment could not be undertaken at the neighbourhood level: another unit – villages – was used, as disaggregated socio-economic data at the local level was found for it. The main conclusions show that the El Progreso village, covering the urban core of the city, has medium vulnerability to floods. High vulnerability is concentrated in rural areas surrounding the city.

Institutional vulnerability issues

Due to constant exposure to hazards, there have been major improvements in the Honduras disaster risk management system, at both the national and local levels. The National Contingencies Law created the Contingency Permanent Commission (COPECO) in 1993, and the most important legislation, the National System for Risk Management (SINAGER), was created by Decree 151-2009 in December 2009. The SINAGER builds upon previous efforts at contingency planning, and improves and expands the role of COPECO. Since the introduction of SINAGER, the national disaster management system is better prepared, resourced and has better defined lines of responsibility and roles. SINAGER has introduced a proactive risk management policy, as disaster risk management considerations span across all aspects of government planning processes and across all levels of territorial and sectoral administration.

A process of decentralization of disaster risk management activities is embedded within SINAGER. The system establishes the creation of institutional authorities – Municipal Emergency Committees (CODEMs) – responsible for the organization and implementation of disaster risk management policies, and complemented by Local Emergency Committees (CODELES), School Emergency Committees (CODECEs), and Workplace Emergency Committees (CEDECELs). All these organizations assist in the dissemination and implementation of national policies on disaster risk management.

El Progreso has developed a strong DRM system, through the presence of a CODEM and 40 active CODELES. The city government is the main authority responsible for the operation and management of the CODEM, and plays a central role in the implementation of disaster risk management operational plans. The CODEM integrates stakeholders from the public sector, civil society and the private sector, and is responsible for strategic planning, coordination and for the direction and coordination of local committees on education, health, logistics, search, evacuation and rescue, security, communications and monitoring.

Despite the existence of a strong DRM network in the city, risk planning and adaptive practices have not been incorporated into risk management strategies. Further, the local institutional system remains understandably reactive rather than proactive in dealing with disaster risk management and future climate change related vulnerabilities: there is little integration of climate change in development planning. At the local level, disaster management and emergency response actions still remain the greater priority.

Thus, a key challenge to climate change adaptation at the local level appears to be the relatively weak institutional capacity to undertake such action. Nevertheless, strong social networks between city level institutions in El Progreso have acted as a robust coping strategy in the face of limited resources. The CODELES offer local social networks for raising awareness and resilience of the local population. Ideally, city level policy change initiatives need to be combined with practical efforts at the community level by local organizations in order to develop more resilient systems for climate change adaptation and planning.

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 El Progreso. 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 El Progreso 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 El Progreso.

The overreaching goal of the strategic plan is to increase resilience to floods and landslides in El Progreso. 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 El Progreso build its resilience against floods and landslides, both now and in the future, are:

(i) consideration of the environmental and socio-economic conditions of rural and peri-urban regions surrounding El Progreso in risk assessment and long term risk management planning for the city; (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; and (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*: water and sewage masterplan in order to improve water management and quality; educational campaigns aimed to raise awareness amongst the local population on climate change adaptation; development of housing policies specifically targeted to low-income populations; creation and/or improvement of mechanisms for data collection, storage and dissemination for better climate monitoring, risk planning, and information sharing; enhancement of zoning and land use planning to guide urban development away from high-risk areas and establish a pattern of sustainable urbanization; and development of a management plan for the Mico Quemado Mountain in order to minimize the risk of hazards through watershed management and the enhancement of governance frameworks.

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; Esteli, Nicaragua and Santos, Brazil.[2] 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:

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. A Strategic Climate Adaptation Investment and Institutional Strengthening Plan. This is based on the findings of the three assessments, and complements and can 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 coastal and inland flood risk and landslide risk for El Progreso. It then considers how climate change may impact these existing flood and landslide hazards in the future.
- ***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

[2] 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.

have for landslide and flood risk. Studying these variables allows assessment of how the urban development trajectory of El Progreso 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 El Progreso and how they take into account and incorporate climate change adaptation issues.
- ***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 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 El Progreso. 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. [3]

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 El Progreso.

Box 1 Using the URA for Assessment in El Progreso

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.

Some provisos are nonetheless required. The URA is avowedly a flexible tool, as it needs to be. In El Progreso, 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, if not deeply

[3] 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.

studied, are understood by city stakeholders given their long-run experience. Precipitation data was not locally available, but was drawn from international data bases. This did permit consideration of the full exploration of the potential impacts of climate change and, consequently, a projection of 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 readily available to us. Population data in particular was outdated (dating to a 2004 Census) and not easily accessible. In addition, the prediction for future changes in hazard levels on account of climate change is broad-brush rather than detailed, as this level 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 El Progreso. 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 El Progreso, 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 El Progreso within its regional, Sula Valley context. 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 willingness of stakeholders to share their experience in planning, primarily for urban development and disaster risk, rather than climate change itself, permitted a full assessment within the time frame. Our assessment attempted to incorporate the dimension of how institutions in El Progreso 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 given demographic data limitations, the most vulnerable ‘villages’ (as neighborhood-level data was unavailable), 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 El Progreso.
5. **Combined strategic climate adaptation investment and institutional strengthening plan**: In a workshop in March 2013 in El Progreso, there was enthusiastic 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 El Progreso. Again, stakeholders in El Progreso will be able to adopt and elaborate the measures proposed as they see necessary.

1.3 Context and study area

The Municipality of El Progreso comprises a territory of 537 square kilometres. It is the westernmost of the 11 municipalities composing the Yoro Department on the eastern part of the Sula Valley, in north-western Honduras (Figure 1.1). It is the most important city in the Yoro Department. About 40 kilometres from San Pedro Sula, the second largest city in Honduras and its most important economic centre, El Progreso has strategic significance as it is located at the crossroads of two of the most important highways of the country.

Fast economic and demographic growth has gone hand in hand in recent years. There was rapid annual population growth of 4% between 2001 and 2011. The municipality's population increased from 147,000 inhabitants in 2001 to 177,000 in 2007, and reached 220,000 in 2011 (Municipalidad de El Progreso, 2012). Most of this growth has been concentrated in the urban area of El Progreso, which represents some 85 to 90% of the overall municipal population. Overall, the city's social development indicators show better results than Honduran national averages. However, poverty is prevalent in Honduras and is also visible in El Progreso. High inequality and public safety are also concerns.

The Sula Valley is part of Honduras's North Coast region which was formerly one the world's foremost banana production areas. Its environmental history has been well-studied.[4] It is characterized by the presence of important water basins. The city is located on the west side of the Ulúa River and is marked by the presence of three tributaries: Pelo, Camalote and Guayamitas. To the east, El Progreso borders the foothills of the Mico Quemado Mountain and the Ulúa River to the west.

The topography is marked by regularity. The city is settled at 80 meters above sea level. The temperature is hot, with an average of 29°C, a minimum of 21°C and a maximum of 42°C. Winter in El Progreso is characterized by intense tropical rainfalls. The ecosystem is predominantly composed by dry tropical forests.

Flooding is a long-run problem for El Progreso and for the Sula Valley, with large-scale floods on the historical record, notably the Great Flood of 1935 and as consequence of Hurricane Mitch in 1998. The city's institutions have undertaken important steps towards dealing with flooding in the last decade-and-a-half, post-Mitch. As seen in other cities in the Latin America and Caribbean region, there is however an understandable over-emphasis in disaster response and climate change mitigation is often seen as synonymous with disaster risk management. Furthermore, improper land uses occurring on protected areas are currently limited, but if left unchecked are very likely to further exacerbate flooding problems in the city. In addition to causing environmental degradation, they may also trigger new hazards, for example landslides, which at the moment do not have a significant direct impact on the city itself.

[4] See Soluri J. (2005) "Banana Cultures: Agriculture, Consumption, and Environmental Change in Honduras and the United States."

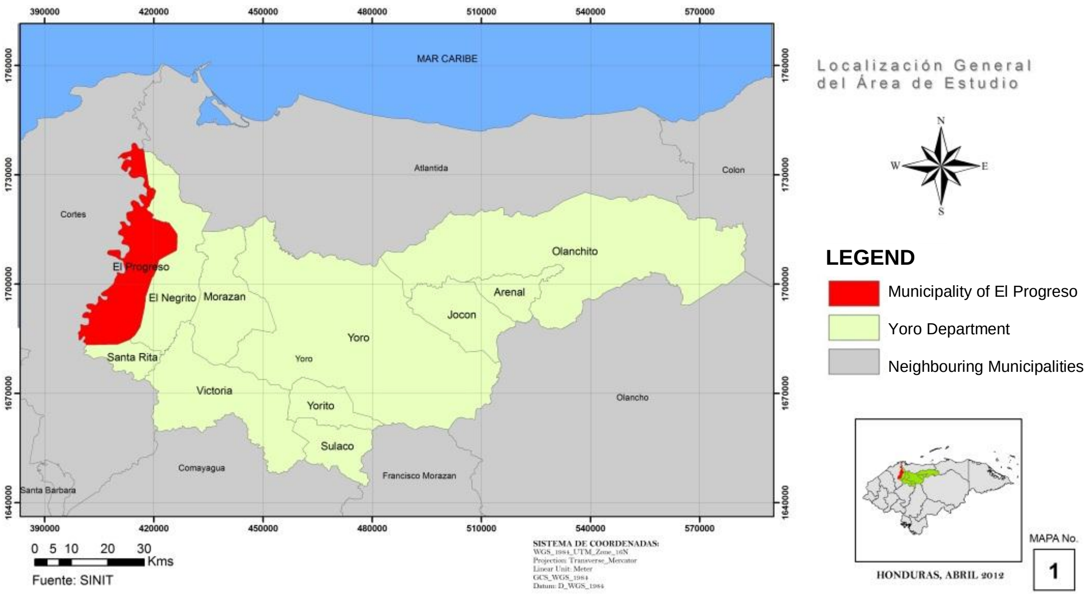


Figure 1.1 El Progreso's location within Honduras, Source: adapted from PATH II in Municipalidad de El Progreso, 2012.

The administrative boundaries of urban El Progreso, as seen in Figure 1.2, are the basis for the area of study. Given the important rural-urban linkages of the city, the socio-economic assessment of necessity covers the area's social, economic and spatial dynamics within both the broader municipal context and the regional (or metropolitan) context of the Sula Valley. Further, the linkages of the city with the protected ecosystem are emphasized in the climate-related hazard assessment as this is very likely to considerably affect hazard risk in the future.

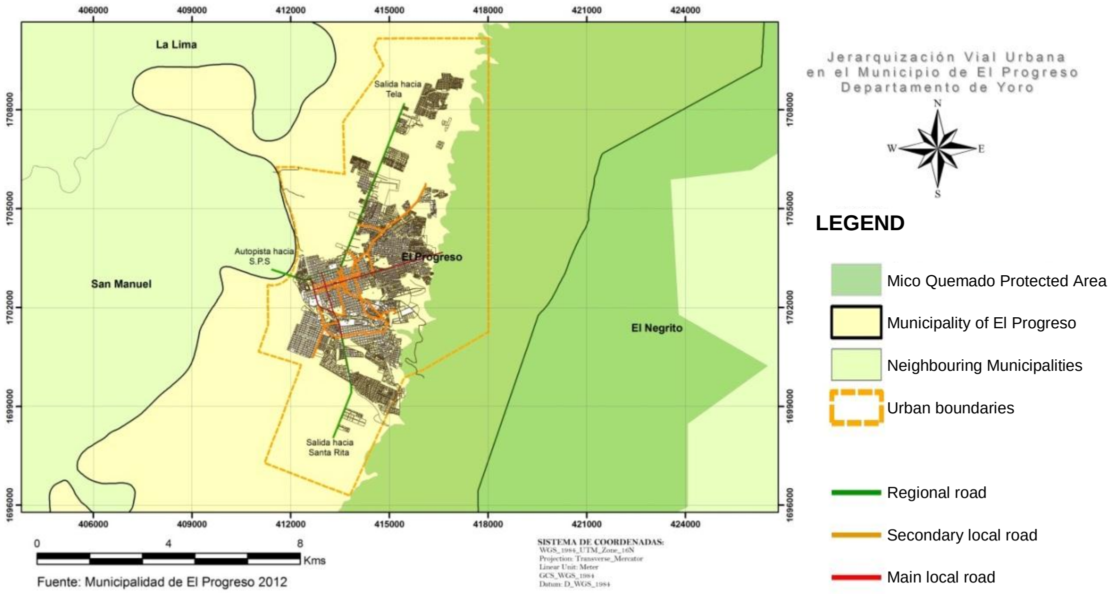


Figure 1.2 The urban boundaries of El Progreso. Source: adapted from PATH II in Municipalidad de El Progreso, 2012

2 Climate-related hazard assessment: floods and landslides

2.1 Introduction

This chapter evaluates present and future flood and landslide risk in El Progreso. According to our interviews with the local authorities, El Progreso is considered highly susceptible to floods. Landslide susceptibility is less of a challenge for the city. This assessment, on the basis of the information available, suggests the same.

Flood and landslide hazards are considered in this chapter, with the analysis divided 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 that are relevant to floods and landslides, and the meteorological drivers of events associated with flood and landslide hazards.
- **Current flood hazard**: a general description of floods, a summary of prior events, and a description of the flood tools used to inform disaster management and municipal planning.
- **Current landslide hazard**: a general description of landslides, a summary of prior events, 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, including a section describing gaps and limitations.

2.2 Methodology

This analysis utilized existing resources used by the El Progreso municipal 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 describe the current hazard level and to consider how the 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 El Progreso 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/adaptation planning.
4. Assess available future precipitation and temperature data for mid-century.
5. Assess the application of three distinct approaches that consider how climate change may impact the tools investigated in Step 3.

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

2.3 Physical description

The City of El Progreso is located in the Ulúa river flood plain at the foothill of the Mico Quemado Mountain. These two geographical boundaries, to the east and west respectively, are also administrative boundaries. This section provides an overview of the physical attributes that affect floods and landslides in the El Progreso: geomorphology, hydrology, and climate and weather.

2.3.1 Geomorphology

The topographic features shown in Figure 2.1 describe the following three distinct regions in the Municipality of El Progreso: mountainous, semi-mountainous, and foothills (ASP Consultores, 2012):

Mountainous region: The average differences in elevation between the mountain peaks and the adjacent valleys are approximately 1,000 meters. The typical slope ranges between 30 and 45-degrees, while the peak areas often exceed 45-degrees.

Semi-mountainous region: This region is characterized by hillsides and covers approximately 25% of the municipal territory.

Foothills region: This region covers a large portion of the municipality, extending along the southern, western and northern boundaries of the Mico Quemado mountain range. The foothills have a typical slope of 28%.

Figure 2.1 Topographical Map of the Municipality of El Progreso, Source: Google accessed January 25, 2013.

Figure 2.2 illustrates the varied topography in the El Progreso Municipality. El Progreso is shown on the eastern edge of the Mico Quemado mountain range.

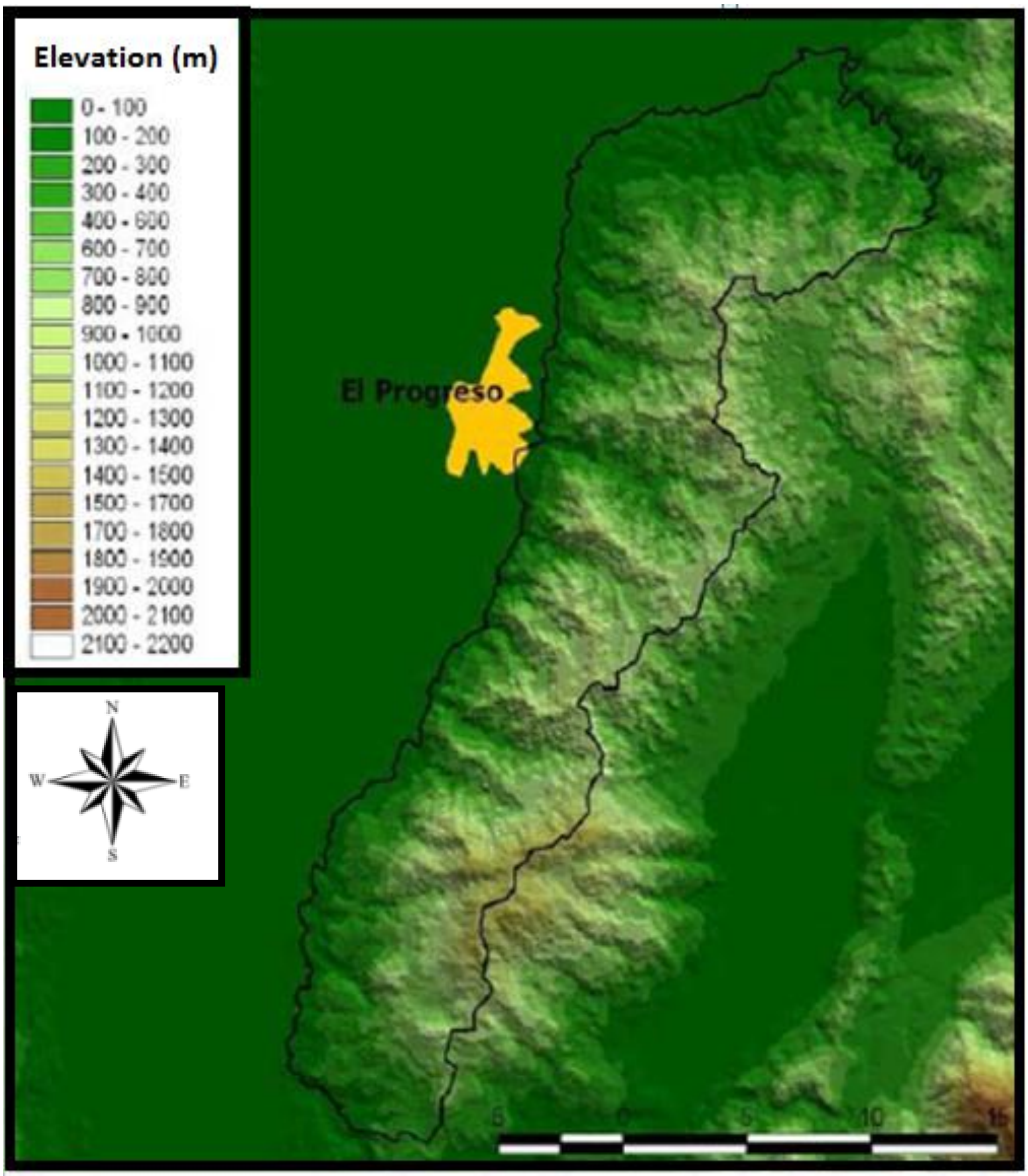


Figure 2.2 Topographical Map with Elevations of the Municipality of El Progreso, Source: Lopez Barrera, 2006.

As illustrated in Figure 2.3, El Progreso sits over various rock formations, which, according to ASP Consultores (2012), include :

- **Valley of Angels Group (Grupo Valle de Angeles):** this formation originates from the mesozoic era and includes a variety of calcareous shale, limestone, siltstone, and volcanic rock.
- **Yoja Group Formation (Formaciones del Grupo Yoja):** this formation is also from the mesozoic era and mostly includes calcareous rock, dolomites, loams and calcarenite (type of limestone).
- **Esquistos Cacaguapa:** this formation is comprised of metamorphic rock from the paleozoic era and includes various types of quartz.

- **Continental Sedimentary (Sedimentos Continentales):** this formation includes gravel deposits located at the base of the mountains and in frequently flooded areas.
- **Instrusive Rocks (Rocas Intrusivas):** this formation is mostly comprised of granite and diorite.

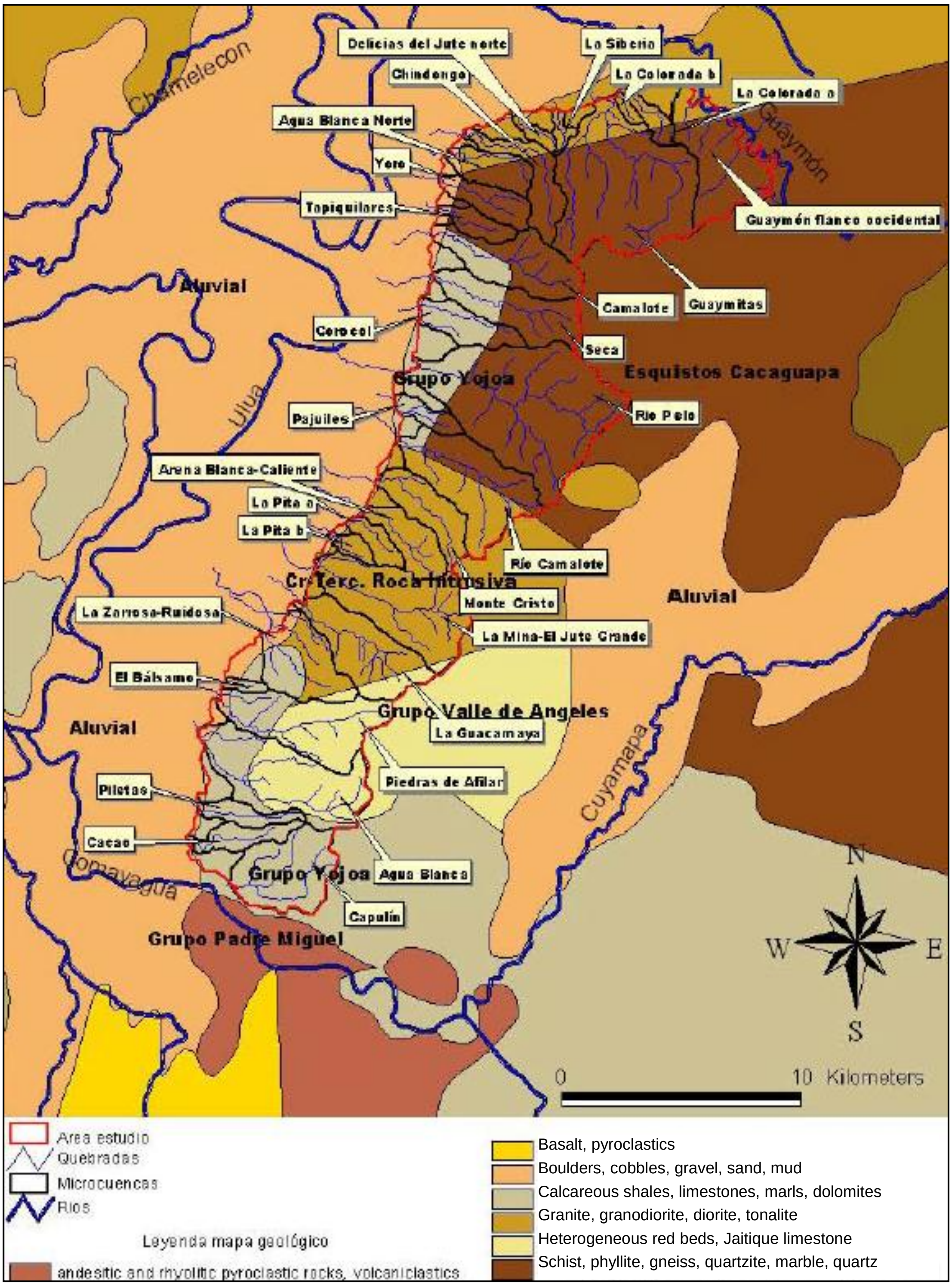


Figure 2.3 Geological Map of the Municipality of El Progreso. The watersheds are labelled with white boxes, the rock formations are labelled with further description provided in the map legend. Source: Lopez Barrea, 2006.

2.3.2 Land use

Figure 2.4 shows the land use types for the Municipality of El Progreso. Large-scale farming is predominant in the north-western quadrant, while tropical and mixed forests extend along the southern and eastern edges of the territorial limits (ASP Consultores, 2012).

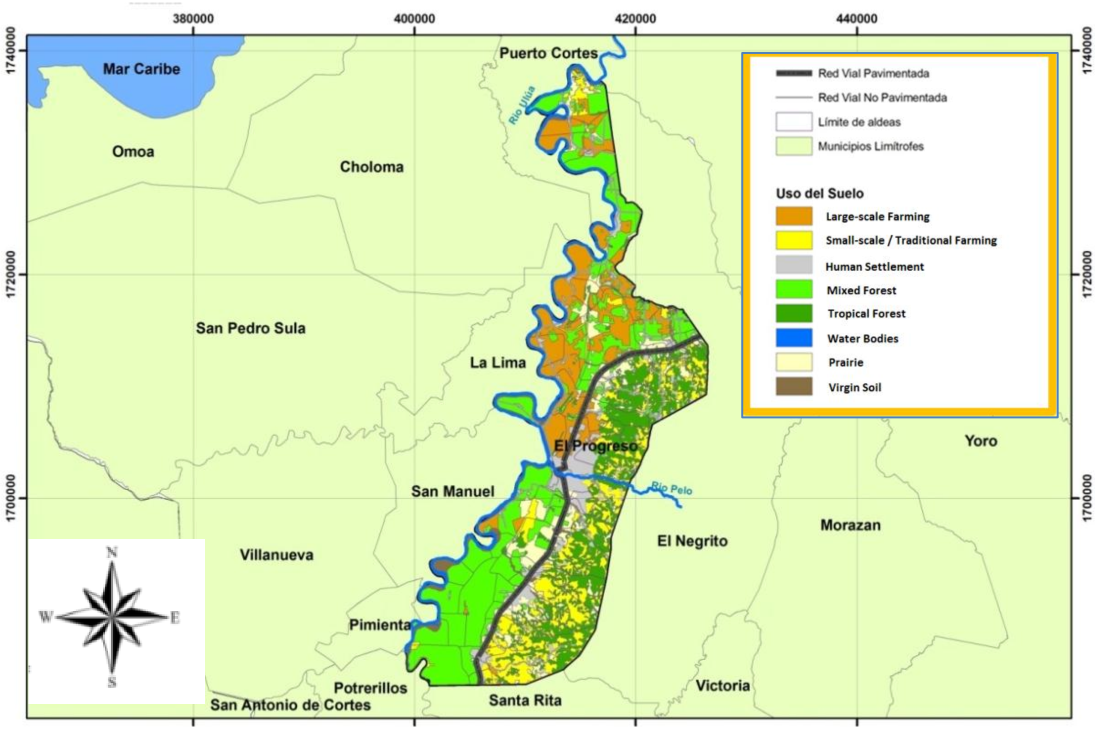


Figure 2.4 Land Use Types in the Municipality of El Progreso. Source: Municipality of El Progreso.

According to interviews in the city, recently land use changes have occurred on the Mico Quemado Mountain, as small scale and traditional farming changes to more intense and resource-demanding agriculture, notably palm oil plantations, have taken place.

2.3.3 Hydrology

El Progreso is comprised of 38 watersheds that eventually feed into the Ulúa River (see Figure 2.3). Figure 2.5 illustrates 29 of these watersheds in greater detail. According to studies produced by the National Academy of Forestry (ESNACIFOR), numerous artesian wells are located in the municipality.

The primary watershed, which forms the Ulúa River, is the second largest watershed in Honduras, extending approximately 21,414km^2 – an equivalent of 19% of the country's total area. As a result, El Progreso's geology has been primarily influenced by the deposits from frequent flooding events (ASP Consultores, 2012).

From the 26 streams studied by Lopez Barrera (2006) at least 11 are not permanent throughout the year with several that have become completely dry during the dry season.

According to the interviews with several stakeholders in the city including NGOs, the municipality and the National Aqueducts and Sewage Service (SANAA), 70% of the water resources have been lost over the past 14 years, including the drying of 16 quebradas. The authorities attribute this to land use change and deforestation occurring on the mountain. SANAA informed that due to the shortage of water from the mountain, extraction from aquifers has increased but there are no studies referring to the aquifer status or to water availability. At the moment there are 38 points of extraction.

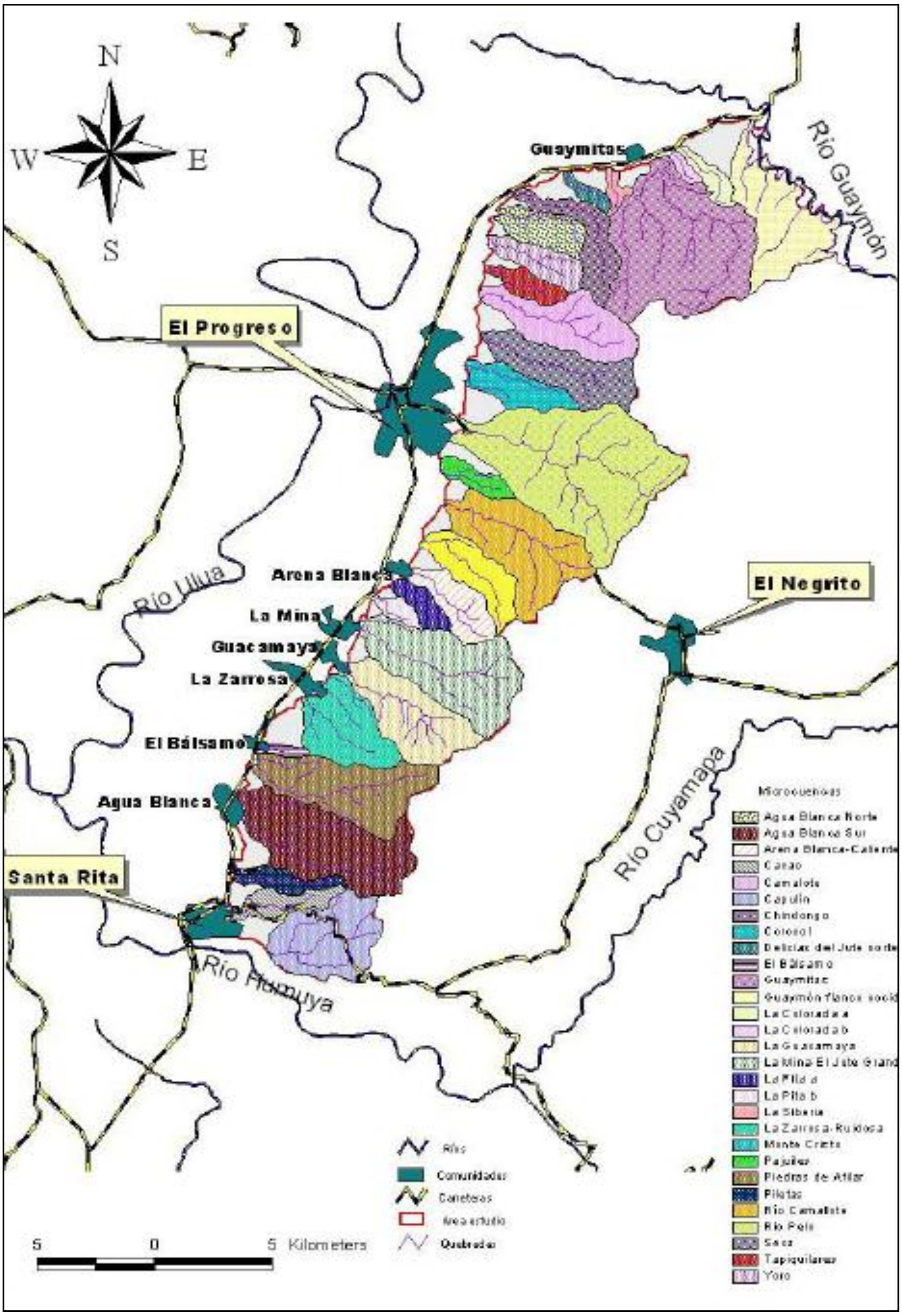


Figure 2.5 Watersheds in the Municipality of El Progreso. Source: Lopez Barrera, 2006

2.3.4 Climate and weather

El Progreso's climate is marked by "wet" and "dry" seasons. The dry season occurs during December through May, and the wet season occurs from June through December.

Temperature. From 1950 to 2000, the average monthly temperature in El Progreso is 27°C (see Figure 2.6). The lowest monthly temperatures are experienced from December through February, while the highest temperatures are in May and June. Relatively high temperatures promote high rates of evapotranspiration. Evapotranspiration, a factor that is influenced largely by temperature, affects soil moisture and can be increased by deforestation. Higher evapotranspiration may reduce flood and landslide hazard levels.

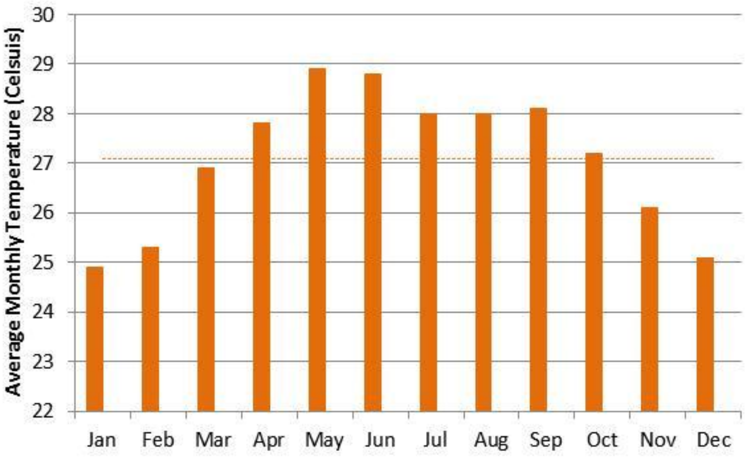


Figure 2.6 **Average monthly temperature (^{o}C) for El Progreso from 1950 to 2000 with the dashed line representing the average monthly temperature over the year. Source: based on data from Hijmans, 2005.**

Precipitation. At the municipal level, total annual precipitation varies between 800 mm to 1,200 mm (ENCC, 2010). The Inter-Tropical Convergence Zone (ITCZ) (see Box 1), through the mid-latitude westerlies, tropical waves, atmospheric low pressure systems, local-scale circulation patterns (such as sea breezes) and tropical cyclones can, affect the rainfall regime in Honduras. The wet season in Honduras can vary considerably from year to year and by location, in part driven by variations in the El Nino Southern Oscillation (ENSO). In addition, tropical cyclones and hurricanes contribute a significant fraction towards high wet-season rainfall totals (ENCC, 2010).

Based on the Figure 2.7, the wet season (defined here as months when precipitation exceeds the mean monthly precipitation) occurs from June through November. El Progreso receives approximately 1,500 mm of average rainfall per year. This annual estimate is high compared to the ENCC (2010) study. The wet season (i.e., June through November) receives an average of 1,080 mm of rainfall, while the dry season (i.e., December through May) receives an average of 430 mm (see Table 2.1).

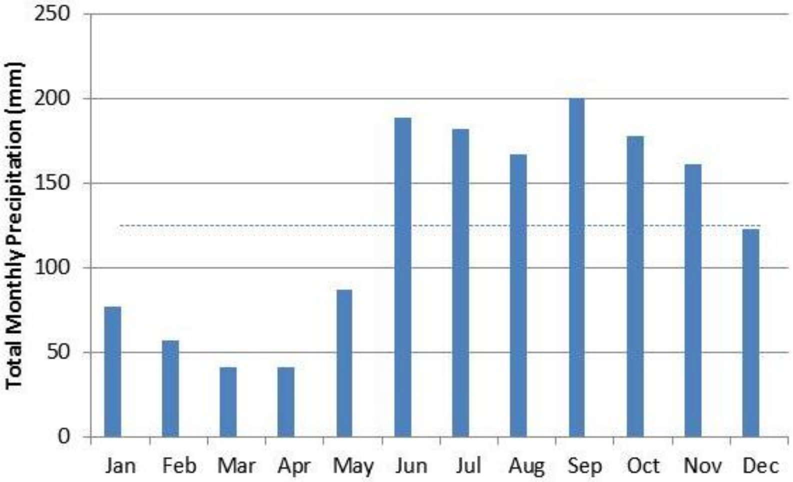


Figure 2.7 **Average monthly precipitation (mm) for El Progreso from 1950 to 2000 with the dashed line representing the average monthly precipitation over the year. Source: based on data from Hijmans, 2005.**

Table 2.1 Monthly average temperature and total precipitation for El Progreso from 1950 to 2000

Month	Temperature (°C)	Precipitation (mm)
January	24.9	77
February	25.3	57
March	26.9	41
April	27.8	41
May	28.9	87
June	28.8	189
July	28.0	182
August	28.0	167
September	28.1	200
October	27.2	178
November	26.1	161
December	25.1	123
Annual	**27.1 (average)**	**1,503 (total accumulation)**

Source: adapted from Hijmans 2005.

Storm events. Maps of precipitation associated with storms of three return periods were provided to us in the form of GIS shapefiles during our site visit.[5] The precipitation of a storm event with a return period of 50 years represents the rainfall associated with a storm that statistically may occur once every 50 years (i.e., has a 2% chance of occurring in any given year). Figure 2.8 provides the amount of precipitation associated with 50-year, 20-year, and 10-year return periods for Honduras. On the basis of the precipitation amounts provided in Figure 2.7 for Honduras, Table 2.2 approximates the rainfall amount for each return period in El Progreso. This provides some indication of the amount of rainfall associated with various types of storms. Projecting how these return periods may change in the future using daily precipitation projections is an important component to be conducted in a risk assessment.

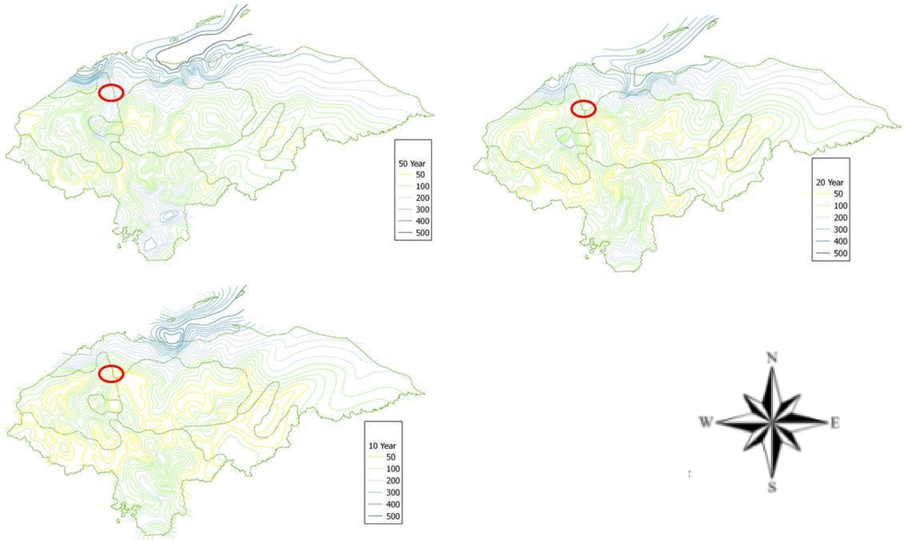


Figure 2.8 The precipitation associated with 50-year, 20-year, and 10-year return periods for Honduras. Source: graphical information provided during our site visit.

[5] The methodology and data used to support the development of these shapefiles were not made available.

Table 2.2 The approximate precipitation amounts associated with return period for rainfall events in El Progreso.

Return Period	Precipitation (mm)
50 Year	200
20 Year	100
10 Year	50

Observed Trends. For Honduras, weather data from meteorological stations suggest significant increases in both mean minimum and mean maximum temperatures have occurred (such meteorological information does not exist for El Progreso). The following significant temperature trends have been observed in Honduras from 1961 to 2003 (ENCC, 2010):

- The number of hot days per year has increased by 2.5% per decade. The number of hot nights per year has increased by 1.7% per decade.
- The number of cold days has decreases by 2.2% per decade. The number of cold nights has decreased by 2.4% per decade.

Figure 2.9 shows the trend in mean annual temperature and total annual precipitation from 1950 to 2010. There is a noticeable increase in mean annual temperature from 1970 to 2010. Yet, no drastic change in annual precipitation is appreciated between 1950 and 2010.

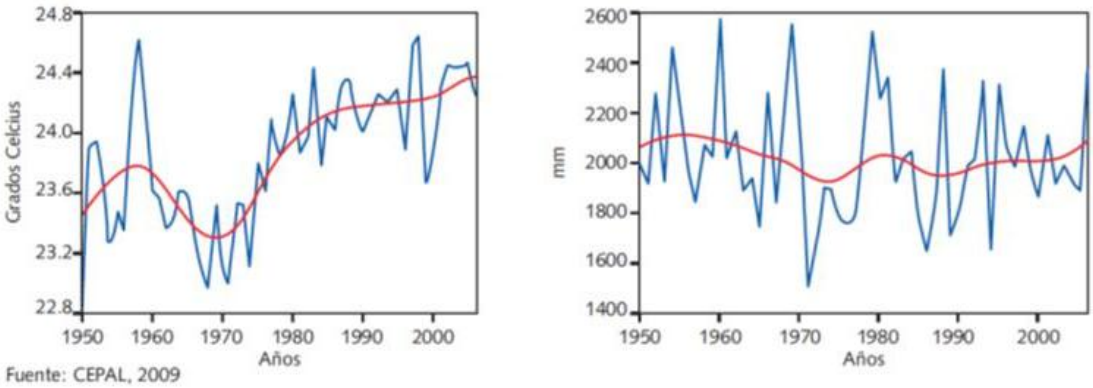


Figure 2.9 Trends in mean annual temperature (left) and cumulative annual precipitation (right) in Honduras (1960 to 2006). The blue lines provide year-to-year records and the red line provides a running average. Source: ENCC, 2010.

Box 1 Overview of meteorological processes that affect Honduras 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 % of all tropical

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.

rainfall rates exceed one inch per hour.

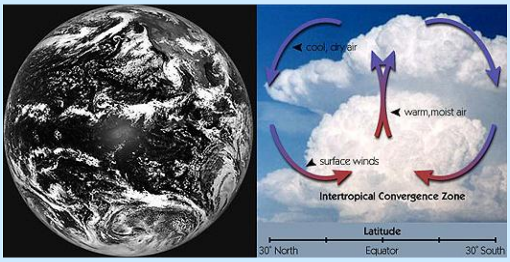


Figure 2.10 Left: ITCZ image from the GOES 14 satellite; Right: Hadley Cell Circulation, Source: NASA GES DISC.

Source: NWS 2012.

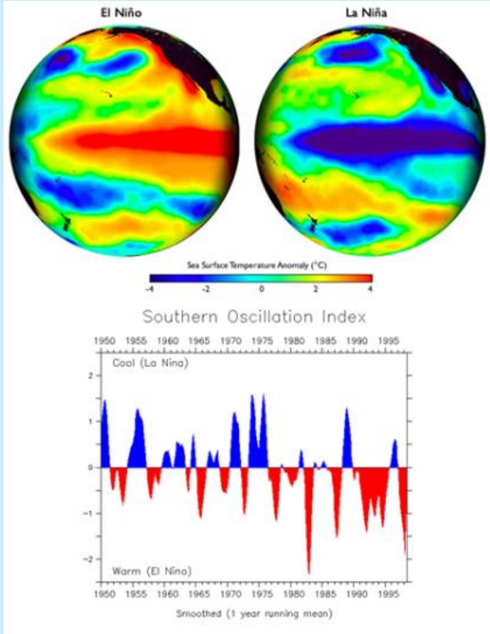


Figure 2.11 **Top: Sea surface temperatures for El Nino and La Nina events; Bottom: El Nino (blue) and La Nina (red) events from 1950 to 2000.**

Source: NOAA 2012a, NOAA 2012b

Meteorological parameters that affect floods and landslides in El Progreso

Meteorological 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 1). These processes along with tropical cyclones can produce enough precipitation to trigger landslides and/or floods:

- **ITCZ**. Floods tend to occur most often in Honduras between August and November when the ITCZ is most active (UNDP, 2013).
- **ENSO**. A recent study investigated the effect of the ENSO cycle on inter-annual precipitation in Honduras. It was based on 67 stations from the National Weather Service that provided at least 30 years of data (ENCC, 2010). This recent study developed surmised that a weak La Nina produced a reduction in precipitation during the months of January, June, and July while a moderate La Nina produced reductions in precipitation during the months of January and July, and increases in precipitation during August and October.[6] These moderate La Nina events have been known to provoke floods (UNDP, 2013).
- **Tropical cyclones**. Typically from June to November, tropical cyclones originating in the Atlantic Ocean can cause heavy rainfall in Honduras increasing the chance of landslides and floods. Statistically, El Progreso is in an area that tends to be affected by a cyclone every three years (though it is located near the boundary between being affected every three years versus every ten years) – no mention of the intensity of the cyclone was provided (UNDP, 2013).

[6] During a weak El Nino, this recent study found a tendency towards an increase in March and November rainfall totals (from 20 to 60%) and a smaller reduction in rainfall totals for the months of May and September (from 10 to 20%). A moderate El Nino intensifies the changes in monthly rainfall totals with February, June, July, and October experiencing a reduction in rainfall from 20 to 40%.

2.4 Current flood hazards

Flood events are most commonly reported during the rainy season and specifically in relation to hurricane events. In addition and based upon our discussions during our field-visit, El Progreso has been impacted by strong hurricanes (about every 20-25 years) since the 1920s. Although the strength of the winds can cause significant damage, floods are the most damaging force.

During the event of extreme or prolonged rainfall, runoff from the mountains flows westward through El Progreso, via several of the streams that then feed into the Ulúa River. The deforestation and poor cultivation practices that occurred within much of the mountainous areas has created erosion and sedimentation problems for many cities along the foothills, such as Agua Blanco, La Mina, and El Progreso (World Bank, n.d. and interviews with local authorities). Period of flooding in the Municipality also poses a risk of extreme silt deposition. For example, the operation of the water treatment plant routinely fails due to the increased sedimentation (SANAA report). Lateral canals help divert excess flow to outside the Municipality; however, engineering studies have cited that its dimensions are too small to handle extreme events (World Bank, n.d.). The Ulúa River's flow is approximately 3,000 m^3/s, while it can reach 10,000 m^3/s during extreme events.

Due to its geographical location close to the Caribbean, the north-west quadrant of Honduras has historically been the region of the country with the highest exposure to hurricanes. Extreme rainfalls often cause the Ulúa River and its tributaries to burst their banks, resulting in floods. This has been exacerbated by the deforestation along the river brooks and the city's limited drainage system which is not sufficient during such heavy rains.

This section provides: (1) a description of the flooding in El Progreso, 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 hazard map for the municipality of El Progreso.

2.4.1 Description of floods

As mentioned above, El Progreso's location along two river banks and adjacent to the Mico Quemado mountains make it prone to flooding (see Figure 2.12).

- **Rivers:** El Progreso is located along the banks of the Ulúa and Pelo rivers, and is situated within the flood plain. Flooding along the river banks can occur during storm events.
- **Mountain:** The steepness of the slopes (i.e., 30 to 60%) and the location of the city make it very susceptible to fast-moving water as it descends from the mountain. This impact has been enhanced by deforestation and poor land management in the upper areas of the mountain, despite the fact that it is a protected natural reserve.

Figure 2.12 Satellite photo of El Progreso. Source: Google accessed January 25, 2013.

Two hydro-meteorological conditions that cause flooding in the city of El Progreso have been identified (Integral Multidimensional Diagnosis – DIM, 2012):

- Minor rain events followed by a heavy precipitation event. Such minor rains saturate the soils and decrease the infiltration volume. When followed by a heavy precipitation event, flooding ensues.
- Heavy precipitation in the surrounding mountains. Increased flooding results when heavy precipitation starts in the mountains and moves its way downstream toward the creeks and into the city; such scenarios are exacerbated whenever the rainfall event moves at the same velocity as the runoff waters. This can cause flash floods and riverine flooding from overtopping of the Ulúa River during torrential or prolonged rain events (Velasco, 2007).

In addition to these meteorological conditions that impact flood risk, the anthropogenic changes in the natural landscape have also affected the frequency and intensity of floods. Urbanization is known to change various hydraulic parameters of the surface, such as reducing the ground's capacity to readily absorb water. According to the Prevention and Mitigation Plan (PMDN, 2002), factors influencing floods at El Progreso include:

- Poor management of watersheds
- Low hydraulic capacity of rivers as a consequence of sedimentation and obstacles
- Migratory agriculture practices
- Deforestation
- Population location in flood-prone areas.

In addition, the Ulúa River levees that were built to protect the city from floods can act as water traps. The levees purpose is to protect the city from flooding by the river when the water level gets too high (i.e., keeping the river overflow from flooding into the city). However, during precipitation events, runoff from the Mico Quemado Mountain that does not infiltrate into the soils descends into the soil and is trapped in the city behind the levees. There have been occasions when the populated areas are flooded by runoff from the mountains and the river water level is also very high.

2.4.2 Past and present floods

Storms and floods are responsible for significant human and economic impact in Honduras. During 1997 to 2006, four storm events caused damages of $127 million (U.S. dollars), and three flood events affected 15,000 people and caused damages of $128 million (U.S. dollars) (World Bank, 2009).

Overflowing of the Ulúa River, Pelo River, and the Guanchías and Guaymitas channels have been responsible for the majority of flooding in El Progreso. Traditionally, floods affect the western part of the city, and the city has been isolated from communications with La Lima, San Pedro Sula and Santa Rita, and other towns such as Agua Blanca, La Mina and Urraco (Perdigon and Vasquez, 2007). Among the most flood-prone neighborhoods are Policarpo Paz García, Centroamericana y Fátima, at the margin of the Ulúa River and the Pelo River or at the interception of these rivers.

Amongst the climatological events that have caused flooding and most severely affected the municipality of El Progreso are: Hurricane No 5 in 1935; Tropical storm Gilda in 1954; Hurricane Francelia in 1969; Hurricane Fifi in 1974; Hurricane Joan in 1988; Hurricane Gilberth in 1988; Tropical Storm Gert in 1993; Hurricane Marcos in 1996; Hurricane Mitch in 1998; Hurricane Gamma in 2005; and Tropical Storm Agatha in 2010 (MITIGAR-COPECO, 2012).

- Hurricane Mitch was devastating to El Progreso's population and economy. During the event, not only did the river overflow but also the ravines, causing widespread and severe damage. Flooding from the Pajuiles Ravine cut off access to roads and destroyed agricultural land, contributing to the extensive losses in the Municipality's agricultural sector estimated at US$27 million (MITIGAR-COPECO, 2012).
- Hurricane Gamma severely affected the entire municipality, including the city. Direct impacts in the city were related to floods in areas bordering the Ulúa River including

Policarpo Paz, 2 de Julio, San Martin, Centroamericana, Fátima and San Miguel and other low areas distant from the river including Mangadi, Buenos Aires, Dos de Marzo, Los Castaños, Palermo and Santa Fe. It is not clear whether the flooding in each settlement is due to river overflow or mountain runoff. Additional impacts included the flooding of agricultural areas and isolation from other cities. The media reports that 60% of the city was flooded as a consequence of both the river overtopping its banks and the amount of rainfall flooding the saturated land. During the storm, dikes protecting the city broke (DesInventar, 2012).

- Tropical storm Agatha impacted the municipality and the city of El Progreso causing severe flooding. An article suggests that some inhabitants from the neighborhoods bordering the Ulúa River, including Policarpo Paz García, Centroamericana and Fátima, had to be evacuated due to issues with the dikes (La Prensa, 2010).

Between 1968 and 2011, there have been 176 flood events in the municipality recorded in the DesInventar Database (version 9.5.12-2011), representing 65% of all disaster events reported. Approximately 98 of these events affected the city of El Progreso. Appendix A.2 provides additional detail of the events reported. The database also provides information of epidemics that may be a consequence of rain and flood events, such as the mosquito-borne disease, dengue fever.

As shown in Figure 2.13, the data collected suggests 84% of flood events in the city of El Progreso occur during the months of September, October, and November, consistent with the latter half of the rainy season.

The majority of reported flood events occurred during the decade of 1969 to 1979 (see Figure 2.14). Recently, the city of El Progreso adopted a successful response plan to protect the population from fatalities during flood events. Because of this, reporting databases may underrepresent total flood events that have recently occurred (i.e., flood events with minimal damage may not be reported).

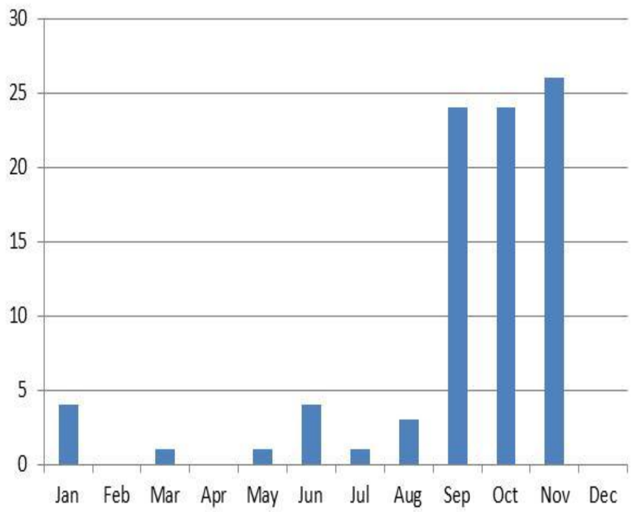


Figure 2.13 Monthly distribution of floods as reported by the media from 1968 to 2011. Source: DesInventar Database (version 9.5.12-2011).

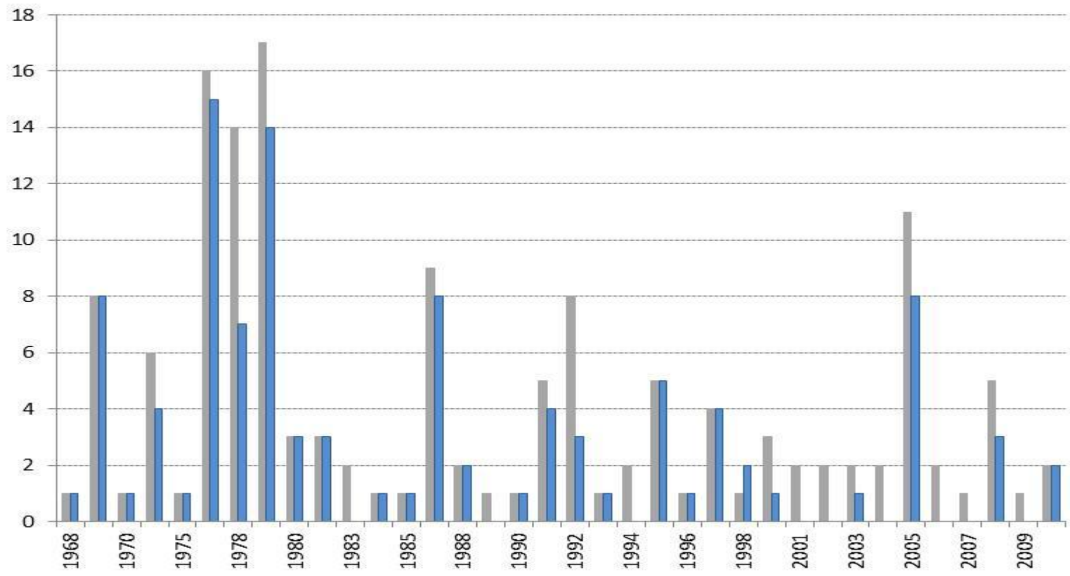


Figure 2.14 Number of events reported from 1968 to 2011 where the grey bars represent all reported events, and the blue bars represent flood events. Source: DesInventar Database (version 9.5.12-2011).

As part of its territorial land planning, the Municipality of El Progreso (2012) identified those areas that have flooded annually during the past 10 years. Table 2.3 summarizes these findings.

Table 2.3 Communities that have flooded annually over the past 10 years, Source: Municipalidad de El Progreso, 2012

River/channel influence area	Urban Community
River flooding	
Rio Pelo	La Compania, Sitraterco, Penjamo, Suyapa, Paty, Policarpo Paz, Inva, Bendeck
Quebrada Corocol	Emmanuel 1 and 2, 2 de Marzo, Corocol 1 and 2, San Jose, Kennedy
Macrocanal - Quebrada Santa Helena	Altos del Progreso, El Porvenir, Carcamo, Esperanza de Jesus, Mangandi, Suazo de Cordova, Emmanuel, Imprema, Alfonso Zelaya
Quebrada los Castaños	La Primavera, Los Castaños
Rio Ulúa	Centroamericana, Fatima, San Martin, 2 de Julio, San Miguel, Buena Vista, Nueva Cobb, Soberano, Rio Chiquito, Las Flores, Naranjo Chino, San Isidro, Excampos bananeros Sector Norte, Urraco Pueblo, Amapa, Monterrey, Palos Blancos, La 70, La tarrera, la, 8,9,10,11, El Socorro, 4 de marzo
Other floods	
Urban areas affected by flooding	Bendeck, Palermo, Montanina, San Antonio, Bogran, Dionisio Avila, 27 de Octubre, Mendieta, Monte Fresco, William Hall, Alameda, 5 de Diciembre

2.4.3 Flood planning resources

The city of El Progreso has four maps that identify areas prone to flooding: a 50-year flood-inundation map, a flood-inundation map based on the Hurricane Iris event, an extreme flood hazard map and an annual flood hazard maps, the last two were developed for spatial planning purposes. Each is discussed in greater detail below.

50-year inundation map. Designed to assist the municipal government address hazard mitigation planning and response, the 50-year inundation map for El Progreso (see Figure 2.15) was developed by the United States Geological Survey (USGS). The floodplain polygons were delineated using the standard one-dimensional hydraulic and hydrologic modelling approach, which accounts for the water cross-section geometry of the various streams and rivers, airborne light detection and ranging (LiDAR) topographic survey of the area[7], a 50-year flood drainage area and mean annual precipitation scenario. As a result, the map shows the 1-in-50 probability that such areas would be inundated in a given year; for cartographic purposes, these areas were categorized based on three flood depth categories: between 0 to 1 meter (shown as light blue), 1 to 2 meters (shown as blue), and over 2 meters (shown as dark blue).

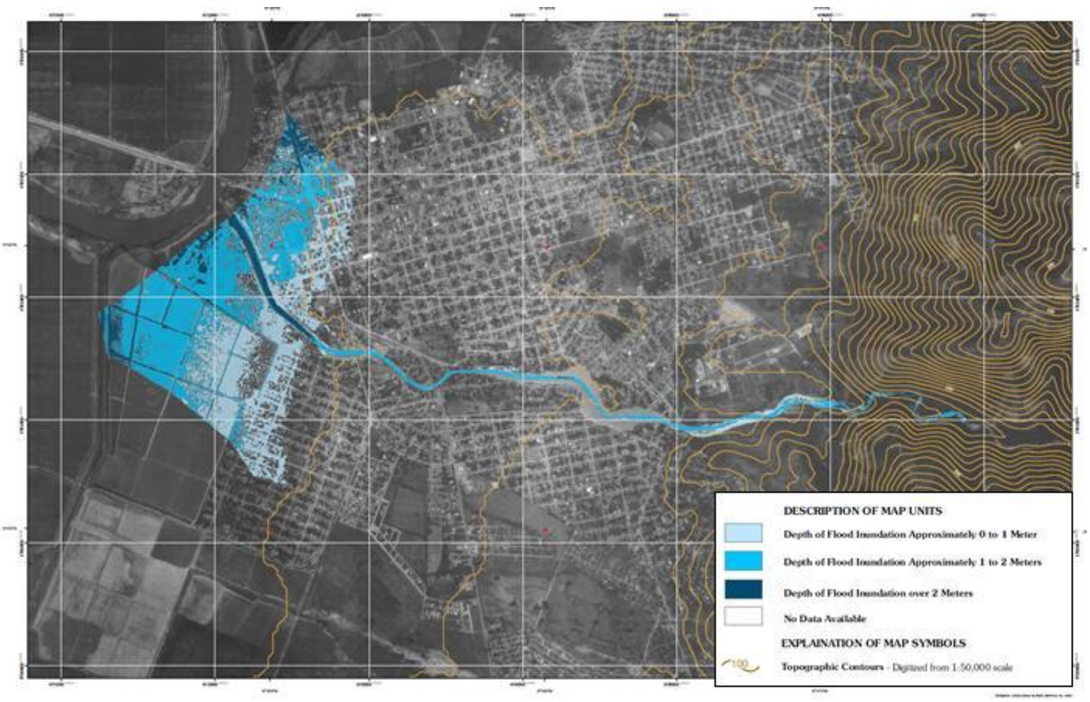


Figure 2.15 50-year Flood Inundation Map and Digital Orthophoto of El Progreso, Honduras. Source: Kresch et al., 2001.

Inundation map of Hurricane Iris. Hurricane Iris in 2001 was responsible for substantial rainfall and flooding in the north-west quadrant of Honduras. Figure 2.16 presents the flood hazard map sponsored by the World Bank and Inter-American Development Bank (IADB), where the floodplain was delineated using a two-dimensional hydraulic model that simulated the effects from Hurricane Iris. Inundated areas show both the extent and maximum flood depth. Some areas were flooded up to 22 feet.

[7] The contours from the LiDAR survey were digitized from 1:50,000 scale topographic maps by the Instituto Geografico Nacional of the Republic of Honduras (National Geographic Institute of the Republic of Honduras).

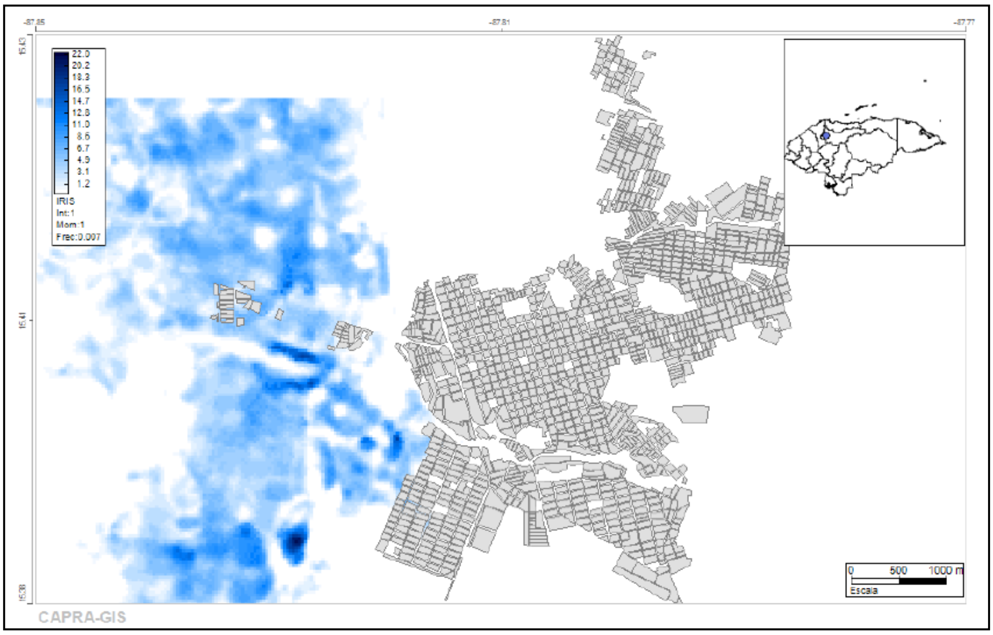


Figure 2.16 Inundation Map for El Progreso of Hurricane Iris. Source: Kresch et al., 2001.

Both maps suggest the western portion of the city is particularly prone to flooding during storm events at the confluence of the Pelo and Ulúa Rivers, or along the western rim of El Progreso. Both maps provide a compelling visual that merges the scenario of a 50-year flood with the actual consequence of a hurricane event (in this case, Hurricane Iris). As a result, it is inferred that overtopping poses a greater threat than flash flood event: water from the various watersheds appear to drain adequately through the Pelo River, until it meets with its larger counterpart, downstream of the city.

Municipality of El Progreso extreme flood hazard map. Both maps are corroborated by the flood map, Figure 2.17, developed by the Municipality of El Progreso (Municipalidad de El Progreso, 2012). It is our understanding from our interviews that these categories were assigned based upon expert knowledge and historical memory. The threat categories of high, medium, and low are thereby not associated with a particular flood event, but simply captures the local knowledge of what regions are susceptible to flooding.

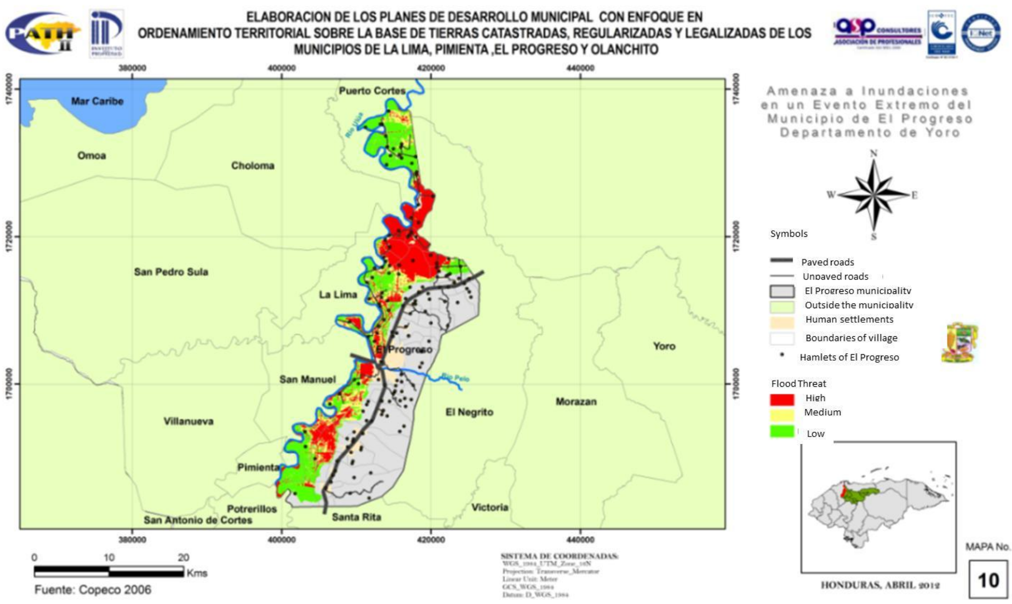


Figure 2.17 Extreme Flood Hazard Map for El Progreso. Source: Municipalidad de El Progreso, 2012.

A final map, Figure 2.18, illustrates areas in the municipality that are prone to flooding annually. The Pelo River which transects the city of El Progreso represents a high flood threat to land adjacent to the river. As with the extreme flood hazard map, this map was also constructed based on expert knowledge and historical memory.

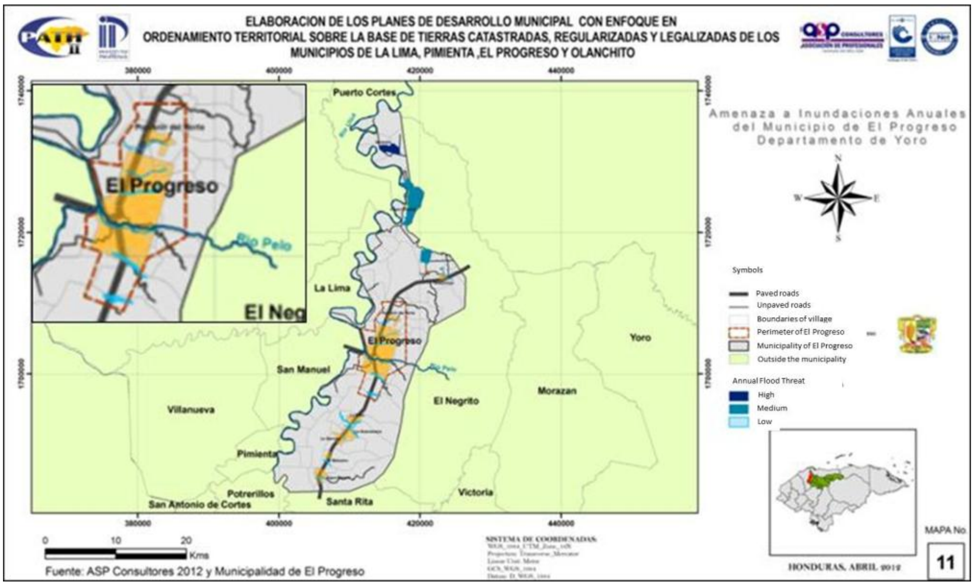


Figure 2.18 Annual flood risk map for El Progreso. Source: Municipalidad de El Progreso, 2012 (abridged version).

2.5 Current landslide hazards

Landslides are unusual in the Municipality of El Progreso and considered a 'minimal' threat (Plan Municipal de Mitigación de Desastres – PMDN, 2012). Reported landslides have occurred in rural areas, rather than in the city of El Progreso.

This section provides: (1) a description of the landslides in the El Progreso area; (2) a summary of a past landslide events; and (3) a description of the landslide tools used by the city planners and emergency management.

2.5.1 Description of landslides

As mentioned, the municipality of El Progreso has experienced very few notable landslides. Generally, landslides can happen in response to precipitation events occurring in areas that have experienced changes in a slope's topography and vegetation due to changes in its land-use (e.g., a natural landscape that is cleared for agricultural or settlement use). The removal of earthern material from the bottom of the slope destabilizes the higher slopes potentially making the area prone to landslides. The removal of the soil to make way for settlements or crops also leads to soil erosion which increases the area's susceptibility. Landslides can also occur by the scouring and undercutting of slopes caused by nearby streams. During our field visit, local stakeholders suggested debris flows may become an issue during periods of heavy rain due to the combination of poor management of the mountain and placement of housing. In El Progreso, areas that show some susceptibility to landslides are where deforestation activities and agricultural expansion north of the municipality have occurred. If these activities continue unabated, then further erosion (i.e., soil destabilization) is likely to induce more frequent landslide events. In contrast, streams located in the central zone (e.g. near Pelo River bifurcating El Progreso) have not encountered this phenomenon as human encroachment has been limited (World Bank, n.d.).

2.5.2 Past and present landslides

Reported landslides have occurred only in the rural areas of the Municipality and, due to erosion, in locations adjacent to the streams flowing from the Mico Quemado Mountains.[1] Collapses of poorly constructed structures related to mass movements are more commonly reported than landslides. These occur because of the construction of the housing (e.g., bags of trash may be used as housing foundation) and the local authorities do not believe these collapses are associated with landslides. Future work could confirm this by analysing the physical and social conditions of each house collapse. Between 1968 and 2011, there were 6 landslide events reported in the municipality according to the DesInventar Database (version 9.5.12-2011), representing 2 % of all disaster events reported. None of these events occurred in the city of El Progreso.

If urban expansion towards the mountain is not controlled and deforestation continues, there could be severe landslide problems in the near future (ERN, 2011; CATIE et al. 2004). Alluvial soils dominate the Sula Valley, while shallow soils dominate Mico Quemado Mountain. If the forest cover is compromised, the steep slopes with shallow soils become susceptible to erosion and landslides. Additionally, poor watershed management may also increase the threat of landslides (Municipality Disasters Mitigation Plan, 2012). From our visual assessment during the site visit, it appears that such susceptibility could worsen if the urban expansion towards the mountain continues and agricultural practices and activities do not consider appropriate measures to preserve the integrity of the soils, as observed in the lower and upper parts of the mountain.

2.5.3 Landslide planning resources

This section describes three resources for considering landslide threat to El Progreso:

- Landslide hazard map created by the World Bank. This map provides an indication of landslide susceptibility induced by an earthquake.
- A landslide hazard map developed by the Municipality of El Progreso. This map suggests areas prone to landslides based on stakeholder memory and expert knowledge. It does not distinguish amongst the potential activities contributing to landslides (e.g., precipitation events, earthquakes, and/or changes in land-use).
- A landslide susceptibility map developed for purposes of this report as an independent analysis. The independent analysis was conducted to broaden the findings of the first two resources by considering how characteristics such as slope and soil type may affect landslides in the municipality; this is important when considering precipitation-induced landslides. The other resources did not connect these characteristics to landslides nor identify locations that were potentially susceptible based on these characteristics.

Each is discussed in greater detail below.

World Bank funded landslide map. The study funded by the World Bank was carried out by Cardona et al.presents an evaluation using the CAPRA disaster risk information platform for decision-making and the results are presented in Figure 2.19.[8]

The methodology used to evaluate the threat of landslides includes the following steps:

- Evaluation of landslide threats induced by a deterministic seismic force of 6.83 Mw under conditions of a saturated soil.
- Data acquisition such as digital elevation models and geotechnical parameters.
- Evaluation assessment using the necessary finite element models for translational failure.

As shown in Figure 2.19, according to the study by Cardona et al. (n.d.), landslide threat within El Progreso is limited to the neighbourhoods in the north-eastern limits of the municipality and adjacent to the Mico Quemado Mountains. These neighbourhoods include Barrio Las Golondrinas, Colonia Corocolito, Colonia Juventino Barahona and Colonia Rodolfo Carcamo. This map illustrates the region within the El Progreso municipality that may be susceptible to landslides (it is assumed to also provide an indication of susceptiblity of precipitation-triggered landslides; however, the analysis is directly triggered by an earthquake).

[8] Additional information about the platform is found in its website www.ecaptra.org.

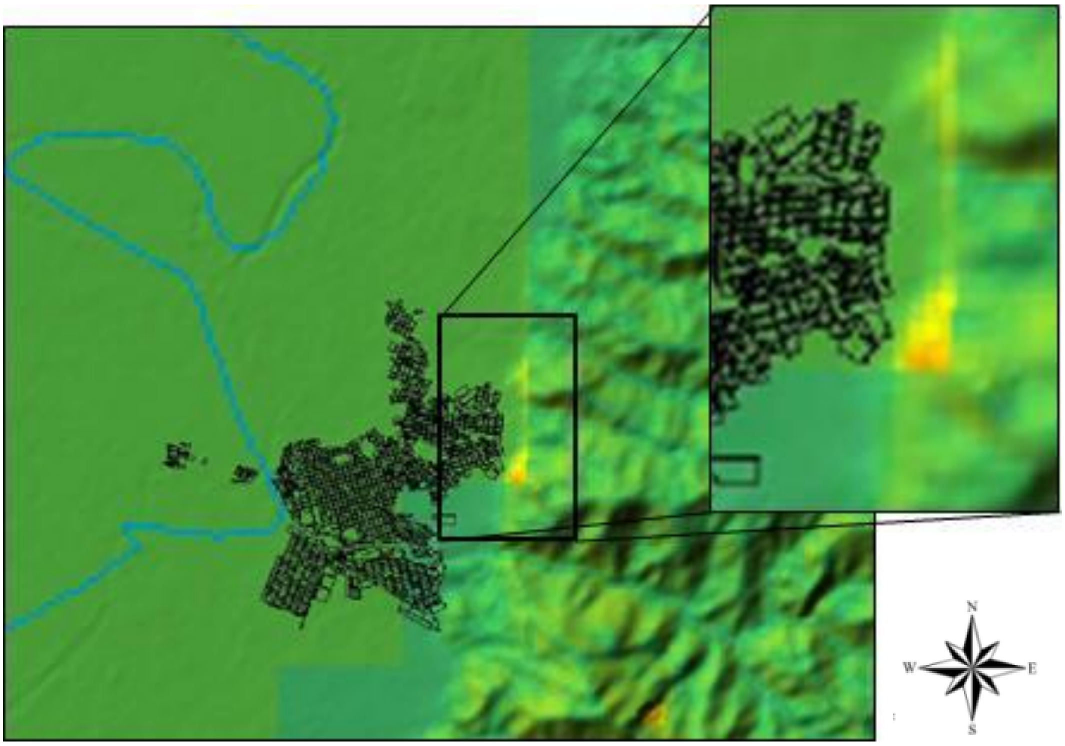


Figure 2.19 Landslide Map for El Progreso based on saturated soil state and translational failure. Source: Cardona et al., n.d.

Municipality of El Progreso landslide map. A landslide map was developed by the Municipality of El Progreso. This map classifies areas prone to landslides into three categories: low (green), medium (yellow), and high (red) (see Figure 2.20). It is our understanding from our interviews during the field visit hat these categories were assigned based upon expert knowledge and historical memory. It is not clear the activities and conditions that were responsible for these landslides (e.g., earthquake, land-use change, and/or precipitation). This map suggests that local experts do not consider landslides a threat to the city of El Progreso. This is relatively consistent with the findings of the World Bank funded landslide map.

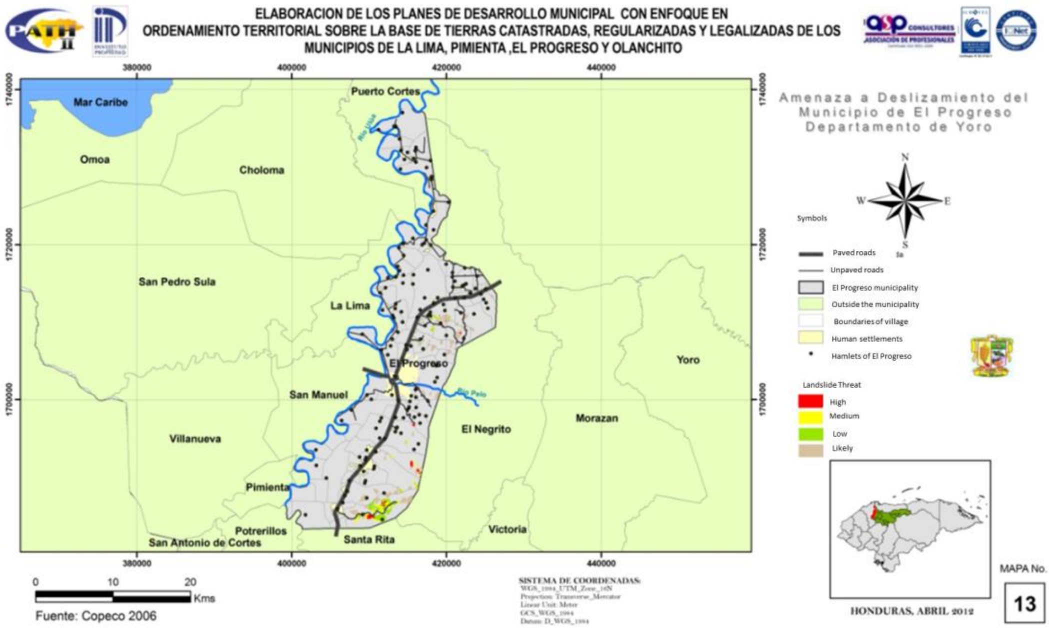


Figure 2.20 Landslide map for El Progreso. Source: Municipalidad del El Progreso, 2012.

Independent analysis. The independent analysis was conducted to consider how characteristics such as slope and soil type may affect landslides in the municipality, opposed to a landslide triggered by earthquakes or an analysis based on anecdotal stakeholder information. To assist in the identifying areas susceptible to landslides, a slope movement susceptibility assessment was produced for purposes of this report. Though precipitation is not a direct factor considered in this independent analysis, the landslide susceptibility discussed here could be triggered by precipitation. Slope movement susceptibility assessments aim primarily to identify potential instable areas; areas where a series of factors meet and could induce to instability (Brabb, 1984). Though helpful, these assessments are limited by not providing the probability of the occurrence of events but an understanding of the physical processes that could trigger landslides.

The susceptibility assessment used an heuristic approach, in which the main factors affecting terrain instability are determined and an assessment of each factor’s importance in the process is estimated (Castellanos and Van Westen, 2008). Probabilistic approaches cannot be used because of: (1) the lack of information regarding past landslides events, and (2) these type of assessments are based on the relationships between each factor and past and current landslide distribution (Carrara, et al., 1995). A multifactorial assessment was applied in this analysis in which Geographic Information Systems was used for the entire analysis including factor classification, the assignment of weights to each determining factor, and the development of the final susceptibility map (Santacana, 2001).

Once all factors were identified and an estimate of their influence on the terrain stability calculated, susceptibility was determined by:

$$S = \sum f_n P_n \quad [1]$$

Where f is factor value of the factor n, and P is the weight assigned.

For El Progreso susceptibility assessment, the following factors were used to assess soil instability:

- **Slopes**: Slopes were classified into five categories as presented in Map A of Figure 2.21. These five categories were chosen as good differentiators of the slopes and is supported by the information provided in the available data. Working with the data provided to us by local stakeholders, the slopes within the study area range from a maximum of almost 36 degrees to a minimum of 6 degrees. The map clearly delineates the river floodplains and the higher slopes at the foothill of Mico Quemado Mountain. A relationship between this data and the occurrence of landslides was not provided. If the frequency of landslides increases for El Progreso, it might be beneficial for local stakeholders to consider future work conducting a more thorough field analysis.
- **Soil type**: Due to the constraints related to the information available, this factor is defined by simply the depth/shallowness of the soils. Map B in Figure 2.21 shows soils distribution according to their depth. Unfortunately, data on the depth of the soil was not available.
- **Land use**: Soils have been classified according to the type of activity and its protectiveness capacity, for example areas of material extraction will be more susceptible to landslides than forested areas. The classification was done using expert knowledge. Five categories based on soil cover rank the land use type from low (Class 1) to high (Class 5): Class 1 is assigned to pavement, Class 2 is assigned to forests, Class 3 is assigned to grasslands or savanna vegetation, Class 4 is assigned to industrial and traditional agriculture, and Class 5 is assigned to extraction areas and bare soil. Map C in Figure 2.21 shows soils distribution according to land use.

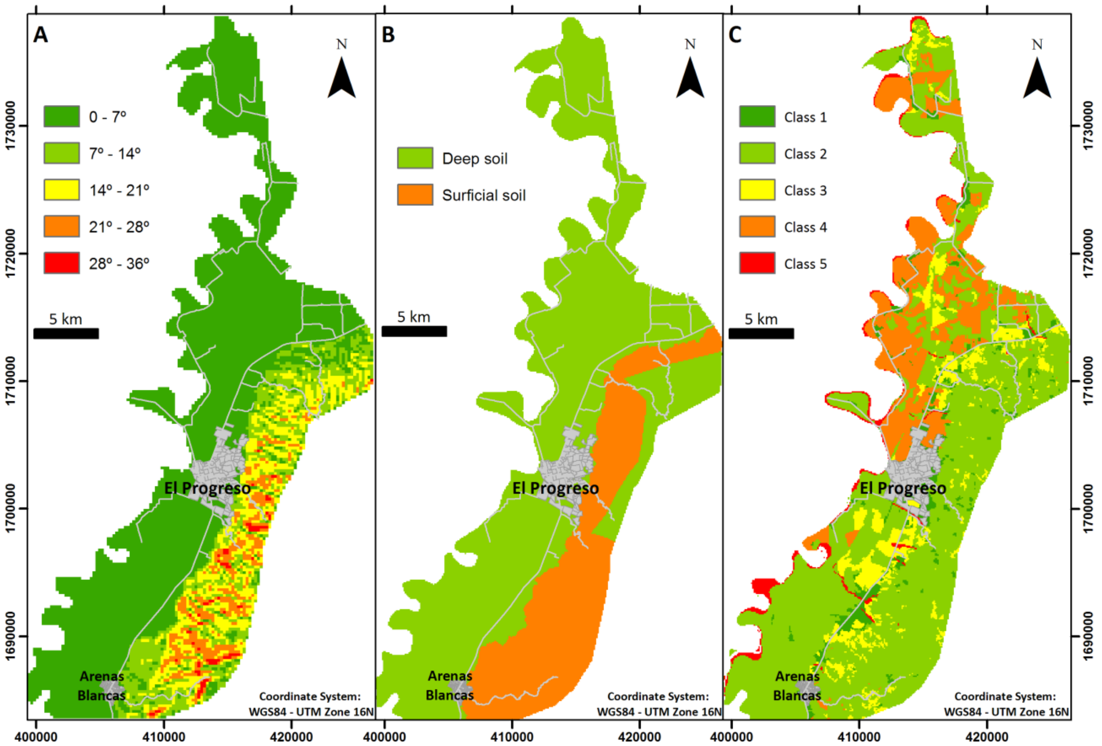


Figure 2.21 Factors used to determine landslide susceptibility A: Slopes Map. B: Soil depth map. C: Land use map. Figure constructed using the analysis described in this report.

These three factors were considered and weighted according to their potential influence on landslides. Weighting was determined based on expert knowledge. Slope was weighted by a factor of 2, geologic material was weighted by a factor of 1.5, and land use was weighted by a factor of 1. This was used to describe the relationship between land use (i.e., soil exposure) and terrain stability. The resulting susceptibility map is seen in Figure 2.22.

The figure shows a clear conditioning factor based upon the terrain topography. Two areas are clearly differentiated: the Ulúa River flood plain and the Cordillera or Mico Quemado west and east of El Progreso.

At the Ulúa River floodplain landslide susceptibility is very low as there is minimal slope. Areas that show medium susceptibility are ones that tend to flood and there is some slope. The Mico Quemado mountain areas show medium susceptibility, this region has forested areas with a strong slope and superficial soils creating a less stable environment.

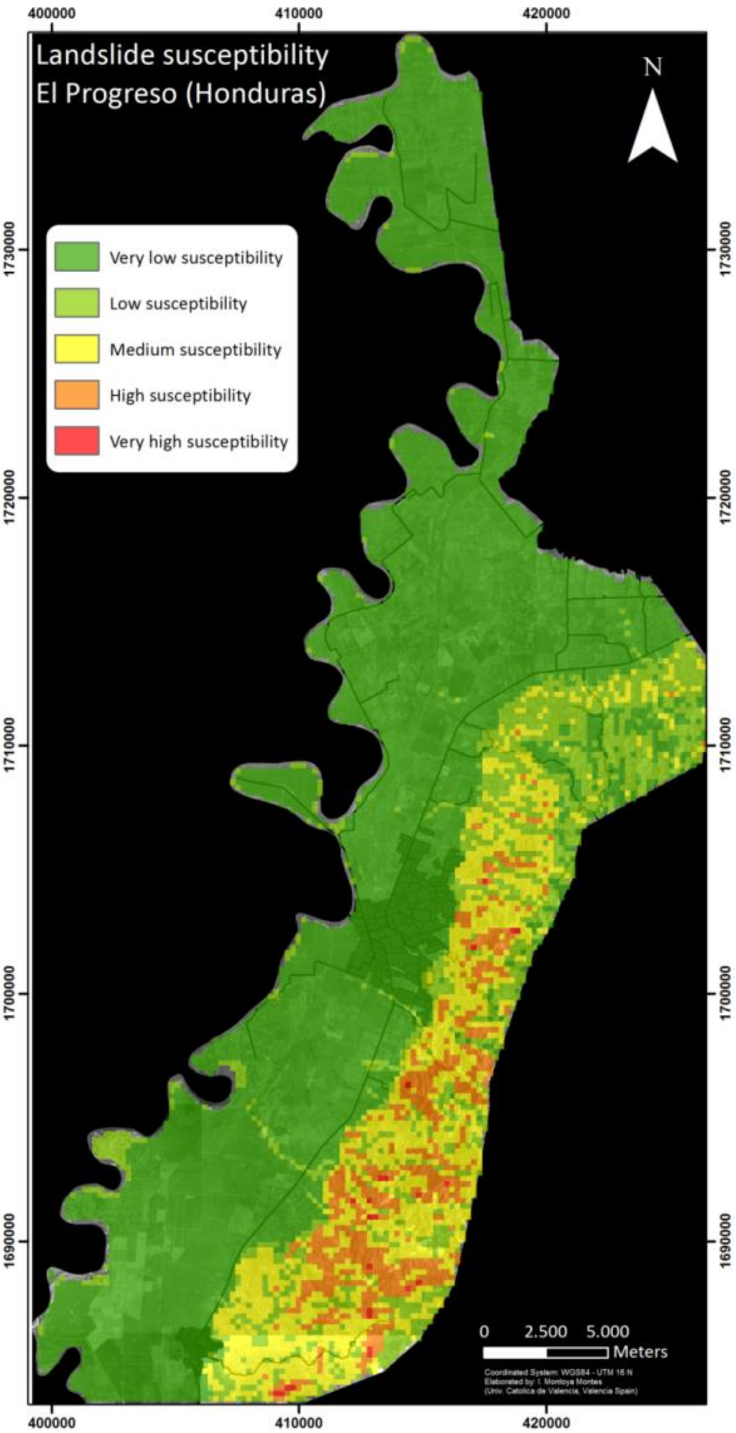


Figure 2.22 Susceptibility assessment of the Municipality of El Progreso. Figure constructed using the analysis described in this report.

The study area assessed is more than 51,000ha and this analysis indicates that it is dominated by very low susceptibility to landslides (67%). Low susceptibility represents 16.7% of the area and medium susceptibility represents 10.7%. High susceptibility areas are not very common (5.5 %) and are concentrated in those areas of steepest? slope. These results are congruent with what has been previously found by CATIE et al. (2004), Perdigón and Vásquez (2007), and ERN (2010) who classify the area as of low geodynamic susceptibility.

In summary, this analysis shows that within the city of El Progreso, high landslide susceptibility is isolated to the sector of Altos del Progreso where the city is expanding into the steep slopes of the mountain. Though this is a nature reserve protected by existing legislation, the deforestation that is taking place upon shallow soils is creating an environment conducive to landslides.

Conclusions. Based on the collective findings across these three resources and specifically based on the independent analysis, our study identified only two small locations potentially susceptible to landslides. These two areas are located in the sector of Altos del Progreso near the base of steep slopes of the mountain.

2.6 Future hazards

This analysis uses available information and data to consider how areas identified within the study region to be susceptible to flood and landslides may change by mid-century. Available climate change projections are reviewed and their impact on existing hazards considered. 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 planning to flood and landslide events. These projections are based on a collection of results from a number of global climate models that were used to inform the Intergovernmental Panel on Climate Change (IPCC). Unfortunately, there is limited information on how precipitation is projected to change in the future in El Progreso – particularly for extreme events - and there is significant uncertainty associated with those projections. The climate models include mathematical representations of ENSO and the ITCZ. Overall, the modelling community found that the basic properties of ENSO are well simulated in global climate models, but there are challenges to producing the associated detailed properties (e.g., diversity of events) (Guilyardi et al., 2012). In simulating the ITCZ, climate models also tend to have too much precipitation over much of the tropics (e.g., Northern Hemisphere ITCZ) and too little precipitation over the equatorial Pacific (Lin, 2007). In addition, global climate models which do not fully represent tropical cyclonic activity (e.g., tropical storms and hurricanes).

Box 2 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

Because of these factors, precipitation projections can be challenging to adequately produce. To reduce some of this potential model uncertainty, this analysis considers only the change in precipitation over time for each climate model and emission scenario opposed to the absolute future simulated values – this is because if the bias in the climate model to over or under simulate precipitation compared to the observed conditions averaged over time continues consistently over the model simulations, then the estimated change removes some of this bias. To fully realize the extent and appropriate treatment, however, robust long-term observational records are needed along with future studies considering how climate may change these processes.

The lack of available observed daily precipitation creates a number of problems for producing robust projections: (1) prohibits a full exploration to determine the daily precipitation thresholds/conditions that lead to floods and landslides, (2) constricts the capacity of training the larger-scale global climate model data to more localized conditions (i.e., statistical downscaling), and (3) prohibits the ability to create a baseline of extreme precipitation conditions (e.g., 5-day maximum) from which to compare similarly tailored projections of future conditions. Because of this, it is strongly encouraged that stakeholders consider the importance in supporting efforts to expand the instrumentation and management necessary for the collection of long-term observational data. The findings presented should be carefully applied to the municipality planning within the context of the associated uncertainty.

2.6.1 A changing climate

By the 2040s, El Progreso is projected to experience warming temperatures and a small reduction in precipitation. This section discusses the seasonal changes in temperature and precipitation.

Wet Season. By the 2040s, the wet season (i.e., approximately June through November) is projected to become drier and warmer. Monthly temperatures during the wet season are projected to rise between 1.1^{o}C and 1.5^{o}C for Scenario 1 and between 1.5^{o}C and 1.9^{o}C for Scenario 2 relative to a 1961 to 1990 baseline. As shown in Figure 2.23, there is a tendency of greater variability amongst the climate models for Scenario 2 (i.e., the bar on the figure that indicates the range between the climate model projecting the greatest increase in temperature and the climate model projecting the smallest increase in temperature).

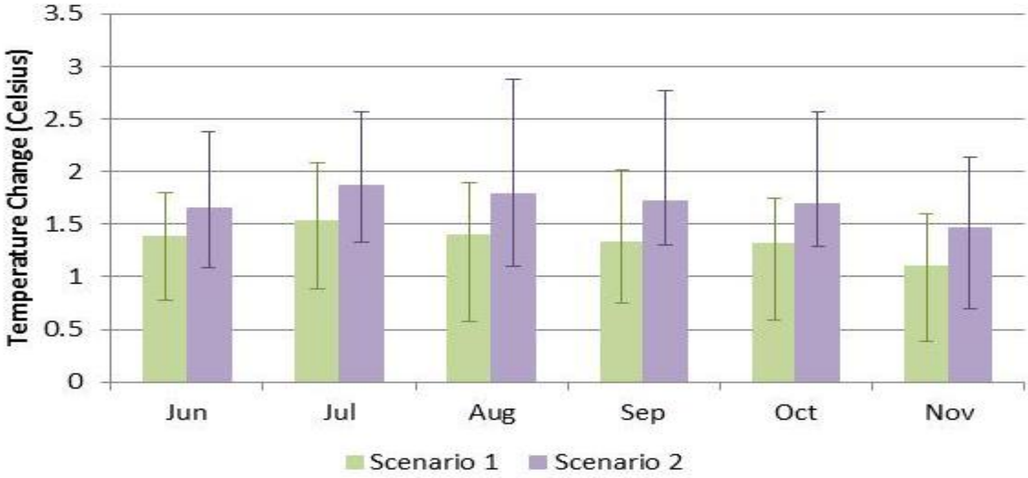


Figure 2.23 Projected change of monthly temperature in the 2040s compared to 1961 to 1990 baseline conditions for the wet season in the El Progreso region. The error bars provide the range in projections across climate models. Source: based on data collected from Givertz, 2009.

Relative to a 1961 to 1990 baseline, monthly precipitation may reduce up to 10% under Scenario 1 and 14% under Scenario 2 (see Figure 2.24). This would lead to an increase in evaporation rates and a decrease in soil moisture. However, the projected change in precipitation varies considerably from month to month. Under Scenario 1, the average monthly precipitation for the wet season is projected to reduce by 5.7%; however, an increase of 4% is suggested for the month of November (all other months suggest a decrease). Under Scenario 2, the average monthly precipitation is projected to reduce by 6% (no months suggest an increase in precipitation).

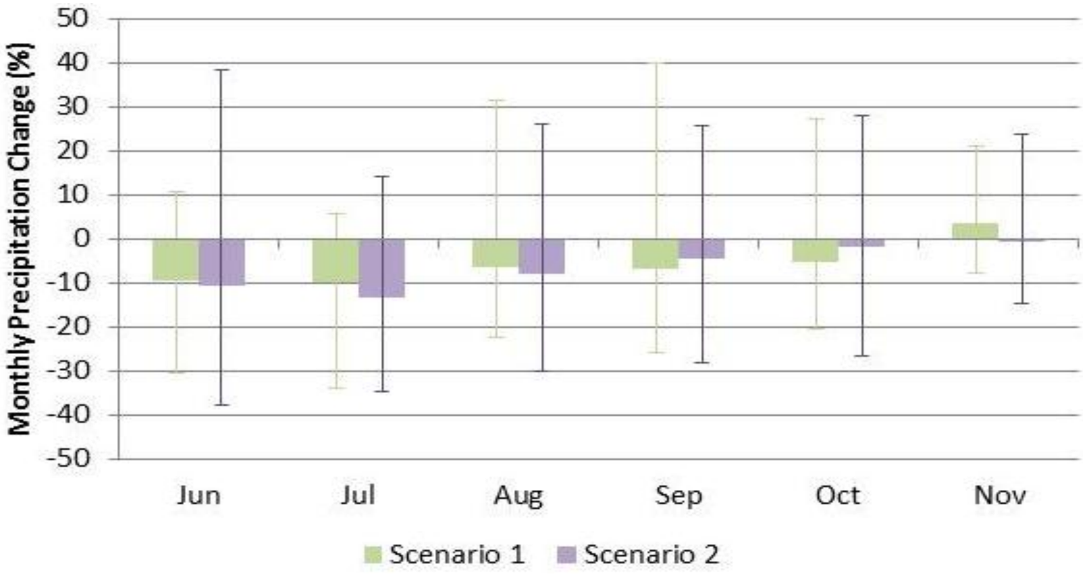


Figure 2.24 Projected % change of monthly precipitation in the 2040s compared to 1961 to 1990 baseline conditions for the wet season in the El Progreso region. The error bars provide the range in projections across 15 climate models, Source: based on data collected from Givertz, 2009.

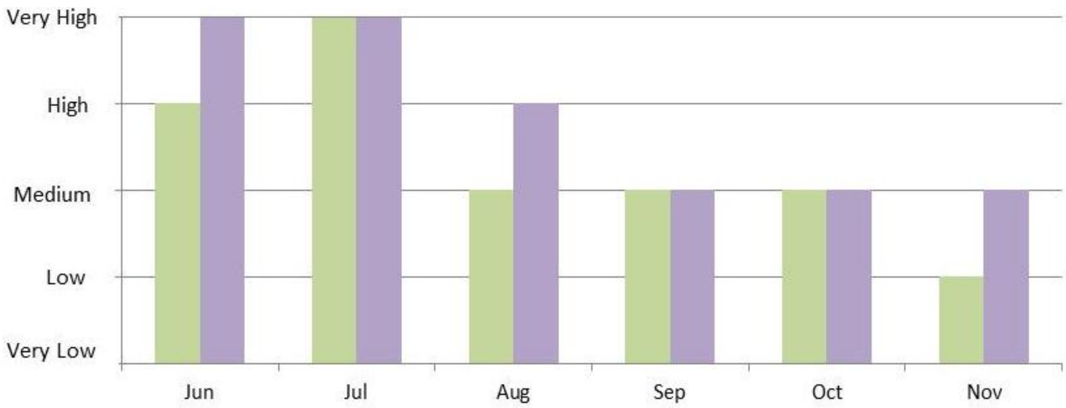


Figure 2.25 Illustrates the confidence in the reduction of precipitation suggested by the climate model ensemble average. A “very high” suggests 13 to 15 climate models agree, “high” suggests 11 to 12, “medium” suggests 6 to 10, “low” suggests 3 to 5, and “very low” suggests less than 3. Source: based on data collected from Givertz, 2009.

For both Scenarios 1 and 2, there is “high” and “very high” confidence that precipitation may decrease during the months of June and July (see Figure 2.25); confidence is determined by the number of climate models that agree that the future climate may experience a reduction in precipitation. There is less confidence for the other months. This suggests the climate model ensemble average is well representative of the potential future for each scenario for June and July. However, there is some notable disagreement amongst the climate models for the remaining months.

The average temperature and precipitation across all climate models under a given scenario (labelled “mean”) as well as the minimum and maximum projection simulated by a given climate model was also investigated (see Table 2.4). This provides another indication of the uncertainty associated with the average precipitation of the climate model ensemble mean. For Scenario 1, though there is substantial range across the precipitation projections (noted by comparing the minimum and maximum projected values for each scenario), the majority of climate models cluster between an 11% reduction to a 4% increase in seasonal precipitation. This is similar to projections under Scenario 2, where a small shift occurs in the majority of projections from climate models that favor a reduction in precipitation.

Table 2.4 Projected temperature and precipitation for the wet season in the El Progreso region for the 2040s relative to a 1961 to 1990 baseline. Projected data is shown for the minimum and maximum results from climate models ("min", "max"), the 75th-%ile and 25th-%ile, and the climate model ensemble mean.

	Obs	Scenario 1 (2040s)					Scenario 2 (2040s)				
		Min	25%	**Mean**	75%	Max	Min	25%	**Mean**	75%	Max
Seasonal Temperature (^oC)	27.7	28.4 (+0.7)	28.7 (+1.0)	**29.0 (+1.3)**	29.3 (+1.6)	29.6 (+1.9)	28.7 (+1.0)	29.0 (+1.3)	**29.4 (+1.7)**	29.6 (+1.9)	30.1 (+2.4)
Seasonal Precipitation (mm)	1,077	862 (-20%)	959 (-11%)	**1012 (-6%)**	1120 (+4%)	1260 (+17%)	851 (-21%)	926 (-14%)	**1012 (-6%)**	1099 (+2%)	1228 (+14%)

Source: based on data collected from Givertz, 2009.

Dry Season. By the 2040s, the dry season (i.e., December through May) is also projected to become warmer and drier. The temperature and precipitation projections are somewhat similar to those discussed for the wet season. As shown in Figure 2.26, monthly temperatures during the dry season are projected to rise between 1.1°C and 1.3°C for Scenario 1 and between 1.4°C and 1.7°C for Scenario 2 relative to the 1961 to 1990 baseline. There continues to be a tendency of greater variability amongst the climate models under Scenario 2.

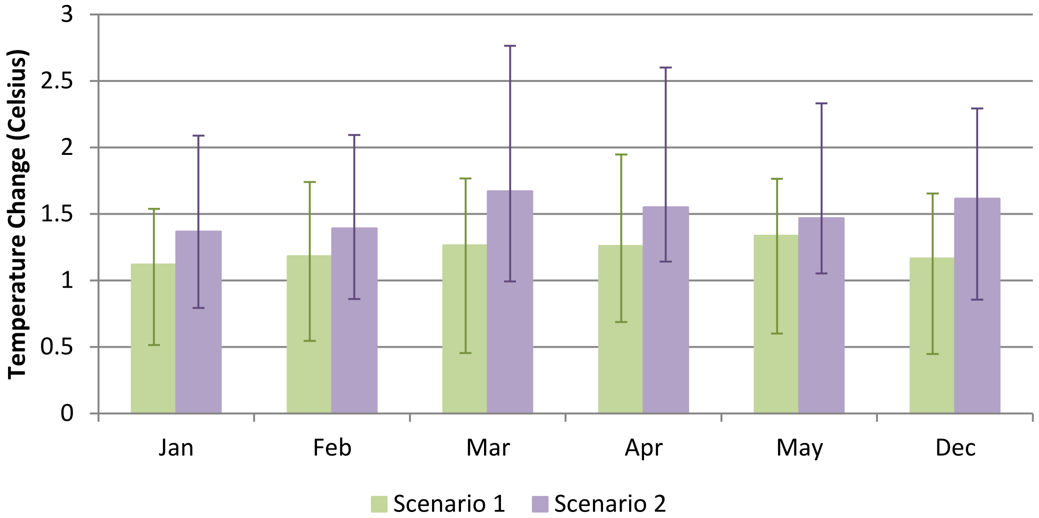


Figure 2.26 Projected change in monthly temperature in the 2040s compared to a 1961 to 1990 baseline for the dry season in the El Progreso region. The error bars provide the range in projections across climate models. Source: based on data collected from Givertz, 2009.

As illustrated by Figure 2.27, monthly rainfall is projected to decrease up to 10 to 20% under Scenario 1 and Scenario 2, respectively, relative to a 1961 to 1990 baseline. There is large month-to-month variability across the projections. April is projected by Scenario 2 to experience the greatest reduction in rainfall, followed by March, while Scenario 2 suggests a relatively consistent reduction occurring from March through May. Though all months project some level of reduction in rainfall, it is less than 5% for the months of January and February. Scenario 1 and Scenario 2 are in general agreement in the projected magnitude and direction of monthly precipitation. However, there are large differences across model simulations for projected monthly changes in precipitation for March, April, and December.

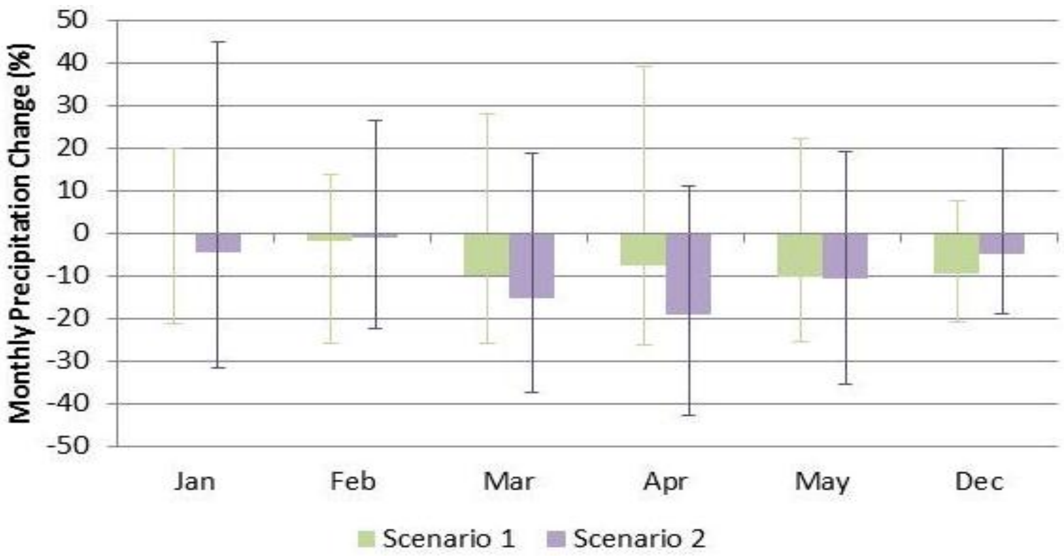


Figure 2.27 Projected % change in monthly precipitation in the 2040s compared to a 1961 to 1990 baseline for the dry season in the El Progreso region. The error bars provide the range in projections across the 15 climate models, Source: based on data collected from Givertz, 2009.

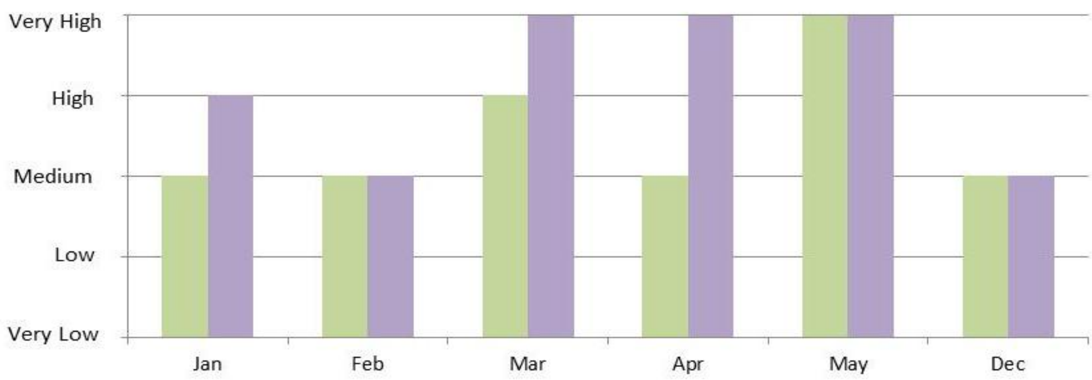


Figure 2.28 Illustrates the confidence in the reduction of precipitation suggested by the climate model ensemble average. A "very high" suggests 13 to 15 climate models agree, "high" suggests 11 to 12, "medium" suggests 6 to 10, "low" suggests 3 to 5, and "very low" suggests less than 3. Source: based on data collected from Givertz, 2009.

As noted, March, April, and May are important months that drive a large amount of the change projected for rainfall during the dry season. For both Scenarios, there is "high" to "very high" confidence in the direction of change for precipitation for the months of March and May; there is "very high" confidence for the month of April under Scenario 2 (Figure 2.28). Though the top figure shows there is a large range across climate models in the monthly projections, the bottom figure suggests that the majority of the models agree that rainfall may decrease in the 2040s. This suggests that the climate model ensemble average is well representative of the potential future for Scenario 2 and somewhat well representative for Scenario 1.

The average temperature and precipitation across all climate models under a given scenario (labelled "mean") as well as the minimum and maximum projection simulated by a given climate model was also investigated (see Table 2.5). This table provides an additional indication of the uncertainty associated with the average precipitation of the climate model ensemble mean. For Scenario 1, there is substantial range across the precipitation projections (noted by comparing the minimum and maximum projected values for each Scenario). But the majority of climate models cluster between a 14% reduction to a 1%

increase in seasonal precipitation. This is similar to projections under Scenario 2 where the majority of climate models cluster between a 19% to a 1% reduction in seasonal precipitation. This further supports the potential reduction in rainfall in the 2040s during El Progreso's dry season.

Table 2.5 Projected temperature and precipitation for the dry season in El Progreso for the 2040s relative to1961 to 1990 conditions. Projected data is shown for the minimum and maximum results from climate models, the 75th-%ile and 25th-%ile, and the climate model ensemble mean.

	Obs	Scenario 1 (2040s)					Scenario 2 (2040s)				
		Min	25%	**Mean**	75%	Max	Min	25%	**Mean**	75%	Max
Seasonal Temperature (°C)	26.5	27.1 +0.6	27.5 +1.0	**27.7 +1.2**	27.9 +1.4	28.2 +1.7	27.5 (+1.0)	27.7 (+1.2)	**28.0 (+1.5)**	28.2 (+1.7)	28.9 (+2.4)
Seasonal Precipitation (mm)	426	324 (-24%	366 (-14%)	**396 (-7%)**	430 (+1%)	533 (+25%)	290 (-32%)	345 (-19%)	**388 (-9%)**	421 (-1%)	528 (+24%)

Source: based on data collected from Givertz, 2009.

Extreme Events. This analysis did find adequate data to support an analysis of how extreme precipitation events may change in the future**.** Though – with additional effort than available for this study - daily precipitation data from climate models can be processed to provide changes in precipitation event indicators (e.g., changes in the 1-day maximum event per year over a future thirty year period), Honduras is lacking adequate observational records to develop the required baseline of extreme precipitation events. For example, if the projections suggest a 5% increase or decrease in rainfall totals associated with the worst 1-day precipitation event each year, it is necessary to have an observed baseline to apply the %-change to understand future change. Without adequate observational records, the exercise in producing and tailoring future projections of extreme weather events is unwarranted.

Though there is much debate regarding how tropical cyclones (e.g., hurricanes, tropical storms) may be affected by climate change, there is general consensus amongst hurricane modelling experts that storms in the Atlantic basin may decrease in frequency but increase in intensity by the end of the century (Knutson, 2010). However, this does not explore potential changes in the hurricane track (i.e., could Honduras be hit more or less by cyclones). This is an area of active research and additional modelling conducted by hurricane modeling specialists will illuminate how the duration and frequency of future hurricanes may change under a changing climate.

Summary. The projected precipitation and temperature changes associated with each of the two scenarios developed for this analysis are summarized in Table 2.6. While there is considerable uncertainty associated with the available climate projections, this first order approach indicates that, by the 2040s, precipitation may be reduced, potentially decreasing the possibility of floods and landslides. It is not clear, however, how the intensity, frequency, and/or duration of rainfall events may change. This is an important area for future research after the development of long-term observational records.

Both El Progreso's dry and wet seasons 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.

Table 2.6 Summary of the projected change in seasonal temperature and precipitation for the 2040s. Source: based on data collected from Givertz, 2009.

Season	Temperature Projected in 2040s	Precipitation Projected in 2040s

	Season	Temperature Projected in 2040s	Precipitation Projected in 2040s
Scenario 1	Dry	1.2°C	-7%
	Wet	1.3°C	-6%
Scenario 2	Dry	1.5°C	-9%
	Wet	1.7°C	-6%

Figure 2.29 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: Scenario 2 is projected to be somewhat warmer during both seasons and slightly drier than Scenario 1 during the dry season. Future work could conduct a more intensive study that considers how precipitation events may change – i.e., as precipitation reduces, how are the intensity, frequency, and duration of storms affected. However, given the uncertainty associated with modelling changes in future precipitation events, it is likely prudent that this study rely more heavily on the more robust projections of changes in seasonal and monthly precipitation when considering impacts on hazards.

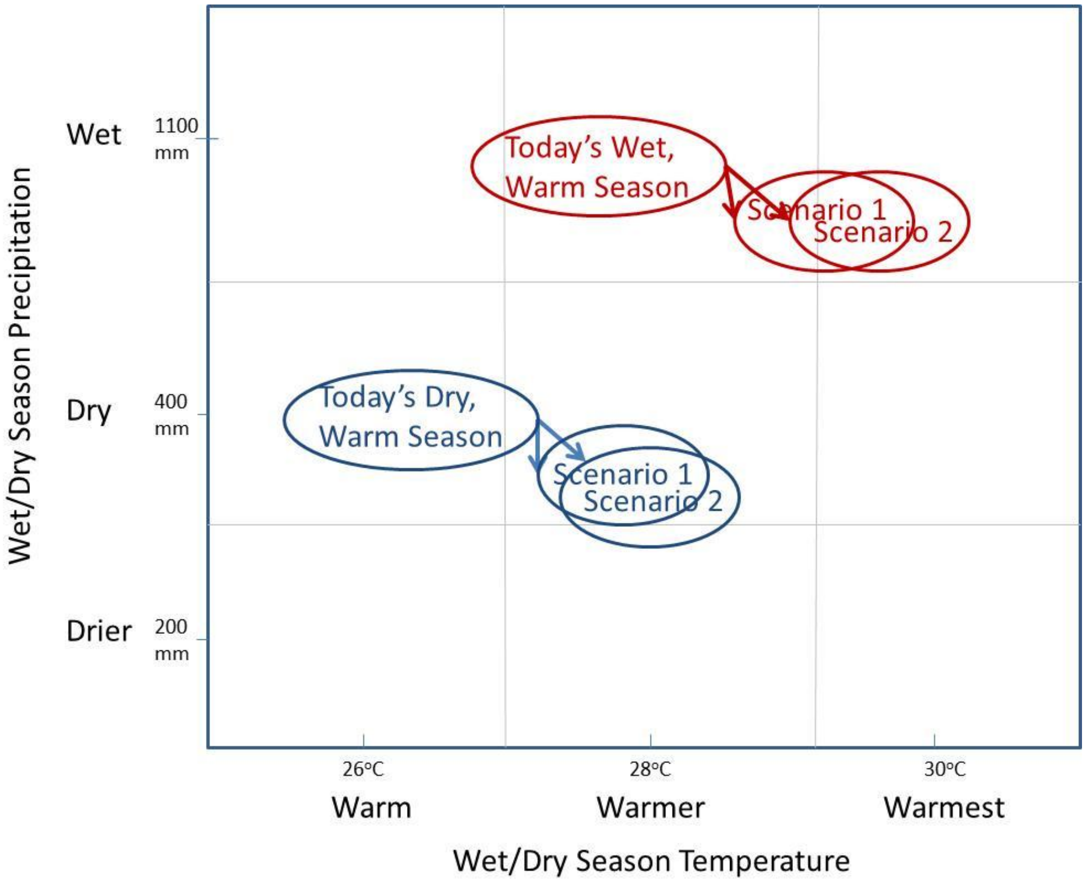


Figure 2.29 Illustrative diagram of the projected mid-century change of today's dry, warm and wet, warm seasons (not to scale).

2.6.2 Changes in future flood and landslide events

Our assessment uses available information and data to identify areas within the study area that may be susceptible to future floods and landslides. These first-order results suggest that the current locations prone to landslides and floods described in the maps provided in sections 2.4.3 and 2.5.3 may face a slightly lower hazard level. Table 2.7 provides a summary of the locations threatened by each hazard and qualitatively considers how future climate change in the 2040s may affect these threats.

Table 2.7 Qualitative summary of change in areas currently prone to flood and landslide hazards in El Progreso by the 2040s.

Hazard	Location	Projection	Projected change in hazard
Floods	La Compania, Sitraterco, Penjamo, Suyapa, Paty, Policarpo Paz, Inva, Bendeck, Emmanuel, 2 de Marzo, Corocol 1 and 2, San Jose, Kennedy, Altos del Progreso, El Porvenir, Carcamo, Esperanza de Jesus, Mangandi, Suazo de Cordova, Imprema, Alfonso Zelaya, La Primavera, Los Castaños, Centroamericana, Fatima, San Martin, 2 de Julio, San Miguel, Buena Vista, Nueva Cobb, Soberano, Rio Chiquito, Las Flores, Naranjo Chino, San Isidro, Excampos bananeros Sector Norte, Urraco Pueblo, Amapa, Monterrey, Palos Blancos, La 70, La tarrera, la, 8,9,10,11, El Socorro, 4 de marzo, Bendeck, Palermo, Montanina, San Antonio, Bogran, Dionisio Avila, 27 de Octubre, Mendieta, Monte Fresco, William Hall, Alameda, 5 de Diciembre have been identified as flood-prone areas.	The climate projections suggest that the threat of floods may be reduced as the seasonal and annual rainfall is generally expected to decrease in the area.	↓
Land-slides	No landslides have been observed in the city; potential vulnerable spot for landslides sector of Altos del Progreso.	The climate projections suggest that the threat of landslides may be reduced as the seasonal and annual rainfall is generally expected to decrease in the area. Reduced precipitation during the "dry season" may reduce soil moisture, also reducing the threat of landslides (except in areas where vegetation has been removed).	↓

Additional factors are not incorporated into Table 2.7. For example, 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 the intensity and frequency of floods and landslides may change. The rankings described in Table 2.8 distinguish areas on the hazard maps where the projections suggest a reduction, increase, or no change in flood and landslide events. 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. A new study which reproduced the USGS flood map under the projected climate would produce a more quantitative analysis of future change to the threat of these hazards.

Table 2.8 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 an overall reduction in the intensity and/or frequency of the hazard.

Ranking	Description of Projected Change in 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 an overall increase in intensity and/or frequency of the hazard.

The areas in El Progreso currently susceptible to floods are projected to decrease as indicated by the blue lines surrounding the flood hazard areas (see Figure 2.30). This determination is consistent for both Scenarios 1 and 2, which project reductions in total rainfall for both the dry and wet seasons. Additional analysis driving the USGS flood model with changes in annual precipitation would provide insight as to how areas that may be affected by extreme flood events may change in the future. This analysis assumes land-use, drainage, and other factors that affect flooding do not change over time.

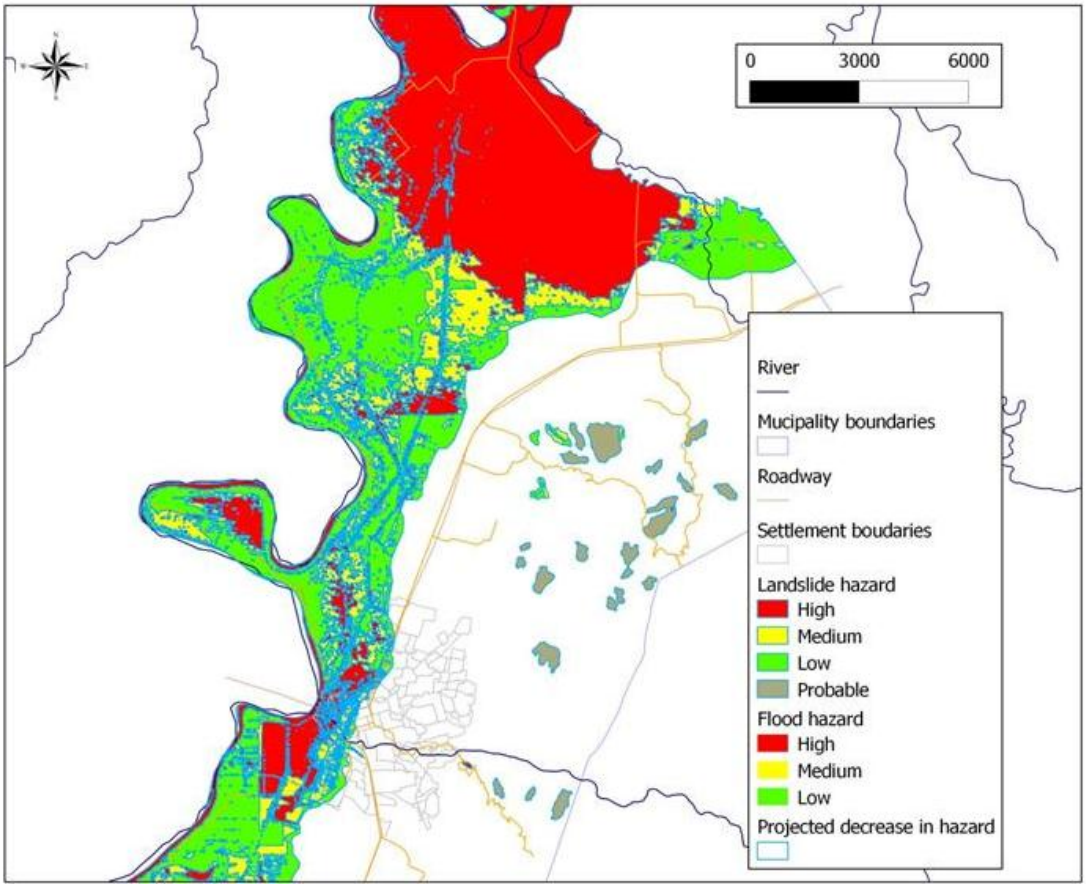


Figure 2.30 Projected change in areas prone to landslides and floods in the 2040s under both Scenario 1 and Scenario 2 where the blue line denotes areas that are currently prone to landslide events are projected to decrease. Source: developed using Shapefiles provided by the Municipality of El Progreso.

Landslide hazard exists in the eastern side of the city and is also projected to decrease in response to reduced precipitation. The landslide map shown in Figure 2.30 denotes the only a few small areas along the sloped edge of the mountain are currently prone to landslides in El Progreso. These areas are projected to decrease in susceptibility to landslides. 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 have not been investigated in this analysis, but if deforestation or landscape transformation continues, reductions in precipitation and covered soils could exacerbate soil erosion, and lead to a higher overall incidence for landslides.

2.6.3 Gaps and limitations

This section provides an overview of the gaps and limitations for each of the two hazard analyses. Overall, this study and any future analysis are limited due to the lack of long-term observational records.

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

- This analysis describes the current climate for El Progreso based on available global datasets. Though this global data are well crafted, this analysis would benefit from using local data. The use of local data allows for historical event analysis (e.g. the precipitation received during a given storm), development of precipitation indicators that describe storm events (e.g., 5-day maximum precipitation), and may more accurately capture conditions given the terrain.
- Running the USGS modelling used to develop today's 50-year flood map with future scenarios of annual precipitation could produce more detailed future scenario maps that directly 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 El Progreso is recommended to further enhance our understanding of how total precipitation and precipitation events may change in the future. It would further be beneficial to conduct a study using daily precipitation projections to consider how the intensity, duration, and frequency of daily rainfall events may change in the future.
- Additional effort could include modelling conducted by hurricane modeling specialists to provide some indication as to how the duration and frequency of future hurricanes may change under a changing climate.

The city of El Progreso is not particularly prone to landslides with only two small areas at the base of the mountain are considered susceptible. Because of this, the local government has a more limited need for collecting and analysing information concerning landslides. 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 El Progreso. 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 likely decrease in storm intensity. 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 the landslide hazard. 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

El Progreso was founded in 1850. At that time it was known as the Río Pelo village. El Progreso was established as a municipality in 1892. The city of El Progreso, located within the El Yoro Department, acts as the seat of the municipality. Located on the right bank of the Ulúa River, on the eastern edge of the Sula Valley, El Progreso is strategically placed at the crossroad of two of Honduras's most important roads. El Progreso is the country's third largest city and it is of the foremost importance in the urban system of northwest Honduras and the Sula Valley.

El Progreso's economic history is marked by the presence of multinational fruit companies (PDM-OT, 2012). Their arrival inevitably transformed the Sula Valley's economic structure. Over time, the city's economic base was reshaped and oriented towards exports, which contributed to creating economic dynamism and improving the standard of living of local populations. At the same time, the presence of multinational fruit companies nurtured the action of social groups defending the rights of workers. The 1954 strike from employees in multinational fruit companies is considered the pioneer in the history of the social rights of workers in Honduras.[9]

The Sula valley is characterized by accelerated demographic and economic growth. The region is a major industrial hub in Central America, as well as Honduras' economic core. The Sula Valley is the only conurbation in Central America. El Progreso thus sits within a large metropolitan area driven by the economic dynamism of San Pedro Sula. The municipality of El Progreso is classified under the *A* category of the Municipal Human Development Index (MHDI), reflecting its high development state within the country. As it will be seen later, regional urban and economic processes are important in understanding the city's expansion patterns. In order to cope with regional issues, the Sula Valley Metropolitan Area was established in 1993.[10] The ZMVS integrates 20 municipalities and its main aim is the coordination of regional planning strategies, the improvement of the regional service provision, and the construction of regional infrastructure.

El Progreso's history is marked by the recurrence of natural disasters, which often have also had severe impacts in the wider region. Following Hurricane Fifi in 1974, thousands of people from all over Honduras were displaced, and many of them settled in El Progreso. More recently, as discussed, Hurricane Mitch caused major devastation to the city. Nonetheless, natural disasters did not permanently halt the socio-economic dynamism in the Sula Valley generally, and El Progreso in particular. El Progreso remains a thriving industrial centre and experiences strong demographic growth. In 2008, the city had a population of 113,553 inhabitants (FUNDEMUN, 2008). The urban core of the Municipality of El Progreso comprises 111 neighbourhoods and is surrounded by 51 villages and 203 *caseríos* (group of houses). The city's urban layout is characterized by an orthogonal grid (CAP, 2012).

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. This is visualized with regard to the trajectory of urban expansion and growth as it is currently taking place in El Progreso, as linked, where possible, to the plan outputs of the urban planning system.

[9] Plan De Desarrollo Municipal Con Enfoque De Ordenamiento Territorial, El Progreso, Yoro: El Progreso – Yoro, Diagnóstico Integral Multidimensional – DIM, 2012.

[10] In Spanish: Mancomunidad de la Zona Metropolitana del Valle de Sula (ZMVS)

Limitations

There is one key limitation associated with the type and format of the information available. Maps showing various socio-economic characteristics have not been made 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.** Social and economic census data are not disaggregated at the neighbourhood level of the city. If such data was available, a more detailed picture of exposure and sensitivity to climate-related hazards at the neighbourhood level could be derived.
- **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 also examine other critical infrastructures located within the study area, such as telecommunications, energy, hospitals, schools, and police and fire stations.
- **Data limitations.** The above points to the fact that there are inconsistencies with data and information. Local validation can potentially resolve this issue.

3.3 Flows between the city and rural areas, the potential economic impacts of disasters, and critical infrastructure

The Sula Valley, where El Progreso is located, is the main driver of economic activity in Honduras. It generates the majority of the country's Gross Domestic Product (GDP). The valley is marked by its natural diversity and economic dynamism. It concentrates 62% of the country's GDP and 64% of the production of hydroelectric energy of the country. Further, it is responsible for 40% of the exports and is located in the most important industrial corridor in Honduras, with 95% of the manufacturing industries located there (PDM-OT, 2012). El Progreso is an important transport hub/passage, with an estimated 35-40% of the country's economic output passing through the municipality. The city is thus located in a strategic position. The economic impact of a disaster event would therefore be devastating not only for the local population but for the country as well.

El Progreso has benefitted from this regional dynamism. Because of El Progreso's importance within the national scheme of regional planning, the city was identified as a development centre for the Northern Region and the Ulúa River Basin. As such, the city is classified as a secondary industrial centre, a centre of agro industrial transportation, a service centre for the sub-region as well as a first order commercial centre (Consultores Financieros Internacionales, 2005).

The municipality's economic structure is diverse, as it consists of agricultural, industrial and commercial production. El Progreso is located in one of the most fertile valleys of Honduras (CATIE and FEMICA, 2004). Agricultural activity is based on permanent cultivations of palm oil, banana and sugar cane (Consultores Financieros Internacionales, 2005). In total, an area of approximately 24,000 hectares is devoted to permanent cultivations and 8,222 hectares are devoted to temporary crops, shifting or fallow land (Ibid.).

Micro, small and medium enterprises (MSMEs) are also of particular relevance for the city. A large number of MSMEs are engaged in trade and services (CATIE and FEMICA, 2004). Approximately 80% of trade is concentrated in micro and 20% in medium and large companies. It is pointed out that the lack of training, technical and financial assistance to micro-entrepreneurs reduces their potential for development and growth. Therefore, this sector could be strengthened, in order to increase its resilience to climate-related hazards.

In recent years El Progreso has experienced an increase of industrial activity due to the establishment of *maquiladoras*[11] (Diagnóstico Ambiental El Progreso; Préstamo BID No. 1478/SF-HO).The municipality concentrates 7 *maquiladoras*, engaged in the manufacture of clothing. The *maquiladoras* generate a large percentage of the local employment nowadays, notably for women (80% of the workers are women between the ages of 16 to 25). According to the Chamber of Commerce, *maquiladoras* employ approximately 9,000 people and there is strong growth potential. This activity has social implications to the city of El Progreso as most workers commute to their villages daily, and others tend to stay in the city or travel back to the home villages on weekends. MSMEs employ over 3,000 people and the sugar industry provides an additional 2,000 jobs (CATIE and FEMICA, 2004).

Economic growth and poverty reduction efforts in Honduras have suffered from the country's exposure to natural disasters, notably hurricanes and tropical storms, and related events such as floods and landslides. Between 1980 and 2010, over 15,000 people were killed and over 4 million were affected by natural disasters in Honduras. Economic effects due to disasters are expected to have reached USD 4.5 billion for the same period.

Due to its geographical location close to the Caribbean, the northwest of Honduras where El Progreso is located has historically been the region of the country with the highest exposure to hurricanes. Because of high rainfalls, hurricanes often cause the Ulúa River and its tributaries to burst their banks, which results in floods. In the last two decades, El Progreso has suffered from a number of serious floods. Severe floods due to hurricanes and tropical storms occurred in 1990, 1993, 1995 and 1996. However, the most significant and recent catastrophe was Hurricane Mitch in 1998. In 2008 and 2009, the city and its rural outskirts saw flood events.

Agriculture and banana production was severely affected during Hurricane Mitch. Since then, much of the agricultural industry around El Progresso has shifted to flood resilient oil palm and sugar cultivation. This shift in cash crop production can be viewed as a form of adaptation to the continuing risk of tropical storms and increased precipitation in the area. The transformation of small and large scale agricultural production has not always been accompanied by efforts from the private sector to study the damage and financial impact of flood risk. Some sugar plantations exercise systems of risk regulation by monitoring river and rainfall levels and there is some evidence of emerging cooperation or coordination between city level government agencies and private sector organisations in mediating future disaster risk through development and investment initiatives. Such an alignment of agricultural industry interests and risk management strategies can potentially result in greater local level coordination in adaptation and risk reduction.

An important consideration with regards to the inter-connections between the rural and urban areas is that people often live in the urban area of El Progreso but their source of income comes from the rural areas. Therefore, often, not only their homes are flooded but their livelihoods can also be affected if a disaster destroys their production.

Box 3 Results of probabilistic evaluation of disaster risk

The results presented here are based on the CAPRA methodology. The table below (Table 3.1) summarizes the results for the selected scenario of a hurricane-induced flooding in terms of economic losses. It was found that 1.54% of the total economic assets of the city are exposed to flooding.

Table 3.1 Economic exposure and losses to flooding

Exposure value	$ 1,867,940,605
Economic loss	$ 28,851,776
	1.54%

The above results are visualized in the maps that follow. These show the geographic distribution of economic losses (Figure 3.1).

[11] Textile factories in a free trade zone (FTZ).

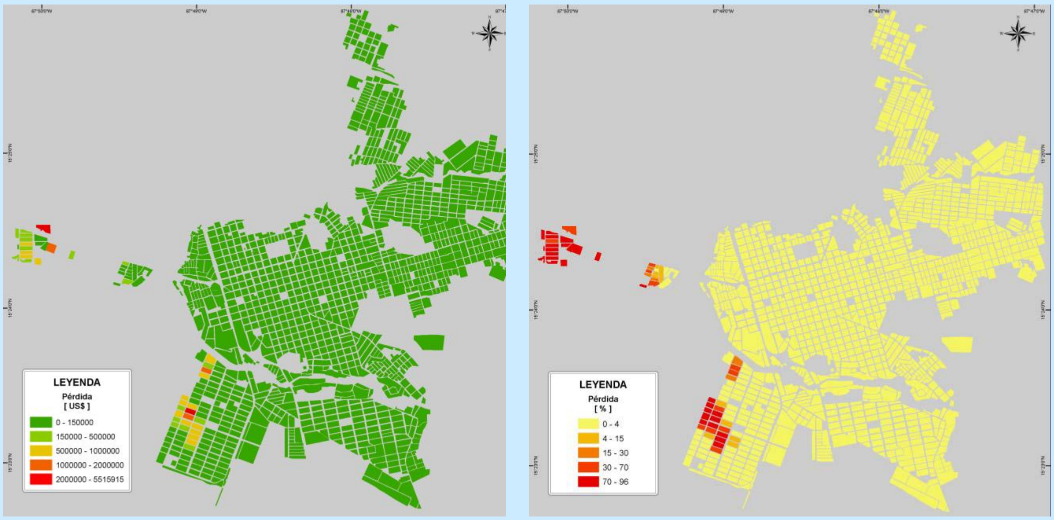


Figure 3.1 Expected loss per acre for the selected scenario (Left: in value, right: percentage).

Table 3.2 summarizes the results for the selected landslide scenario in terms of economic losses. The results indicate landslide hazard calculated with the methodology presented in this study did not induce any risk on the exposed population and infrastructure. This result must be seen within the scope and limitations of the model used in the simulation. This model estimates the landslide susceptibility analysis of the region in terms of the instability factor but does not include assessments about the volume of earth slipped, their speed, or their location and disposal once the movement is triggered.

Table 3.2 Economic exposure and losses to landslides

Exposure Value	$ 1,867,940,605
Economic loss	$ 0
	0%

Source: ERN América Latina.

With regards to critical infrastructure, there are no particular problems with the sole exception of the water treatment plant, which often has to be shut down during flood events (and be cleaned) because of the amount of sediments carried down. This is a problem that the city experiences every single year. Deforestation is considered the main reason for this issue. Nonetheless, the plant is not directly exposed to flood risk.

According to our interview with representatives of the telecommunications and energy sectors, as well as end-users, disaster events in the past, such as floods, have never caused any problem in their operations. Similarly, the road network appears to be adequate for the needs of the city (Diagnóstico Ambiental El Progreso; Préstamo BID No. 1478/SF-HO).

As seen in Figure 3.2, with the exception of settlements within the Mico Quemado reserve area and the rural settlements, the urban core is characterized by easy access. Further, the location and quality of distribution networks and main equipment does not provide any concern about potential future impacts of disaster events.

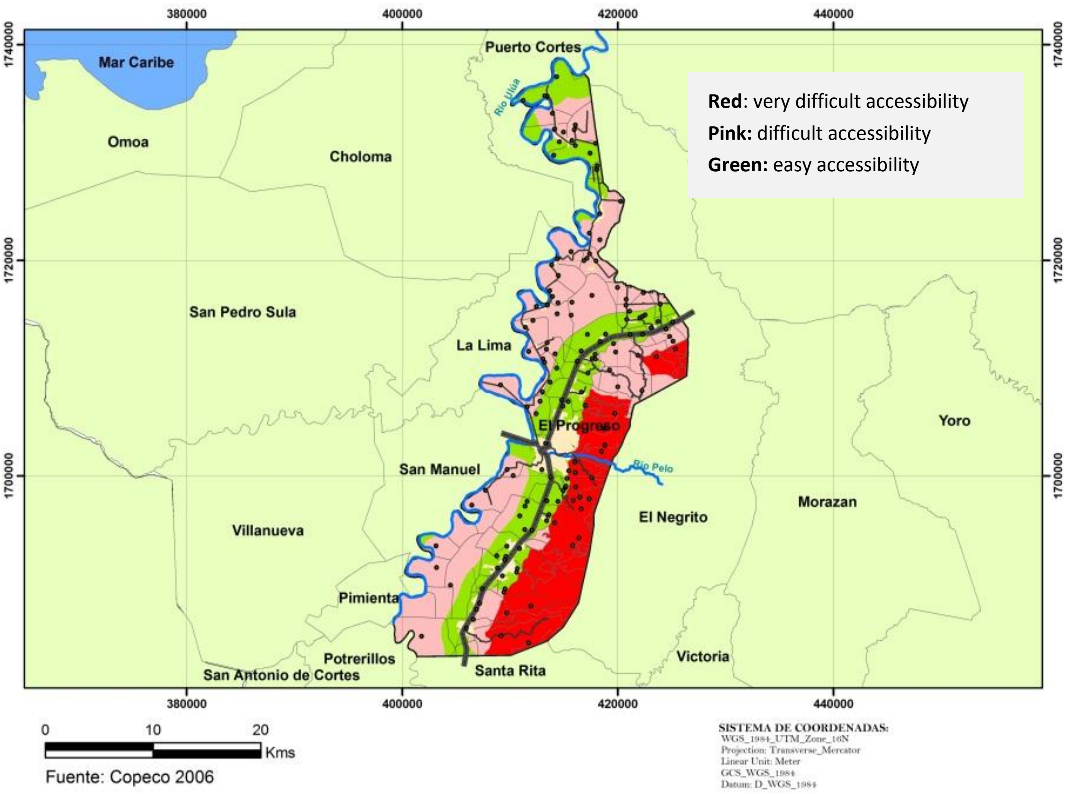


Figure 3.2 Road accessibility in El Progreso, Source: PATH II in Municipalidad de El Progreso, 2012.

3.4 Urban development, spatial expansion and demographic change

3.4.1 Urban growth

In the second half of the twentieth century, El Progreso experienced fast demographic growth. This is directly linked to the strong economic dynamism that the Sula Valley experienced during the same period, as described above. Since the 1950s, San Pedro Sula went through a phase of rapid urban expansion, incorporating surrounding rural areas. Nonetheless, it is only after 1976 that demographic growth really took off in the region. In 1976, the national government decided to establish the Cortés Free Trade Zone. Free Trade Zones in other cities in the region followed. This development strongly increased population in-flows.

With this pattern, an industrial corridor in El Progreso was formed. Its emergence in the last decades is intrinsically related to both the strategic economic considerations of policymakers at the central government level and the influence of regional economic groups, notably actors related to the manufacturing industry and production services. In the 1990s, as seen above, the central government and regional economic groups decided to facilitate the installation of *maquiladoras* (textile factories) to foster local economic development (PDM-OT, 2012).

With this process of industrialization, urban growth was generalized throughout the region. Industrialization triggered a conurbation phenomenon, giving rise to the first metropolitan area in Honduras. The incorporation of rural areas into existing urban cores that started since the 1950s in the Sula Valley was consolidated from the 1990s onwards and allowed for the appearance of an integrated large-scale metropolitan region. Growth mainly occurred along communication links, notably alongside paved roads (PDM-OT, 2012). This process also led to the creation of the Sula Valley Metropolitan Area (ZMVS), of which El Progreso is an integral component.

Established in 1993, the Community consists of 20 municipalities and covers an area of 7,872.58 km². Its objective is to promote sustainable socio-economic development in the region by focusing on five pillars: economic development and competitiveness, qualify of life, environment, civil engagement and territorial planning (Consultores Financieros Internacionales, 2005).

The industrialization of the region generated a strong demand for workforce, which in turn attracted considerable waves of new inhabitants that were seeking employment opportunities in the Sula Valley. Many municipalities and small cities were not prepared to cope with this strong population increase. San Pedro Sula was the only city that had the capacity to deal with large scale industrial development (PDM-OT, 2012).

As seen in Table 3.3, the city of El Progreso almost doubled its urban population in the period 1989-2008. As a result of this fast demographic growth, cities in the region, including El Progreso, had to adapt to the new demands that local economic development had brought.

Table 3.3 Urban demographic growth, 1989-2008

Year	Population	Increase (%)
1989	57,201	N.A.
2008	113,553	98.5

Source: Fundación para el Desarrollo Municipal (FUNDEMUN), 2008. Estudio de Zonificación Urbana, Alcaldía Municipal de El Progreso.

Nonetheless, urban growth in the region occurred following spontaneous and disordered patterns, these often lacking congruence with urban planning instruments. Further, each municipality responded to the new challenges in an isolated manner and often problems raised due to accelerated urban expansion. Regional economic development and the subsequent conurbation process it brought have thus created high pressures on the territory. At that time, measures and actions following an integrated metropolitan planning approach were actually absent (PDMOT-OT, 2012). El Progreso was no exception in the aforementioned trend.

As seen in Table 3.4, El Progreso is expected to keep growing in the years to come. Urban expansion is occurring according to a north-south pattern, along the transversal highway that crosses the city from north to south. The result has been an extended morphology following a major north-south transportation route. This raises the issue of establishing and implementing appropriate planning instruments to deal with expansion.

Table 3.4 Municipal population growth

Year	Population	Average annual growth rate (%)
2001	147,369	*Base year*
2007	177,583	3.2%
2011	220,000	5.5%
2015	237,988	2.0%

Source: estimated with data obtained from PDM-OT, 2012.

3.4.2 Land uses

Given that El Progreso is experiencing demographic growth and the city is a regional administrative, production and commercial centre, it requires an appropriate land use plan that allows the city to adequately guide urban growth (PDM-OT, 2012). It is important to highlight that urban planning studies at the municipal level in Honduras are virtually non-existent. This is mainly due to a lack of a national legal framework that mandates the presence of such studies in municipal planning strategies. The work undertaken by the Natural Disasters Mitigation Project (PMDN) and the Honduras Land Management Program (PATH II) partly alleviates the absence of a national framework by establishing the compulsory presence of municipal urban planning studies. On the one hand, the PMDN encourages municipalities to assess how land use and land regulation interact with urban expansion to create exposure conditions to natural disasters. On the other hand, PATH II aims at strengthening land regulation and administration through land use studies. Through the study and incorporation of risk and land assessments, the PDMN and PATH II thus seek to set the basis for urban planning strategies at the municipal level.

In El Progreso, following the methodology embedded within PATH II, and supported by the PMDN, the municipality elaborated a Municipal Urban Planning Plan (*Plan de Desarrollo Municipal con Enfoque en Ordenamiento Territorial* – PDM-OT) which included a Multidimensional Integral Diagnosis (*Diagnóstico Integral Multidimensional*). The Diagnosis covers five core areas: social challenges, infrastructure, the municipal economy, land, environment and climate change.

Land use studies are thus an integral part of municipal urban planning studies. The municipality has gathered relevant data in land use and has tried to incorporate it when formulating the PDM-OT. As seen in Table 3.5, El Progreso's urban core is characterized by the diversification of land use. However, residential use dominates and it is also important to note the presence of 'no specific use'[12] areas.

Table 3.5 Land uses in urban El Progreso, 2003

Land Use	Allocated urban land (%)
Residential	42%
Streets	19%
Commercial	3.3%
Industrial	2.2%
Institutions	3.6%
Communal centres	2.9%
No specific use	26.9%

Source: Consultores Financieros Internacionales, 2005.

The municipality elaborated a land assessment study following an Integral Multidimensional Diagnosis. The land assessment study was incorporated into the 2012 Municipal Development Plan (PDM-OT) and forms the basis for a Municipal Zoning Proposal. The proposal identifies different potentials for the spatial configuration of the municipality. It creates a scenario of spatial organization by evaluating current levels of production and protection, and by associating them with possible risks and threats (PDM-OT, 2012).

The study revealed that by 2006, approximately 62% of the land in the municipality was being used in an appropriate manner (Figure 3.3). Appropriate land use areas were distributed evenly across the municipality. Almost 19% of the available land was being overexploited. An overexploited land use means that the utilization of the land exceeds its capacity and suggested land use. Regarding sub-use, the 2006 figures revealed that 9% of the land in the municipality was marked by this condition, and that sub-use areas were located mainly to the west of the city. Only 7% of the municipality's land is considered urban and flat, while the 1.2% and 1.8% of the areas is considered urban and hillside or occupied by water streams respectively.

[12] Areas that lack a designated specific land use.

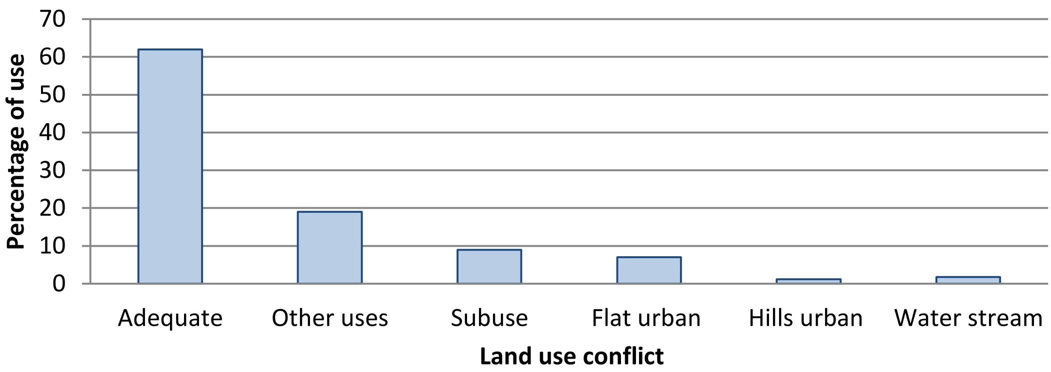


Figure 3.3 Land Use in El Progreso Municipality in 2006. Source: PDM-OT, 2012.

Further, the municipality identified areas within the urban core where land use conflicts prevail. As seen in Figure 3.4, conflict areas are mostly located to the west of the city, and refer to land tenure and inadequate settlement planning in proximity to the Mico Quemado reserve area.

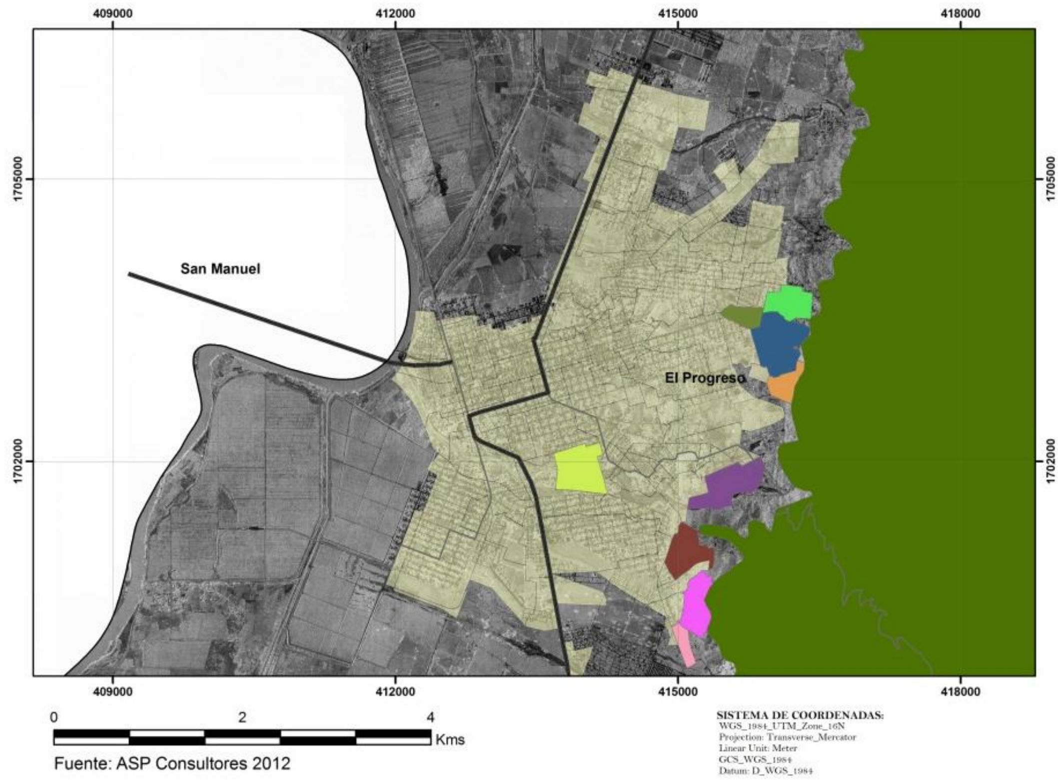


Figure 3.4 Land use conflict areas in urban El Progreso are shown in colour shades, Source: PDM-OT, 2012.

In order to avoid conflicting land uses, the municipality has been proactive in adopting zoning and land use plans, and has attempted to complement them with transport plans. With the objective of giving a direction to urban growth, limiting unplanned expansion and enhancing environmental protection, the municipality has made specific zoning proposals (Figures 3.5 and 3.6). These are:

- Concentrate industrial activity in the northern and southern peripheries
- Resolve conflicting land uses in illegal settlements adjacent to the Mico Quemado protected area
- Stimulate urban growth along the main highway that crosses the city following a North-South axis, while also stimulate urban growth to the south following the aforementioned highway, to reach the limits of the current urban fringe

- Halt or forbid urban development to the east, as the current urban area has reached its limits and has invaded the protected area of the Mico Quemado as well as essential areas for water supply in the municipality
- Limit urban expansion to the west, along the Ulúa River, as this area presents high exposure risks to flooding and other natural disasters. Most of the area has been zoned for agricultural use
- Explore the option of controlled densification in the areas where existing regulations would allow it, taking into account indexes on occupation, construction and population density.

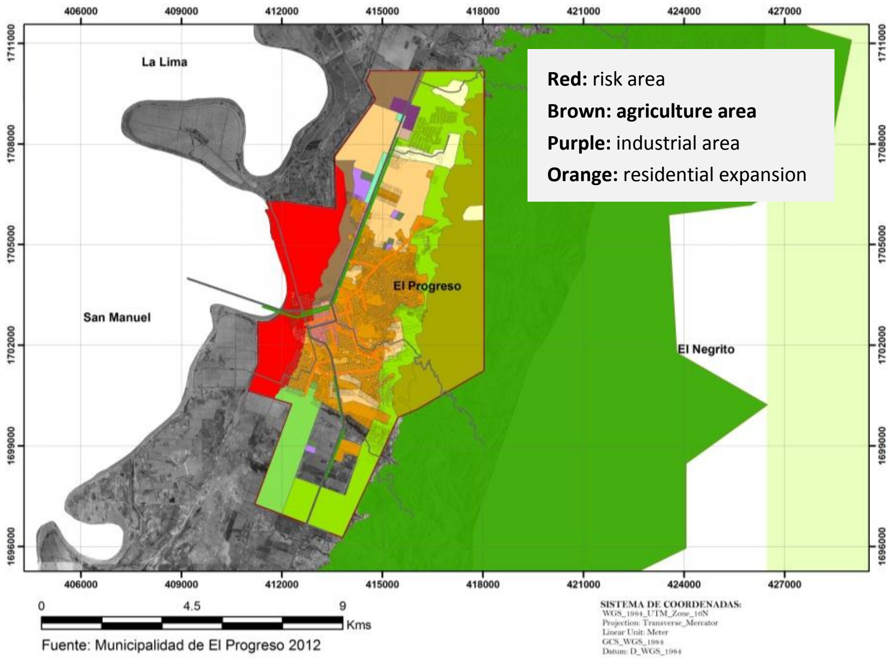


Figure 3.5 Proposed zoning for urban El Progreso, Source: PDM-OT, 2012.

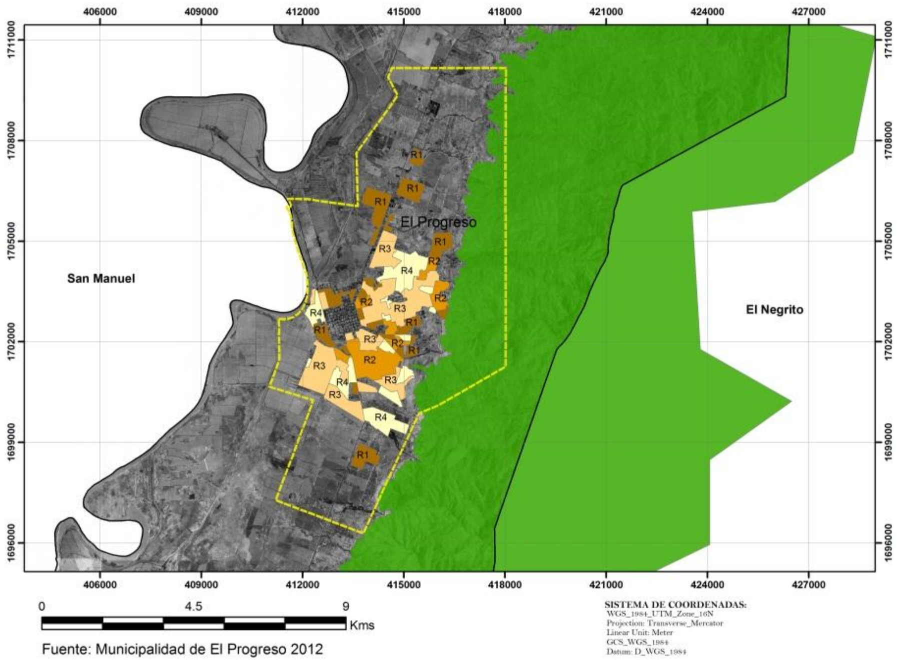


Figure 3.6 Residential zoning and densities. Darker shade for higher density, Source: PDM-OT, 2012.

El Progreso has therefore been proactive in developing a Master Plan that follows an integrated approach. Land use, risk and transport are taken into consideration when establishing a long-term vision of the development of the city. It is important to emphasize that community engagement has been a very important element of their approach. Municipal authorities have made sound efforts to include communities in the development of long-term strategies. This process has also helped to raise awareness of urban disaster risks (IDRC, n.d.).

The urban growth guidelines established in the 2012 PDM-OT clearly show how the land assessment study carried on by the municipality has helped to integrate risk into land use policy and planning. The authorities have identified overall risk areas within the urban core and have advanced urban expansion guidelines accordingly. The rationale is to prevent development from occurring in exposed areas. Based on this, the municipality has carried out a study that identified neighbourhoods exposed to floods and landslides. The findings are presented in the following section.

3.4.3 Exposure to flooding

As previously discussed, the city of El Progreso is located within one of the most flood-prone municipalities in Honduras. The municipality is marked by the confluence of two rivers: the Ulúa River, with a high volume of flow, and the Pelo River, with a lower volume of flow. A particularly critical area is where the two rivers converge, where a water pool is formed that concentrates large amounts of water, which frequently creates conditions for flooding (Duarte, 2010).

Section 2 includes maps showing the level of hazard to flooding areas in the Municipality of El Progreso.

The 2012 PDM-OT identified neighbourhoods exposed to flooding within the urban core. Tables 3.6, 3.7 and 3.8, provide a list of the exposed neighbourhoods. All of these neighbourhoods have reported yearly floods. Figure 3.8 that follows the tables spatially locates these neighbourhoods within El Progreso in four zones (NW: north-west; SW: south-west; NE: north-east; SE: south-east).

Table 3.6 gives a list of the five exposed neighbourhoods along the banks of the Ulúa River.[13] The Ulúa River affects the highest number of neighbourhoods in the city.

Table 3.6 Flood-Exposed Neighbourhoods in Proximity to the Ulúa River

Neighbourhood	Zone
Col. Centroamericana	NW
Fátima	NW
Bº San Martin	NW
Col. 2 de Julio	NW
Bº San Miguel	NW

Source: Trabajo Grupal realizado por ASP Consultores, durante el primer taller para la elaboración del PDM-OT, 12 de Noviembre de 2011.

The Pelo River also affects a considerable number of neighbourhoods in El Progreso. As seen in Table 3.7, 14 neighbourhoods are exposed to flooding.

Table 3.7 Flood-exposed Neighbourhoods in Proximity to the Pelo River

Neighbourhood	Zone

[13] Neighbourhoods listed as prone to flooding which could not be located within the urban boundaries of the city are not included. This limitation points to the fact that there exist many inconsistencies with data and information based on their source. This may be because the names of neighbourhoods may have changed or because neighbourhoods may have been classified as urban or rural after/prior to a specific publication. Local validation could resolve this issue.

Neighbourhood	Zone
Col. Sitraterco	SW
Col. Penjamo	SE
Bº Suyapa	SE
Col. Paty	SW
Col. Policarpo Paz	NW
Col. Inva	SW
Col. Bendeck	SE
Col. 2 de Marzo	NE
Col. Corocol 1	NE
Col. San José	NE
Col. Corocol 2	NE
Col. Kennedy	NE

Source: Trabajo Grupal realizado por ASP Consultores, durante el primer taller para la elaboración del PDM-OT, 12 de Noviembre de 2011.

In addition to the neighbourhoods exposed along the banks of the Ulúa and Pelo rivers, other neighbourhoods are exposed in El Progreso due to the large presence of water streams in the city.

Tables 3.8, 3.9, and 3.10, list exposed neighbourhoods along the Macrocanal, the Los Castaños Ravine and the Santa Elena Ravine.

Table 3.8 Flood-exposed neighbourhoods in proximity to the Macrocanal

Neighbourhood	Zone
Altos del Progreso	SE
El Porvenir	SE
La Esperanza de Jesús	SE
Col. Mangandi	SE
Col. Suazo Córdova	NE

Source: Trabajo Grupal realizado por ASP Consultores, durante el primer taller para la elaboración del PDM-OT, 12 de Noviembre de 2011.

Table 3.9 Flood-exposed neighbourhoods in proximity to the Los Castaños Ravine

Neighbourhoods	Zone
Col. Los Castaños	SE

Source: Trabajo Grupal realizado por ASP Consultores, durante el primer taller para la elaboración del PDM-OT, 12 de Noviembre de 2011.

Table 3.10 Flood-exposed neighbourhoods in proximity to the Santa Elena Ravine

Neighborhood	Zone
Alfonzo Guillen Zelaya	NE

Source: Trabajo Grupal realizado por ASP Consultores, durante el primer taller para la elaboración del PDM-OT, 12 de Noviembre de 2011.

Table 3.11 Flood-exposed neighbourhoods during the rainy season

Neighborhood	Zone
Col. Bendeck	SE

Neighborhood	Zone
Col. Palermo	SW
Bº San Antonio	SW
Col. 27 de Octubre	SE
Col. Mendieta	SE
Col. Alameda	SW
Col. 5 de Diciembre	SW

Source: Trabajo Grupal realizado por ASP Consultores, durante el primer taller para la elaboración del PDM-OT, 12 de Noviembre de 2011. Note: flood-exposed neighbourhoods on the list that were not found in the provided municipal list of neighbourhoods were deleted.

In total, 33 neighbourhoods out of 111 are exposed to floods in El Progreso.[14] Most of them are located in the north-west and south-west areas, thus establishing an east-west divide to flooding exposure in El Progreso. However, improper use of land in the protected area, including along the banks of ravines and steep areas, is very likely to lead to an increase in the number of neighbourhoods exposed to flooding towards the east of the city in the future.

[14] In fact, 47 neighbourhoods out of 111 are identified as exposed to floods in the Municipality of El Progreso. 33 of them could be identified as falling within the urban boundaries of the city.

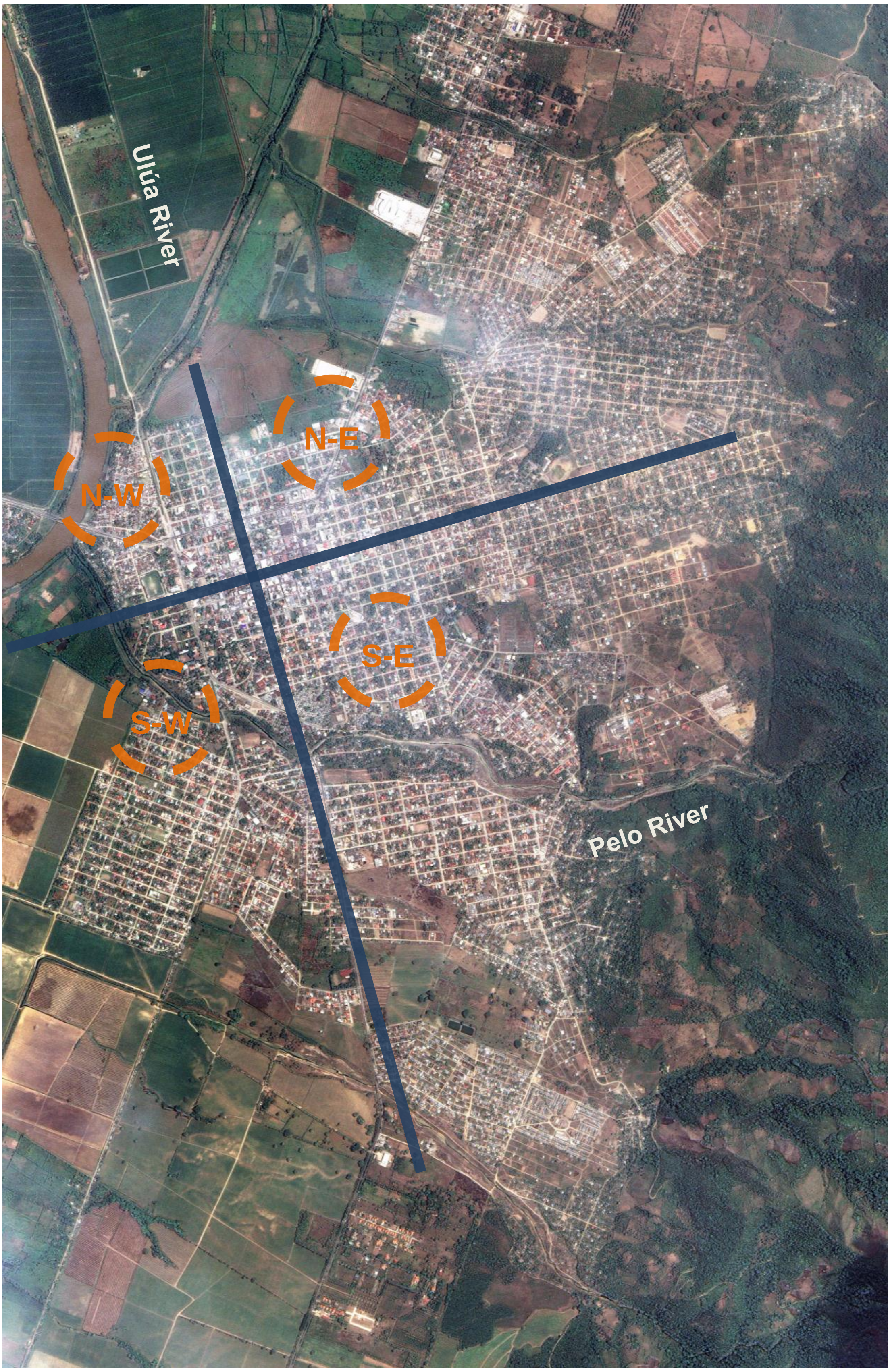


Figure 3.1 Satellite photo of El Progreso, Source: NASA Earth Observatory, acquired May 30, 2009.

3.4.4 Exposure to landslides

Under the analysis made by the Natural Disasters Mitigation Program (PMDN), landslide risk was not considered as a major threat in El Progreso. Given the city's relatively flat topography, the potential occurrence of landslides is low, and is mostly located in neighbourhoods west of the city, in proximity to the Mico Quemado (PMDN, no date). Despite the city's low-exposure to landslide risks, high-risk landslide events were reported in the rural areas of the municipality.

3.5 Socio-economic characteristics

3.5.1 Location of low-income groups

In analyzing the way in which urban development has taken place in El Progreso, several elements interplay and exacerbate exposure to climate-related hazards. As it has been previously seen, El Progreso has gone through a phase of rapid urban expansion in past decades. Nonetheless, urban growth often took place in an unplanned manner, resulting in land misuse and the emergence of settlements in inappropriate areas, including the banks of rivers, watersheds and ravines, as well as steep areas (Duarte, 2010).

In 2012, the Municipality of El Progreso, in order to guide urban development and expansion, and with support by the World Bank, developed a Municipal Development Plan with a focus on territorial planning. Aiming at orienting sustainable and resilient urban growth, the plan also includes various projects for risk reduction. The plan gives a direction to urban growth, directs expansion along the North-South corridor, following the main highway, and away from the river, in order to avoid high risk areas.

This planning instrument is particularly welcomed as both historical and recent fast urban expansion in El Progreso over the past decades has led to the appearance of settlements located in hazard risk areas. The safest and more habitable land is usually available to groups in the highest income strata. Land in high risk areas is more affordable, and is thus often the choice of lower-income groups.

Although new urban development has at most times been directed away from risk areas, there are still many communities located in hazard prone locations, as seen above. Local stakeholders also pointed out that some of the communities along the Ulúa and Pelo Rivers get flooded every year. The communities at the north-west of the city where the two rivers intersect are considered the most exposed. In total, it is initially estimated that up to 50,000 people can be directly affected by floods, if generalized flooding from rainfall and run-off from Mico Quemado Mountain occurs. This high concentration of people and assets also increases exposure to climate change impacts and the risks of disasters that accompany it.

From our discussions with residents living in flood affected communities, as well as various other stakeholders, it became apparent that although for some residents resettlement could be an option, for others it would not. For most people, their livelihoods depend on their location. Residential location may be close to the city centre (and thus close to work and employment opportunities) and/or the house may have space for cultivation (and thus provide revenues at the same time). Only people living in the more urbanized and densely populated areas, who are nonetheless working in the agriculture sector, would consider relocating at the periphery of the city or even in rural areas. Interestingly, one interviewee pointed out that some communities existed since the 1960s at least, and an alternative to relocation could be to elevate houses on stilts as was done in the earliest forms of building in the city.

3.5.2 Human development indicators

El Progreso's social development indicators indicate better results than Honduran national averages, which mean that the city has a relatively better social and economic capacity to cope with disaster risks, including climate-related hazard risks.

At 88.3%, the Municipality's adult literacy rate is slightly higher than the national average (82.5%). The same is observed with the income index: 0.614 for El Progreso compared to 0.606 for Honduras.[15]

Table 3.12 Human development indicators

	Education Index	Life Expectancy	Income Index	Adult Literacy
Honduras	0.761	70.5 years	0.608	82.5
Yoro	0.760	82.2 years	0.565	82.2
El Progreso	0.806	71 years	0.614	88.3

Sources: Informe sobre Desarrollo Humano, Honduras (2005-2007); Indicé de Pobreza Humana (IPH) 2001-2006; Censo Nacional de Estadísticas 2001, INE.

Similarly, only 5.9% of the city's population lacks access to proper water sources, as opposed to 12.8% nationally (Municipalidad de El Progreso, 2012). Despite some good social and economic indicators, poverty challenges are present and visible in El Progreso. Out of the 29,485 households, almost 4,000 have sewage issues, while in most cases the water that is received is of poor quality. Some 6,000 have subsistence capability problems and almost 5,000 suffer from overcrowding (Municipalidad de El Progreso, 2012). High inequality and public safety concerns have to be added to the issues.

Further, a significant amount of the city's population is marked by aspects of poverty such as lack of access to water, sewage problems, overcrowding, subsistence capabilities and low child enrolment in primary education (Table 3.13). It is important to highlight that poverty level is much higher in rural areas than in urban areas, clearly establishing a poverty urban/rural divide in the municipality of El Progreso.

Table 3.13 Unsatisfied Basic Needs (UBN)

	Without access to water (%)	With sewage problems (%)	With kids not enrolled in elementary education (%)	Without subsistence capabilities (%)	With overcrowding (%)
Urban	3	12.2	6.8	26.6	13.8
Rural	22.4	16.7	12.9	27.2	25.1
El Progreso total	7.3	13.2	8.2	20.5	16.4
National	18.4	32.1	10.7	21.5	16.8

Source: INE. Censo de Población y Vivienda 2001.

However, despite these good social indicators, poverty remains a reality in El Progreso. While 6.5% of the city's population lives with less than $1 USD per day, this number increases to 21.9% living with less than $2 USD per day (Table 3.14). This indicates that despite high economic dynamism, poverty remains a challenge in the city.

Table 3.14 Poverty in El Progreso (2010)

	Population living with less than $1 USD per day (%)	Population living with less than $2 USD per day (%)
El Progreso Urban	6.5	21.9
El Progreso Rural	36	64.9
Honduras	22.8	45.5

[15] The index is based on GDP per capita data. For more information see: PNUD, 2006.

Source: INE, 2010 & PDM-OT, 2012.

Table 3.15 gives a more detailed account of poverty conditions in El Progreso. It is estimated that 42.6% of the households in the city suffer from Unsatisfied Basic Needs (UBN).

Table 3.15 Households Affected by Unsatisfied Basic Needs (UBN), El Progreso Municipality , 2001

	Percentage (%)
Households suffering from UBNs	42,6
1 UBN	26,5
2 UBN	10,4
3 UBN	5,6

Source: PDM-OT, 2012.

3.5.3 Housing conditions

The condition of housing is another good indicator for city resilience to climate-related hazards. The use of resistant materials means that buildings can withstand and recover more easily from a climate-related event. In contrast, the use of low-quality materials reduces the capacity of buildings to cope with floods and landslides.

Tables 3.16 and 3.17 give an account of the material used in walls and floors in El Progreso households. They show the prevalence of high quality materials such as cement. El Progreso thus benefits from a relatively widespread use of high-quality materials in housing construction.

Table 3.16 Material used in walls in El Progreso households (2001)

Material	Cement	Wood	Other materials
Percentage (%)	77.8	13.2	9

Source: Consultores Financieros Internacionales, 2005.

Table 3.17 Material used in floors in El Progreso households

Material	Cement	Dirt	Other
Percentage (%)	69	11	20

Source: Consultores Financieros Internacionales, 2005.

3.6 Spatial, social and economic impact upon disaster risk

Overall, the urban social and economic adaptive capacity assessment of El Progreso 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 3.18 Socio-economic characteristics that impact upon climate related disaster risks

Characteristic	Description	Level of influence
Location of human	Although new urban development has at most times been directed away from risk areas, there are still many	Moderate

Characteristic	Description	Level of influence
settlements	communities located in hazard prone locations. In total, 33 neighbourhoods out of 111 are exposed to floods in El Progreso. Most of them are located in the north-west and south-west areas, thus establishing an east-west divide to flooding exposure in El Progreso. However, improper use of land in the protected area, including along the banks of ravines and steep areas, is very likely to lead to an increase in the number of neighbourhoods exposed to flooding towards the east of the city in the future. Given the city's relatively flat topography, the potential occurrence of landslides is low, and is mostly located in neighbourhoods west of the city, in proximity to the Mico Quemado	
Demographic change	There was rapid population growth between 2001 and 2011, with an increase of approximately 4% on an annual basis. The municipality's population increased from 147,000 inhabitants in 2001 to 177,000 in 2007, and reached 220,000 in 2011. Most of this growth has concentrated in the urban area of El Progreso, which represents some 85 to 90% of the overall population.	Low
Economic characteristics	The municipality's economic structure is diverse, as it consists of agricultural, industrial and commercial production. Micro, small and medium enterprises (MSMEs) are also of particular relevance for the city. A large number of MSMEs are engaged in trade and services. Approximately 80% of trade is concentrated in micro and 20% in medium and large companies. Economic growth and poverty reduction efforts in Honduras have suffered from the country's exposure to natural disasters, notably hurricanes and tropical storms, and related events such as floods and landslides. An important consideration with regards to the inter-connections between the rural and urban areas is that people often live in the urban area of El Progreso but their source of income comes from the rural areas. Therefore, often, not only their homes are flooded but their livelihoods can also be affected if a disaster destroys their production. Further, the city is an important transport hub/passage. It is estimated that 35-40% of the country's economic output passes through the municipality. The economic impact of a disaster event would therefore be devastating not only for the local population but for the country as well.	Significant
Spatial expansion	Urban expansion is occurring according to a north-south pattern, along the transversal highway that crosses the city from north to south. The result has been an extended morphology following a major north-south transportation route. With the objective of giving a direction to urban growth, limit unplanned expansion and enhance environmental protection, the municipality has made specific zoning proposals to limit urban expansion to the west, along the Ulúa River, as this area presents high exposure risks to flooding and other natural disasters. El Progreso has therefore been proactive in developing a Master Plan that follows an integrated approach.	Low
Urban design and characteristics of low-income housing	El Progreso benefits from a relatively extended use of high-quality materials in housing construction. The presence of high-quality materials, such as cement, in households' walls and floors helps to increase El	Low

Characteristic	Description	Level of influence
	Progreso's resilience to floods and landslides.	
Urban infrastructure	Only 5.9% of the city's population lacks access to proper water sources, as opposed to 12.8% nationally. Nonetheless, out of the 29,485 households, almost 4,000 have sewage issues, while in most cases the water that is received is of poor quality.	Moderate
Critical infrastructure networks	There are no particular problems with the exception of the water treatment plant. The water treatment plant often has to be shut down during flood events (and be cleaned) because of the amount of sediments carried down. This is a problem that they experience every year. Deforestation is considered the main reason of the issue. However, the plant is not directly exposed to flood risk. Disaster events in the past, such as floods, have never caused any problem in the telecommunications and energy sectors. Similarly, the road network appears to be adequate for the needs of the city.	Low
Urban poverty	El Progreso's social development indicators indicate better results than Honduran national averages, which mean that the city has relatively better social and economic capacity to cope with disaster risks, including climate-related hazard risks. However, despite some good social and economic indicators, poverty issues are present and visible in El Progreso. Some 6,000 households have subsistence capability problems and almost 5,000 suffer from overcrowding. High inequality and public safety concerns have to be added to the issues.	Significant

4 Institutional adaptive capacity assessment

4.1 Institutional context

El Progreso's location at the cross roads of two major transport highways in Honduras, and its proximity to San Pedro Sula, the second largest city in the country make it an important point in the transport of goods across the country. Like most small and medium cities, development and expansion in El Progreso is closely linked with economic and social activity in its surrounding peri-urban and rural areas. The city's rise as an urban hub in the region is fuelled by the growth of commercial activity, industry and agricultural plantations located on the outskirts of the city. Most residents of the city are employed in these sectors, highlighting the inter-dependence of urban El Progreso with its surrounding region.

The rapid rate of in-migration 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. Government departments suffer from under-funding and a shortage of human capacity. 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 El Progreso 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 utilised background data provided in the local consultant 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 El Progreso, 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.

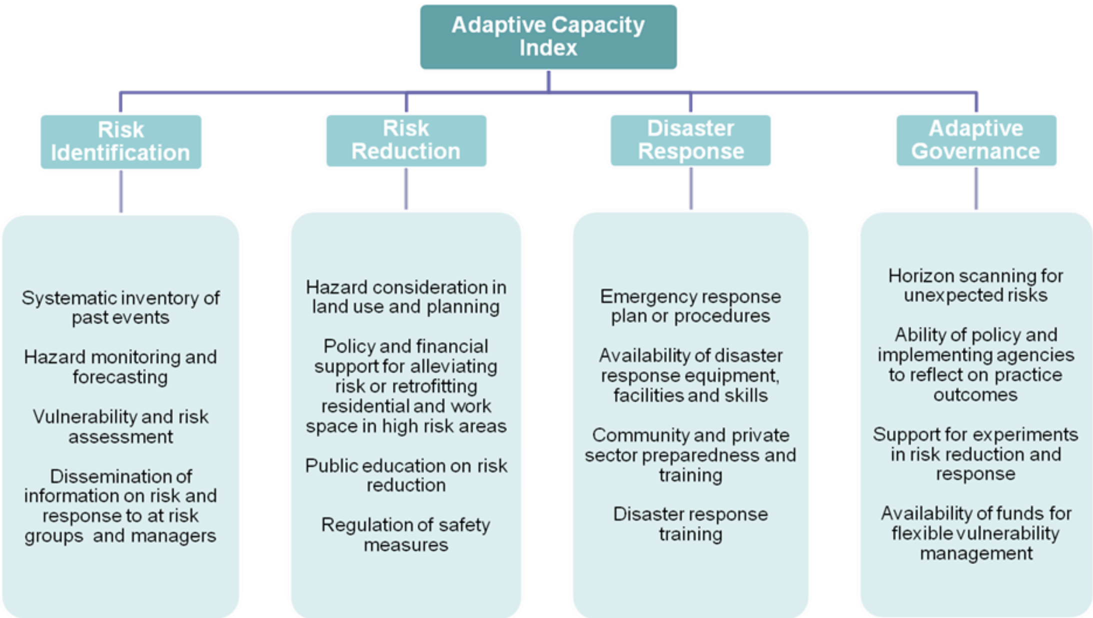
4.2.1 Background data

For Honduras and El Progreso, 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 for climate change adaptation and risk management in the city of El Progreso. A list of available documents, reports and policy resources was also provided. Although the report provides data for the mapping of risk institutions for El Progreso, it does not outline national level policy instruments or institutions engaged in climate change planning or risk management for Honduras. Further data was required to construct a picture of national level planning and implementation, and 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.



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 El Progreso, 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 El Progreso.

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.

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 good guide on the institutional framework for risk management in the city 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 El Progreso.

4.3 Policy instruments

4.3.1 National

The First National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) for Honduras was delivered by the Climate Change Unit within the Secretariat of Natural Resources and Environment (SERNA) in 1999. It emphasised that impacts of climate change on rain and temperatures patterns ‘could lead to a situation of disaster’ in agricultural and other economic activities ‘if the appropriate (adaptation) measures are not undertaken in a timely manner’ (SERNA, 2000:64). In particular, it identified the Sula valley as one of the regions where agricultural activity could be severely impacted by climate shifts in the hydrological cycle (SERNA, 2000).

A Second National Communication for Honduras has been recently been published in 2012. The report includes national studies that are intended to contribute to the creation and adoption of adaptation policies in key sectors, with the strengthening of national capacities in the field of climate change as the main aim of the strategy. It proposes specific mitigation and adaptation measures to climate change for the various sectors of the economy through the National Strategy of Climate Change Adaptation and Mitigation in Honduras. The Inter-institutional Technical Committee for Climate Change (CTICC) has been formed to lead on the implementation of the objectives of the national communications and promote institutional coordination and dialogue. The strategy also includes outcomes and commitments of activities in education, training and public awareness, as well as the Second National GHG Inventory using 2000 as the base year.

At a regional level, Honduras 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 sectoral 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.

Climate change adaptation and mitigation is identified as one of the eleven strategic themes in the Development Plan and Vision for 2010 to 2038 for Honduras (Honduras 2010). For adaptation, the strategy advocates the development of monitoring and measurement systems, early warning systems, new forms of soil use and agricultural production, construction codes, local risk management, preventative land-use planning, water storage and watershed conservation as key measures. It highlights the necessity for climate change to be mainstreamed into sectoral planning and public and private investment decisions as a long term strategy. The plan also contains a set of strategic objectives, one of which is to reduce climate risk in Honduras as measured by the Global Climate Risk Index. According to this index, Honduras is currently the third most vulnerable country globally but the government aims to reduce this ranking to below fifty. Climate change is also mentioned as a cross-cutting theme under other strategic objectives such as Regional Development, Natural Resources and Environment.

The law for the National Plan was approved in February 2010, and divides Honduras into six regions based on the main river basins in the country. According to this law, a Regional Development Committee must be created in each region. These regional committees incorporate both public and private actors, and are responsible for the elaboration of a regional development plan, with the support of a regional technical unit. The integration of all the regional development plans (that include a significant land management component) will constitute the national development plan.

In addition, Honduras approved a national Water Law in 2009 that provides the framework for responding to the challenges faced by this sector. Under this strategy, a new Water Authority has mandate over management of national water resources, as well as all dependent ecosystems and their (natural) resources. The Water Authority, which operates under the auspices of SERNA, was developed out of the merger of two pre-existing government departments: the Meteorological department and the Water Resources department. The National Water Resources Management Institute is a technical body charged with provision of scientific information and policy briefs for the implementation of the Water Law.

There are a relatively high number of climate change adaptation projects being implemented in Honduras. Most of these projects are primarily focused on research and assessment, and are being implemented as part of larger, multi-country regional or global initiatives. One project involving concrete adaptation action, called Encouraging Climate Change Adaptation in High-Risk Municipalities and Communities in Honduras, is currently being implemented. Honduras will also host one of the first projects financed by the Adaptation Fund. Both projects are run by UNDP, in collaboration with SERNA.

Honduras has over 15 national laws that relate to disaster risk management. The National Contingencies Law created the Contingency Permanent Commission (COPECO) in 1993, and the most important legislation, the National System for Risk Management (SINAGER), was created by Decree 151-2009 in December 2009. The SINAGER builds upon previous efforts at contingency planning, and improves and expands the role of COPECO. It has introduced a proactive Risk Management Policy for governing the integration of disaster risk management considerations in all aspects of the government's planning process at all levels of territorial and sectoral administration. According to SINAGER, disaster risk reduction must be incorporated into the regular planning activities of all government agencies and the private sector as a critical component of the country's sustainable development goals. It ensures that Honduras has a dynamic legal framework for developing capacity for disaster risk reduction by enhancing the country's institutional capacity for preparedness, response, and recovery from shocks caused by natural phenomena.

The establishment of a National Emergency Preparedness and Response Fund (Fondo Nacional de Preparación y Respuesta a Emergencias, FONAPRE) in 2009 is an important initiative by the government of Honduras. The fund is created for the acquisition of goods and services needed for preparedness and response in cases of emergencies caused by intense natural phenomena and disasters caused by human actions. The Fund will be administered by COPECO through the National Commissioner who can access the Fund's resources to ensure rapid preparedness and humanitarian assistance actions of any kind aimed at mitigating potential damages, and to respond to the needs of affected populations in the shortest time and in the best way possible. Up to fifty % of FONAPRE's accrued financial resources can be invested in any given fiscal year in risk reduction and emergency preparedness activities, and the remainder will be available to respond to any materialized emergency.

Another policy development aimed at strengthening the legal and institutional framework supporting disaster risk management in Honduras has been the approval of the National Territorial Zoning Law in 2003. The Territorial Zoning law sets out the government's policies with regard to the integral development of the national territory, and has resulted in the creation of the National Plan of Territorial Zoning, as well as the Departmental and Municipal Territorial Zoning Plans. These local level plans are hierarchically and strategically linked to the National Plan to ensure the implementation of complementary local and regional territorial zoning strategies. The Law also mandated the creation of a National Directorate of Territorial Zoning (DGOT), and a National Council of Territorial Zoning (CONOT).

4.3.2 City Level

In addition to its central administrative role, COPECO has seven regional offices that function as local prevention, preparedness and emergency response units. The SINAGER Act also establishes the creation of disaster and risk management structures at the regional, departmental, municipal and local levels. At the municipal level, the institutional authority responsible for organization and implementation of disaster risk policies and management is the Municipal Emergency Committee (CODEM). It integrates all state and private sector institutions, and has a provision for the participation of charities and NGOs. The SINAGER decree also mandates the creation of Departmental Emergency Committees (CODED), Local Emergency Committees (CODEL), School Emergency Committees (CODECE), and Workplace Emergency Committees (CEDECEL). This is part of a national level process for the decentralization of disaster management and risk and all these organizations assist in the dissemination and implementation of national policies on disaster risk management in El Progreso.

4.4 Institutional mapping

4.4.1 National

The Secretariat of Natural Resources and Environment (SERNA) is the national authority in charge of climate change issues in Honduras. SERNA was established in 1996 by Executive Decree 218-96 and is responsible for the formulation, coordination, implementation and evaluation of policies related to the management of environmental resources in the country. SERNA is also responsible for the implementation of international treaties (such as the UNFCCC and its Kyoto Protocol) and leads the development of all the National

Communications, as well as the National Strategy on Climate Change Adaptation and Mitigation. SEPLAN was established by Decree No. 286-2009 and is responsible for overseeing the implementation of the National Plan, and specifically territorial planning in the country. In accordance with the Country Vision and the National Plan, SEPLAN is assigned with the responsibility for planning early warning systems and early recovery in addition to designing a general methodology for regional planning. Emergency response is currently activated from the central level through COEN, the coordinating agency for emergency response.

COPECO was created in December 1993, and is the key organization responsible for coordinating public and private actions related to disaster risk management at the national level. COPECO is the Executive Secretariat for the Board that governs SINAGER. The Board is comprised of 25 members and meets at least three times a year and it can meet under extraordinary circumstances any other time as needed. Other national agencies responsible for environmental planning, such as SERNA, SEPLAN, and AMHON, assist and collaborate with COPECO in its disaster risk activities. AMHON is a non-profit entity representing the interests of the country's 298 municipalities. It is the organization driving the decentralization process in Honduras, and serves as a valuable partner in facilitating local level disaster risk management and territorial planning efforts. The national system for emergency management is officially activated through the National Emergency Response Center (COEN).

4.4.2 City Level

At the municipal level the city government is the governing authority for disaster management, risk and adaptation to climate change, and the mayor plays a central role in the implementation of operational plans. The municipal government's main function in disaster risk management is the coordination of the CODEM, NGOs, and the private sector. The CODEM in El Progreso is responsible for strategic planning, coordination and for the direction and coordination of local committees on education, health, logistics, search, evacuation and rescue, security, communications and monitoring. It has specific responsibilities that it must perform during the prevention, response and recovery phases of disaster management.

CODEM is also responsible for the formation of the Local Emergency Committees (CODELs) in areas considered vulnerable. Currently, there is one CODEM, and 40 CODELES active in the city of El Progreso. The CODELES are composed of members of the community, and are supported by the city government and the Permanent Contingency Commission (COPECO). There is still a lack of functioning CODECE and CEDECEL in El Progreso. However the implementation of Safe School Project aims to create 16 CODECE. Some of the other organizations that play an active role in disaster management include the Secretariat of Education, the Secretariat of Health, and SANAA, the agency responsible for administration of water and sewage services in the city.

The majority of these local level organizations are well organized and prepared to play an important and decisive role in disaster risk management. However, risk management and planning for adaptation to climate change remains weak at the city level. This is in part due to a lack of policy instruments at the local level for integrating climate change planning into city development actions. There is low technical understanding of climate change risks among individuals working in disaster management, and no risk mitigation mechanisms or specific sectoral measures for adaptation exist at this level of governance.

4.5 Gaps in existing capacity and opportunities for adaptation

There have been major improvements in disaster risk management in Honduras at both the national and local level. Since the introduction of SINAGER, the national disaster management system is better prepared, resourced and has better defined lines of responsibility and roles. The government has developed effective legal frameworks, emergency plans, and contracts and agreements for disaster risk reduction, and invested in training, awareness, and planning. The city of El Progreso has developed a Municipal

Emergency Plan for disaster response and management under the national system of disaster risk management, which has been successfully deployed during numerous flood events experienced in the city over the past years. However, interviews with stakeholders revealed the absence of a consistent approach towards long-term recovery and reconstruction. Thus far, risk planning and adaptive practices have not been incorporated into risk management strategies and the local institutional system remains reactive rather than proactive in dealing with disaster risk management and future climate change related vulnerabilities.

More recently, policy frameworks such as the National Strategy on Climate Change and Adaptation, and the Country Vision have set out the agenda for planning and adaptation to climate change in Honduras. Despite the development of such initiatives, efforts towards adaptation and planning at national level have not filtered down to the municipal or regional level, and as yet there is little integration of climate change in development planning. At the local level, disaster management and emergency response actions still remain the greater priority. This is slowly changing and the country's adaptation needs have been identified if not yet prioritized through national policy instruments.

A key challenge to climate change adaptation at the local level appears to be the relatively weak institutional capacity to undertake such action. Although disaster management capacity is of a reasonably good standard in El Progreso, integration of climate adaptation into development activities requires creating new knowledge and skills, for example, to undertake comprehensive vulnerability assessments and to develop climate change scenarios, as well as to incorporate climatic variables into their relevant decision and planning processes.

To some degree, the development of local skills and knowledge is impeded by the absence of relevant technical information. Critical information and data to orient decisions at the sub-national and local level, as well as for the elaboration of climate change induced socio-economic scenarios, is still missing in El Progreso. Without this information, it is impossible to undertake local adaptation activities that rely on the downscaling of climate change models and climatic data. This challenge can be seen as a reflection of larger national problems with weak communication flow between scientists and policy-makers as well as between institutions and different economic sectors, and insufficient local and national capacities to mainstream climate risk considerations into development planning and programming processes. In addition, awareness of climate change impacts and adaptation options for climate-resilient development remains low within local government agencies in El Progreso.

Lack of financial resources and legislative capacity of city level public institutions is also a challenge for local risk management and planning. Shortage of physical resources and qualified staff is prevalent in local institutions involved in risk management activities, resulting in weak implementation and regulation of risk management policies. For example, implementation of building controls and land use planning is limited by a shortage of resources and staff to undertake these activities.

This capacity deficit is exacerbated by a rapid rate of urbanization and population growth in El Progreso, stressing a system for urban risk management that is already ineffective in its implementation. Basic systems of drainage and rubbish collection are also missing at places in the city. In addition to policy strengthening for climate change adaptation, there is likely the need for greater investment into capacity building for risk management and infrastructural strengthening at the city level. The Municipality, with support from the World Bank, has, as discussed above, recently developed a Municipal Development Plan with focus on Territorial Planning. Aimed at directing sustainable and resilient urban growth away from high risk areas, the Plan also incorporates projects for risk and vulnerability reduction.

Despite the existence of this planning instrument, the fast urban expansion in El Progreso has resulted in some, albeit limited, high-risk informal settlements. In addition, private developers regularly create housing schemes in areas that do not have basic public infrastructure, creating problems for the municipality.

Deforestation of surrounding hillsides is also a potential contributing factor for flood risk in El Progreso. Flood risk and water supply in El Progreso is directly affected by water basin and slope management of the Mico Quemado mountain range, and its protection and restoration is crucial for managing water availability for the city. Although the mountain range is designated as a protected natural reserve, it suffers from deforestation, illegal cultivation and urban expansion. The reserve lacks a comprehensive management plan since its jurisdiction falls under three municipalities in two different departments: El Progreso, Santa Rita and El Negrito. Low levels coordination on part of the municipalities, and a fragmented institutional setup pose a challenge to future risk reduction for flooding and water management in El Progreso. Overall, disaster risk management and adaptation planning for the city needs to be aligned with land management practices and institutional arrangements governing water basin management in the region surrounding El Progreso.

Agriculture and banana production was severely affected during Hurricane Mitch in 1998. Since then, much of the agricultural industry around El Progresso has shifted to flood resilient oil palm and sugar cultivation. This shift in cash crop production can be viewed as a form of adaptation to continuing risk of tropical storms and increased precipitation in the area. This transformation of small and large scale agricultural production has not been accompanied by comprehensive efforts by the private sector to study the damage and financial impact of flood risk. Some sugar plantations exercise systems of risk regulation by monitoring river and rainfall levels but there is little evidence of cooperation or coordination between city level government agencies and private sector organizations in mediating future disaster risk through development and investment initiatives. Such an alignment of agricultural industry interests and risk management strategies can potentially result in greater local level coordination in adaptation and risk reduction.

Strong social networks between city level institutions in El Progreso have acted as a robust coping strategy in the face of limited resources. Similarly, at the community level the frequent incidence of flooding combined with shortcomings in the support provided by public organizations for risk management has resulted in strong informal collaboration between nongovernmental organizations and community members. Civil society organizations such as Aside and the Red Cross continue to play a significant role in disaster management by assisting communities during episodes of flooding and providing help in the recovery phase. Despite frequent flooding incidents, overall public engagement with risk reduction practices remains low, with illegal fly tipping and rubbish disposal causing problems in the maintenance of streams and the drainage system. Community level organizations, or CODELES, offer local social networks for raising awareness and resilience of the local population. Ideally, city level policy change initiatives need to be combined with practical efforts at the community level by local organizations in order to develop more resilient systems for climate change adaptation and planning.

5 Climate-related vulnerability assessment

5.1 City profile

In the last two decades, El Progreso has suffered from a number of serious floods. Severe floods due to hurricanes and tropical storms occurred in 1990, 1993, 1995 and 1996. However, the most significant and recent catastrophe was Hurricane Mitch in 1998. In 2008 and 2009, the city and its rural outskirts saw flood events. Currently limited improper land uses occurring on protected areas, if left unchecked, are very likely to further exacerbate flooding problems in the city. In addition to causing environmental degradation, they may also trigger new hazards, for example landslides, which at the moment do not have a direct impact on the city.

The purpose of the climate-related vulnerability assessment is to synthesize 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. This analysis provides an indication of how climate change may affect the vulnerable locations (e.g., for a vulnerable neighbourhood will the future susceptibility increase or decrease). This information helps guide future planning and provides a foundation for future work, identifying the regions/hazards that would benefit from a more costly and focused risk assessment.

About 40 kilometres from San Pedro Sula, the second largest city in Honduras and its most important economic centre, El Progreso, has strategic significance as it is located at the crossroads of two of the most important highways of the country.

Fast economic expansion has gone hand in hand with demographic expansion. There was rapid population growth between 2001 and 2011, with an increase of approximately 4% on an annual basis. The municipality's population increased from 147,000 inhabitants in 2001 to 177,000 in 2007, and reached 220,000 in 2011 (Municipalidad de El Progreso, 2012). Most of this growth has concentrated in the urban area of El Progreso, which represents some 85 to 90% of the overall population. Overall, the city's social development indicators show better results than Honduran national averages. However, poverty issues are present all over Honduras and are also visible in El Progreso. High inequality and public safety concerns have to be added to the issues.

The administrative boundaries of urban El Progreso, as seen in Figure 5.1, are the base for the area of study.

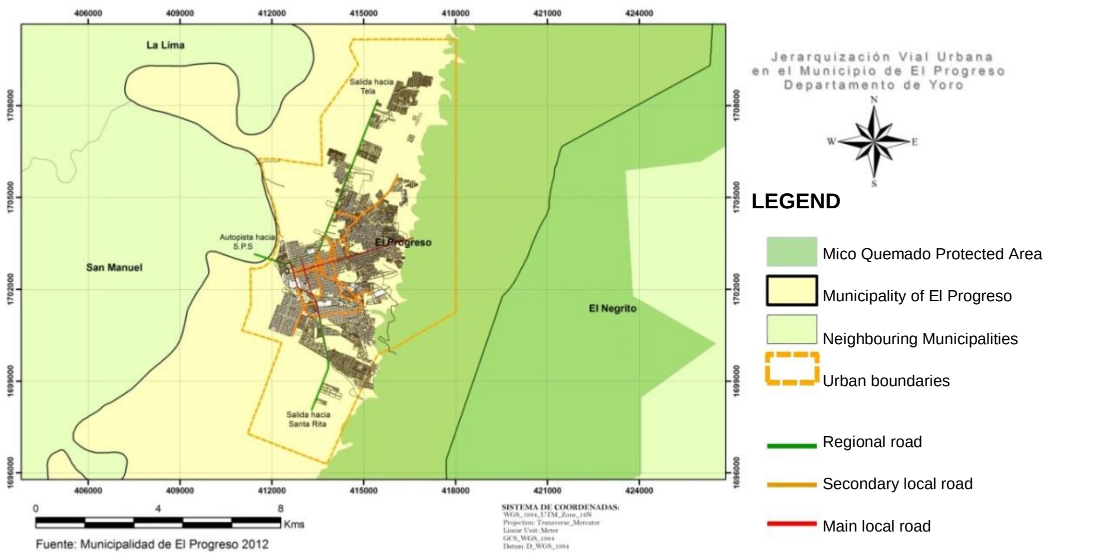


Figure 5.1 The yellow line represents the urban boundaries of El Progreso. Source: adapted from PATH II in Municipalidad de El Progreso, 2012

As discussed above, El Progreso has experienced fast urban growth and expansion over the past decade. Much of this growth is the result of in-migration from rural areas as well as from other urban areas. Urban development is most times controlled and captured within the urban development plan. It follows the main highway, between the urban boundaries of the Ulúa River to the west and the Mico Quemado Mountain to the east.

In 2012, the Municipality of El Progreso, in order to guide urban development and expansion, and with support by the World Bank, developed a Municipal Development Plan with a focus on territorial planning. Aiming at orienting sustainable and resilient urban growth, the plan also includes various projects for risk reduction. The plan gives a direction to urban growth: it directs expansion along the North-South corridor, following the main highway, and away from the river, in order to avoid high risk areas.

This planning instrument is particularly welcomed as both historical and recent fast urban expansion in El Progreso over the past decades has led to the appearance of settlement located in hazard risk areas. The safest and more habitable land is usually available to groups in the highest income strata. Land in high risk areas is more affordable, which is thus often the choice of lower-income groups. Although new urban development has at most times been directed away from risk areas, there are still many communities located in hazard prone locations.

El Progreso is expected to keep growing in the years to come. Urban expansion is occurring according to a north-south pattern, along the transversal highway that crosses the city from north to south. The result has been an extended morphology following a major north-south transportation route. This raises the issue of establishing and implementing appropriate planning instruments to deal with expansion.

Predominant features of the built environment and urban population that impact upon flood and landslide hazard risks are summarized in Figure 5.2.

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

Figure 5.2 Predominant features of the built environment in El Progreso that impact upon flood and landslide hazard risks.

5.2 Institutional vulnerability in El Progreso

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 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.

Climate change policy instruments

There have been major improvements in disaster risk management in Honduras at both the national and local level. Since the introduction of SINAGER in 2009, the national disaster management system is better prepared, resourced and has better defined lines of responsibility and roles. The government has developed effective legal frameworks, emergency plans, and contracts and agreements for disaster risk reduction, and invested in training, awareness, and planning.

The City of El Progreso has developed a Municipal Emergency Plan for disaster response and management under the national system of disaster risk management, which has been successfully deployed during numerous flood events experienced in the city over the past years. However, more efforts need to be focused on developing a consistent approach towards long-term recovery and reconstruction. Thus far, risk planning and adaptive practices have not been incorporated into risk management strategies and the local institutional system remains reactive rather than proactive in dealing with disaster risk management and future climate change related vulnerabilities.

Policy frameworks such as the National Strategy on Climate Change and Adaptation, and the Country Vision set out the agenda for planning and adaptation to climate change in Honduras. Despite the development of such initiatives, efforts towards adaptation and planning at national level have not filtered down to the municipal or regional level, and as yet there is little integration of climate change in development planning. At the local level, disaster management and emergency response actions still remain the greater priority. This is slowly changing and the country’s adaptation needs have been identified if not yet prioritized through national policy instruments.

Institutional capacity for adaptation

A key challenge to climate change adaptation at the local level appears to be the relatively weak institutional capacity to undertake such action. Although disaster management capacity is of a reasonably good standard in El Progreso, integration of climate adaptation into development activities requires creating new knowledge and skills, for example, to undertake comprehensive vulnerability assessments and to develop climate change scenarios, as well as to incorporate climatic variables into their relevant decision and planning processes.

To some degree, the development of local skills and knowledge is impeded by the absence of relevant technical information. Critical information and data to orient decisions at the sub-national and local level, as well as for the elaboration of climate change induced socio-economic scenarios, is still missing in El Progreso. Without this information, it is impossible to undertake local adaptation activities that rely on the downscaling of climate change models and climatic data. This challenge can be seen as a reflection of larger national problems with weak communication flow between scientists and policy-makers as well as between institutions and different economic sectors, and insufficient local and national capacities to mainstream climate risk considerations into development planning and programming processes. In addition, awareness of climate change impacts and adaptation options for climate-resilient development remains low within local government agencies in El Progreso.

Lack of financial resources and legislative capacity of city level public institutions is also a challenge for local risk management and planning. Shortage of physical resources and qualified staff is prevalent in local institutions involved in risk management activities, resulting in weak implementation/enforcement and regulation of risk management policies. For example here, the enforcement of building controls and land use planning is limited by a shortage of resources and staff to undertake these activities.

This capacity deficit is exacerbated by a rapid rate of urbanization and population growth in El Progreso, placing stress on a system for urban risk management that is already weak in its implementation. Basic systems of drainage and rubbish collection also need to be improved in the city. In addition to policy strengthening for climate change adaptation, there is likely the need for greater investment into capacity building for risk management and infrastructural strengthening at the city level.

The Municipality, with support from the World Bank, has recently developed a Municipal Development Plan with focus on Territorial Planning. Aimed at directing sustainable and resilient urban growth away from high risk areas, the Plan also incorporates projects for risk and vulnerability reduction. Despite the existence of this planning instrument, the fast urban expansion in El Progreso has resulted in limited high-risk informal settlements. As seen above, implementation/enforcement of planning laws and building control remains a challenging task in El Progreso. There also needs to be greater coordination between agencies for effective risk management. For example, private developers regularly create housing schemes in areas that do not have basic public infrastructure, creating problems for the municipality.

Deforestation of surrounding hillsides is also a potential contributing factor for flood risk in El Progreso. Flood risk and water supply in El Progreso is directly affected by water basin and slope management of the Mico Quemado mountain range, and its protection and restoration is crucial for managing water availability for the city. Although the mountain range is designated as a protected natural reserve, it suffers from deforestation, illegal cultivation and urban expansion. The reserve lacks a comprehensive management plan since its jurisdiction falls under three municipalities in two different departments: El Progreso, Santa Rita and El Negrito. Low levels coordination on part of the municipalities, and a fragmented institutional setup pose a challenge to future risk reduction for flooding and water management in El Progreso. Overall, disaster risk management and adaptation planning for the city needs to be aligned with land management practices and institutional arrangements governing water basin management in the region surrounding El Progreso.

Agriculture and banana production was severely affected during Hurricane Mitch in 1998. Since then, much of the agricultural industry around El Progresso has shifted to flood resilient oil palm and sugar cultivation. This shift in cash crop production can be viewed as a form of adaptation to continuing risk of tropical storms and increased precipitation in the area. This transformation of small and large scale agricultural production has not been accompanied by efforts by the private sector to study the damage and financial impact of flood risk. Some sugar plantations exercise systems of risk regulation by monitoring river and rainfall levels but there is little evidence of cooperation or coordination between city level government agencies and private sector organizations in mediating future disaster risk through development and investment initiatives. Such an alignment of agricultural industry interests and risk management strategies can potentially result in greater local level coordination in adaptation and risk reduction.

Strong social networks between city level institutions in El Progreso have acted as a robust coping strategy in the face of limited resources. Similarly, at the community level the frequent incidence of flooding combined with shortcomings in the support provided by public organizations for risk management has resulted in strong informal collaboration between nongovernmental organizations and community members. Civil society organizations continue to play a significant role in disaster management by assisting communities during episodes of flooding and providing help in the recovery phase. Despite frequent flooding incidents, overall public engagement with risk reduction practices remains low, with illegal fly tipping and rubbish disposal causing problems in the maintenance of streams and the drainage system. Community level organizations, or CODELES, offer local social networks for raising awareness and resilience of the local population. Ideally, city level policy change initiatives need to be combined with practical efforts at the community level by local organizations in order to develop more resilient systems for climate change adaptation and planning.

5.3 Landslides and floods vulnerability in El Progreso

By the 2040s, the warming temperatures El Progreso has already experienced over the past few decades are projected to increase. Seasonal and annual precipitation is projected to decrease (though it is not clear how the intensity, frequency, and/or duration of rainfall events may change). **This suggests areas prone to floods and landslides may be at slightly less risk.** An exception is areas where vegetation has been removed which may be at higher susceptibility to landslides during the dry season given the potential increase in evaporation rates and decrease in soil moisture. This analysis assumes current conditions such as land use, health of forests, and vegetation cover remain consistent with today's conditions.

This analysis considers which areas are exposed to floods and landslides and considers the associated vulnerability to these hazards. Further, locations where urban expansion may take place are included in the vulnerability analysis.

5.3.1 Approach

This section synthesizes information on El Progreso'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 neighbourhood 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 neighborhoods are more likely to be affected by landslides and floods by mid-century.

The *Urban, social and economic assessment* identified neighborhoods in the study region that are prone to floods or landslides. The urban core of the Municipality of El Progreso comprises 111 neighbourhoods and is surrounded by 51 villages and 203 *caseríos* (group of houses). Though statistical data to support a vulnerability assessment is not publicly available at the neighborhood scale, it is available at the 'village' scale (i.e., where a 'village' contains a number of neighborhoods). To explore possible future changes, adjacent 'villages' along the main rivers are also included in this analysis.

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 neighborhoods 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, neighborhoods, 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 5.3). Each of these components is discussed in more detail below.

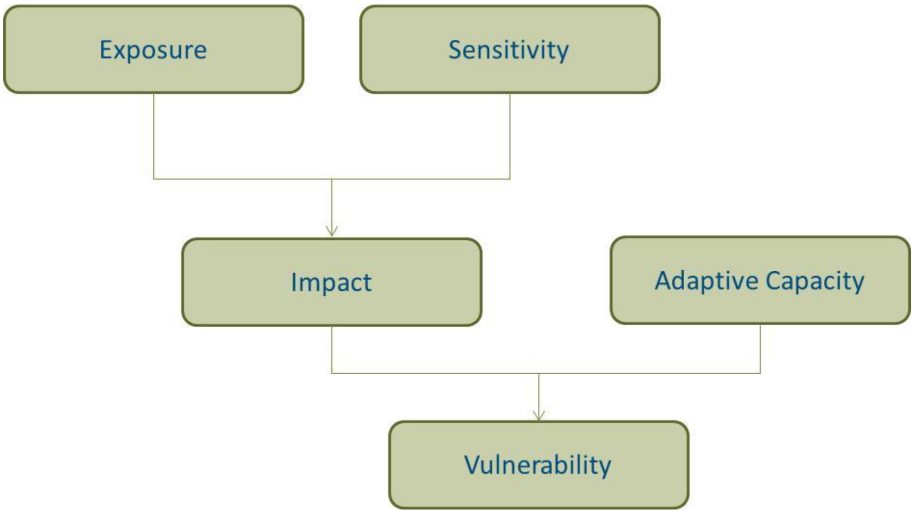


Figure 5.3 Schematic of the vulnerability analysis for landslides and floods.

- **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 regions and settlements 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 4).

Box 4 Projected changes in hazards

Due to climate change, El Progreso'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 village was ranked based upon the percentage of households that use cement for the exterior walls. The percentage of cement households was used as a proxy to suggest the proportion of housing that are less likely to suffer damage during a flood and more able to withstand landslides. According to the *Urban, social and economic assessment,* close to 80% of the building stock in El Progreso contains cement exterior walls. Additional data was used to provide geographically disaggregated housing information at the village level.

- **Adaptive capacity.** Adaptive capacity considers how an impacted settlement (i.e., a settlement 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 households with unsatisfied basic needs (UBN) in each village. In El Progreso, it is estimated that about 43% of the households in the city experience UBN. This metric was used based upon the assumption that settlements that rank high will be less capable of responding to and/or protecting against the hazard.

Table 5.1 provides a description of the number of housing that uses cement construction and UBN for each village.[16] According to the 2001 Census, El Progreso with the greatest population has the greatest percentage of housing with cement exterior walls and the lowest UBN. San Antonio with the lowest population has the lowest percentage of housing with cement exterior walls and the highest UBN.

Table 5.1 Total housing and that made of cement construction for each village. Source: 2001 Census.

Village	Total housing	Cement housing	% of housing that is cement	UBN
Campo Buena Vista	103	41	40%	36%
Cuatro de Marzo	64	23	36%	60%
El Progreso	22,130	18,941	86%	32%
Santa Elena	104	10	10%	43%
San Antonio	37	3	8%	92%

Table 5.2 details the rankings used for estimating the sensitivity and adaptive capacity for each village.

Table 5.2 The rankings of sensitivity and adaptive capacity.

Rank	Sensitivity	Adaptive Capacity
0	More than 80% of housing is cement	UBN less than 8%
1	60 to 80% of housing is cement	UBN less than 15%
2	40 to 60% of housing is cement	UBN less than 20%
3	20 to 40% of housing is cement	UBN less than 25%
4	Less than 20% of housing is cement	UBN greater than 25%

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

The rankings of sensitivity and adaptive capacity were used to assess potential vulnerability (see Table 5.3). 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.

[16] UBN is an indicator of measuring poverty and is calculated based upon the following basic needs: drinking water, sanitation, education, subsistence capacity, overcrowding, and state housing. The numbers provided were obtained from the 2001 census (see *Urban, social and economic assessment* for more detail).

This evaluation is applied for both the landslide and flood vulnerability analyses.

Table 5.3 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				

5.3.2 Vulnerability results

This project focuses on floods and landslides which can be triggered by rainfalls and storm events. Table 5.4 provides an overview of anthropogenic and climatic stressors that affect floods and landslides in El Progreso. These events can have significant impact on people, infrastructure, and the country's economy. This section investigates the (1) settlements, and the (2) facilities and critical infrastructure that may be vulnerable to these hazards in each district.

Table 5.4 Summary of anthropogenic and climatic stressors of landslides and floods, and a description of the projected change in climate by the 2040s.

	Stressors		Projected climate change
	Anthropogenic Activities	Climatic	
Landslides	■ Deforestation and land clearing for urban expansion and agriculture.	■ Prolonged intense precipitation	By the 2040s, the threat of landslides may be reduced as the seasonal and annual rainfall is generally expected to decrease in the area. Reduced precipitation during the "dry season" may reduce soil moisture, also reducing the threat of landslides (except in areas where vegetation has been removed).
Floods	■ Poor watershed management. ■ Deforestation of upstream areas in the watershed and migratory agricultural practices. ■ Levees along the Ulúa River trapping runoff from the mountains. ■ Paving, construction, and	■ Minor rain events followed by a heavy precipitation event ■ Intense rainfall ■ Heavy precipitation in the surrounding mountains	By the 2040s, the threat of floods may be reduced as the seasonal and annual rainfall is generally expected to decrease in the area.

	Stressors		Projected climate change
	Anthropogenic Activities	Climatic	
	activities which minimize the absorptive capacity of the soil. ■ Rivers' low hydraulic capacity as a consequence of sedimentation and obstacles.		

Floods A number of neighborhoods in El Progreso are prone to flooding as shown in Figure 5.4. These neighborhoods fall within the village of El Progreso. Flooding can occur: (1) due to overtopping of the river banks during storm events, or (2) within rain-event flood-prone areas. The steepness of the mountains along the eastern side of the city make it very susceptible to riverine flooding caused by the fast moving water as it descends from the mountain.

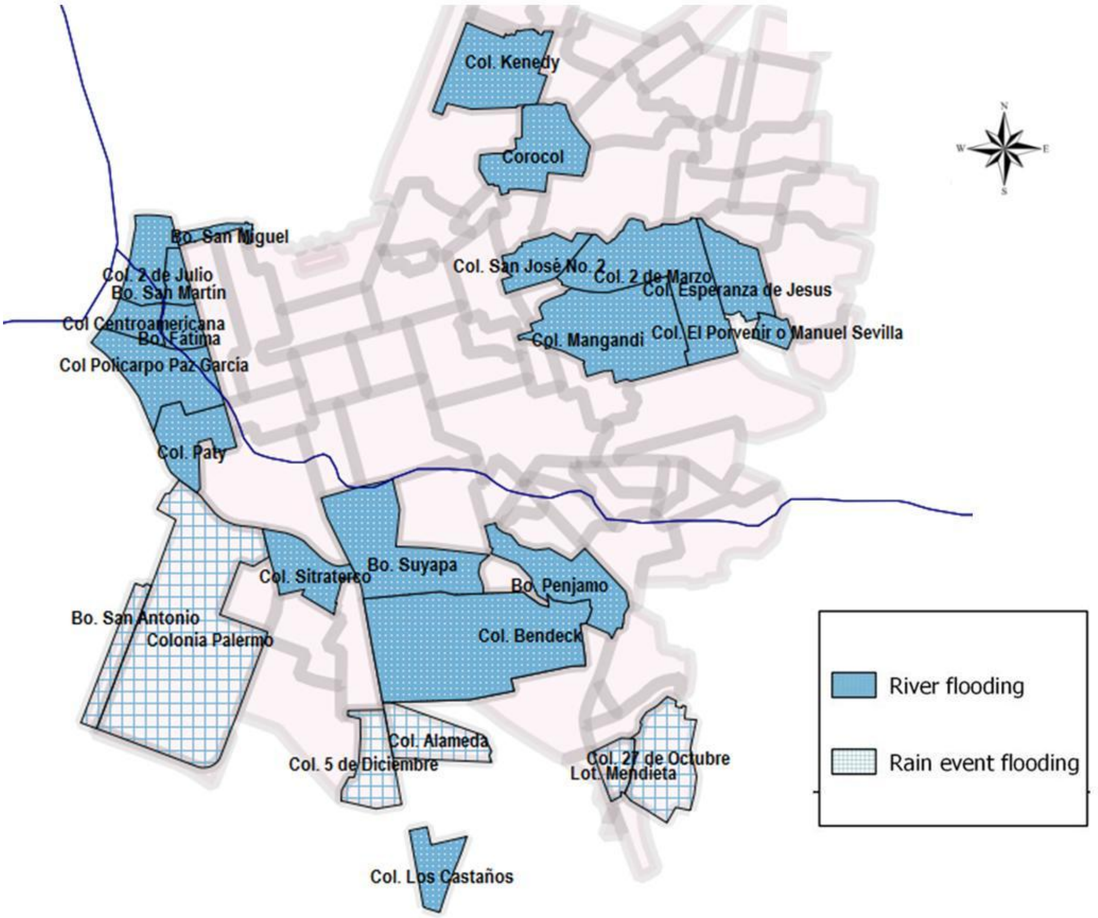


Figure 5.4 **Flood-prone neighborhoods as identified in the socioeconomic assessment (neighborhoods not included in the map: Col. Inva, Col. Corocol 2, Altos del Progreso, Col. Suazo Cordova).**

Figure 5.5 in the next page overlays the flood-prone neighborhoods with urban characteristics of the city. A large swath of the urban environment falls within flood-prone areas.

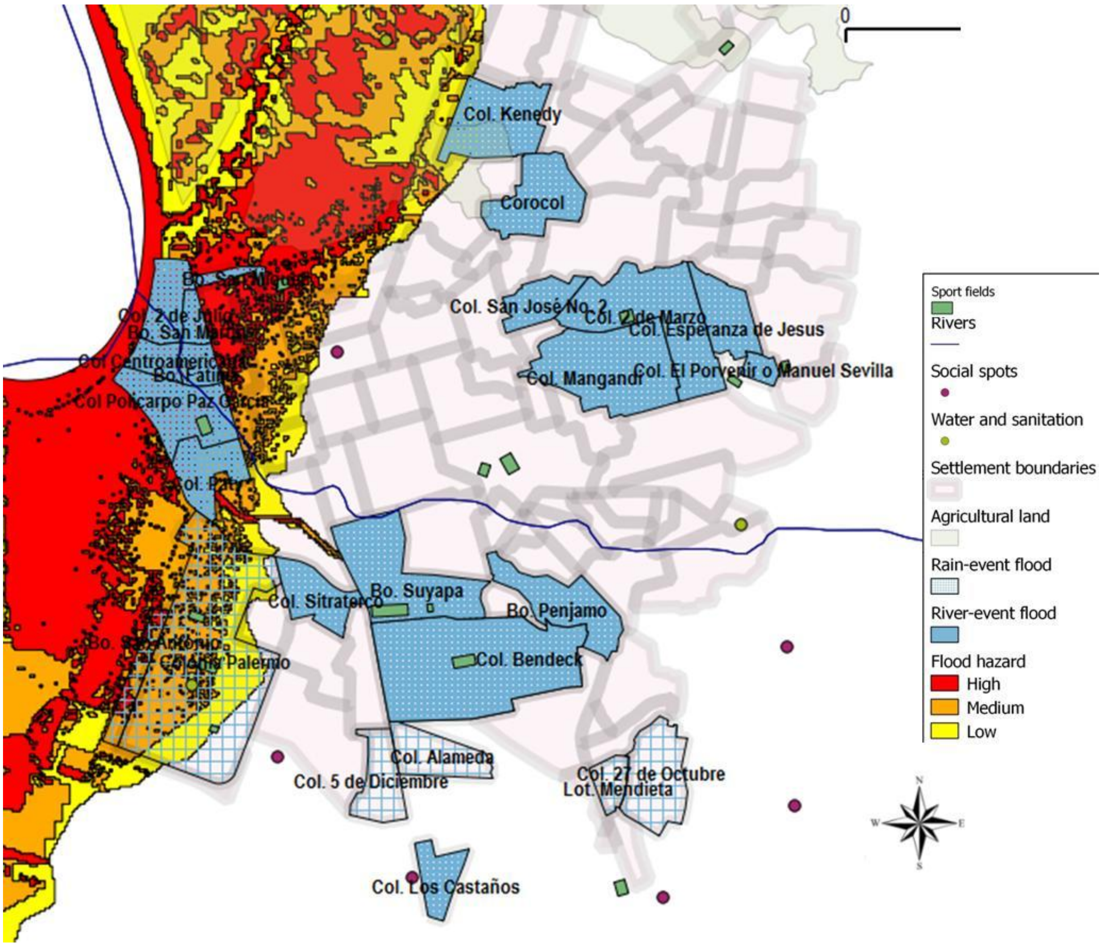


Figure 5.5 The urban characteristics of flood-prone areas. Source: GIS layer provided by the Municipality of El Progreso.

Landslides Under the analysis made by the Natural Disasters Mitigation Program (PMDN), landslide hazard was not considered as a major threat in El Progreso. Given the city's relatively flat topography, the potential occurrence of landslides is low, and is mostly located in neighbourhoods west of the city, in proximity to the Mico Quemado (PMDN, no date).

As shown in Figure 5.6, the landslide threat within El Progreso is limited to the neighbourhoods in the north-eastern limits of the municipality and adjacent to the Mico Quemado Mountains. These neighbourhoods include Barrio Las Golondrinas, Colonia Corocolito, Colonia Juventino Barahona, and Colonia Rodolfo Carcamo.

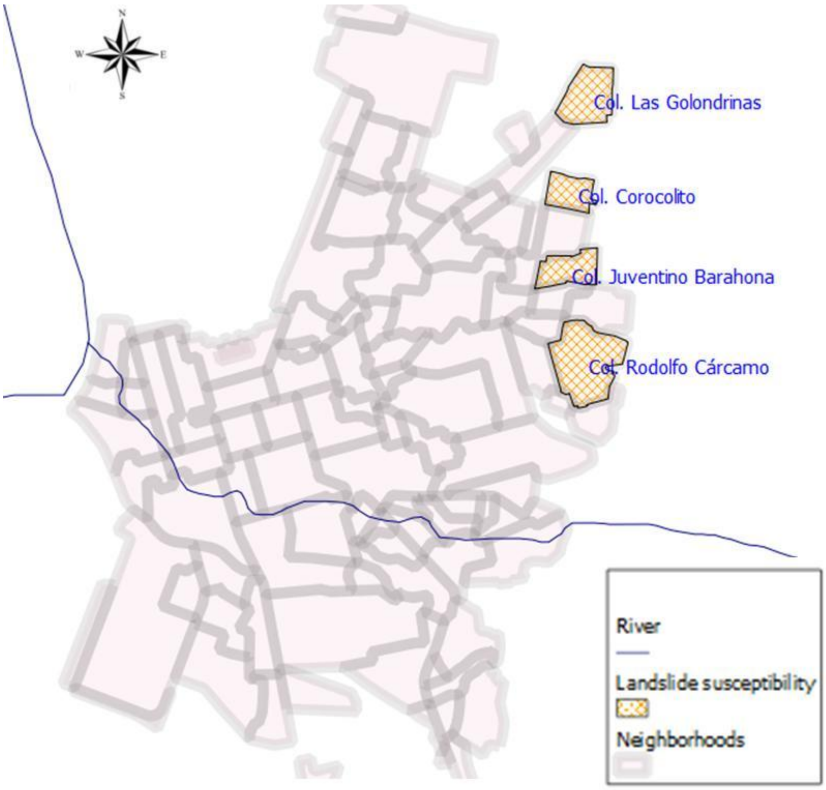


Figure 5.6 Neighborhoods identified to be threatened by landslides in the hazard assessment, Source: GIS layer provided by the Municipality of El Progreso.

Figure 5.7 overlays these neighborhoods with urban characteristics to expose which of these neighborhoods contain a greater density of urban housing. Though all four neighborhoods are urban, Colonia Corocolito, Colonia Juventino Barahona, and Colonia Rodolfo Carcamo appear to be particularly settled.

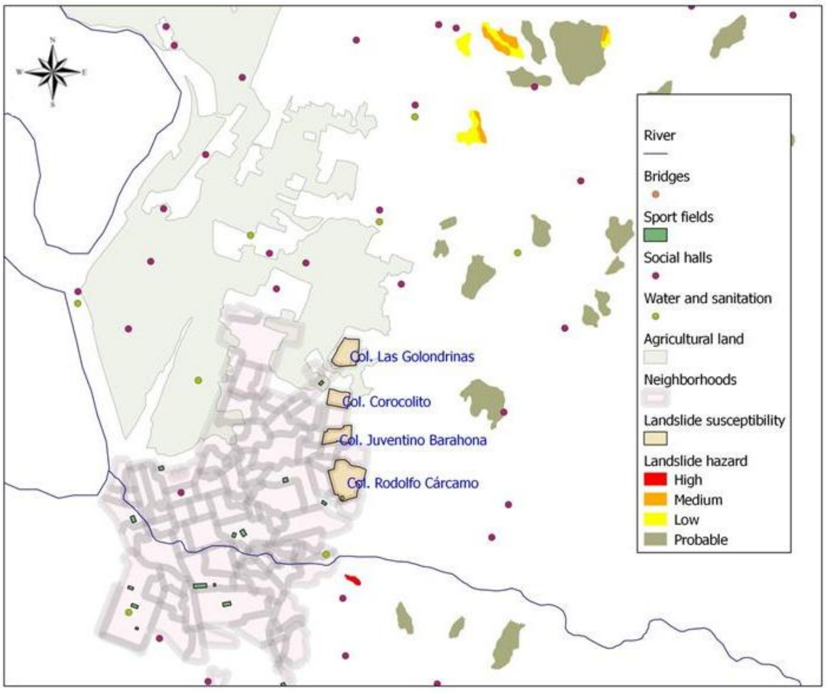


Figure 5.7 The urban characteristics of the landslide prone areas. Source: Source: GIS layer provided by the Municipality of El Progreso.

Results. The future exposure to landslides and floods may slightly decrease; however, it is not clear the degree of decrease and how that will impact the exposure. As this region has minimal exposure to landslides, the Table 5.5 is developed for the flood hazard; however, the vulnerability score is applicable to either flood or landslide hazards. This table shows villages surrounding urban El Progreso that have high vulnerability to hazards.

Table 5.5 Summary of villages that are potentially vulnerable to floods.

Settlement	Population	Potential Vulnerability				
		Exposure Today*	Future Exposure	Sensitivity	Adaptive Capacity	Vulnerability Score
Campo Buena Vista	588	**Y**	↓	3	4	**H**
Cuatro de Marzo	217	**Y**	↓	3	4	**H**
El Progreso	90,475	**Y**	↓	0	4	**M**
Santa Elena	331	NA	↓	4	4	**H**
San Antonio	111	NA	↓	4	4	**H**

*Note: *Villages in the bolded "Y" indicate areas that fall within the high flood-prone areas as indicated by the Categorical Flood Map of El Progreso. "NA" refers to areas not indicated as flood-prone by the Categorical Flood Map of El Progreso; however, are included in case future settlements arise along the river.*

Figure 5.8 illustrates the results of the vulnerability analysis by village. All villages in and around the El Progreso study area are considered moderate to highly vulnerable to hazards. While all five villages are impacted by floods, Campo Buena Vista and Cuatro de Marzo are two villages that are extremely affected. Santa Elena is the only village that may also be exposed to landslides.

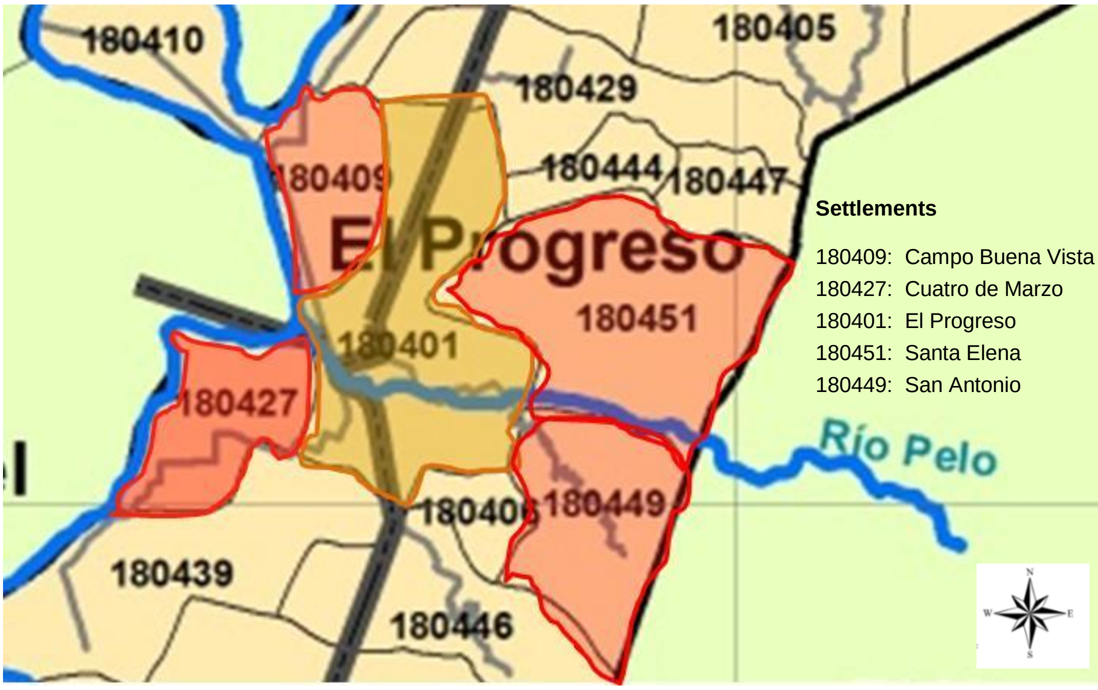


Figure 5.8 Potential vulnerability of settlements within each village to hazards where red shading represents high vulnerability and orange shading represents medium vulnerability.

Facilities and critical Infrastructure

Though GIS-data of facilities and infrastructure in El Progreso was not available, a few considerations regarding infrastructure exposure to floods and landslides can be discussed. An assessment of the vulnerability of critical infrastructure in El Progreso shows no particular concerns except for the road networks and the water treatment plant. Currently, landslides do not pose any major threat to the city and its infrastructure, while flooding does present a significant and recurring risk. Transportation networks in and around El Progreso are of great importance as the city is strategically located at the crossroad of two of the most important highways in Honduras. It is estimated that 35 to 40% of the country's economic output passes through the municipality. During Hurricane Mitch in 1998, flooding from the Pajuiles Ravine cut off access to roads and destroyed agricultural land, causing severe economic losses to the city. Hurricane Gamma in 2005 resulted in the flooding of 60% of El Progreso and isolated it from other cities.

The water treatment plant is not directly exposed to floods, but has been shut down during flood events and then cleaned afterwards due to the accumulation of sediments. El Progreso experiences this problem every year with deforestation in the mountainous areas is found to be the main cause. Other critical infrastructure, however, do not appear to be vulnerable to weather hazards. Interviews with representatives and end-users of the telecommunication and energy sectors suggest there have been no impacts to the infrastructure networks during past disaster events. Future work should include the geo-referencing of critical infrastructure for the urban area of El Progreso.

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.

Assuming long-term observational records are developed, the following studies are suggested for El Progreso to continue its development and collection of pertinent risk information to inform risk assessments:

- 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. 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 USGS modelling efforts 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.
- 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 could change 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 El Progreso.

6 Strategic climate adaptation investment and institutional strengthening plan

6.1 Introduction

El Progreso is susceptible to floods but landslides do not pose a significant threat to the city. Reported landslides are unusual and have occurred only in rural areas of the wider Municipality of El Progreso. However given the city's location in northwest Honduras, in proximity to the Caribbean and at the confluence of the Pelo and Ulúa Rivers, exposure to floods is significant in the city. By the 2040s, the warming temperatures El Progreso has already experienced over the past few decades are projected to increase. Seasonal and annual precipitation is projected to decrease (though it is not clear how the intensity, frequency, and/or duration of rainfall events may change). This suggests areas prone to floods and landslides may be at slightly less risk. An exception is areas where vegetation has been removed which may be at higher susceptibility to landslides during the dry season

The city has recently developed planning strategies to address unplanned urban expansion and exposure to risk. Local authorities formulated a Municipal Development Plan (PDM-OT) in 2012, which incorporates land use studies as a core element. The municipality elaborated a land assessment study that forms the basis for a Municipal Zoning Proposal. The proposal identifies different potentialities for the spatial configuration of the municipality. It creates a scenario of spatial organization by evaluating current levels of production and protection, and by associating them with possible risks and threats (PDM-OT, 2012). El Progreso is thus taking the first steps in integrating risk when formulating municipal planning strategies.

El Progreso has developed a strong DRM system, through the presence of a CODEM and 40 active CODELES. Despite the existence of a strong DRM network in the city, climate change adaptation has not been incorporated into risk management strategies. Further, the local institutional system remains understandably reactive rather than proactive in dealing with disaster risk management and future climate change related vulnerabilities.

The purpose of the *El Progreso 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 El Progreso.

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 El Progreso.

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 El Progreso 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 El Progreso.

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 El Progreso 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 El Progreso 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 11 below describes.

Box 5 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 El Progreso. 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 El Progreso build its resilience against floods and landslides, both now and in the future, can be outlined as follows:

- **Consideration of the environmental and socio-economic conditions of rural and peri-urban regions surrounding El Progreso in risk assessment and long term risk management planning for the city:**
  - Consider urban expansion and future demographic trends, as well as physical and climate vulnerabilities in land use management for the city.
  - Integrated management plans for the Mico Quemado range for long-term risk prevention in El Progreso.
- **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 El Progreso 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.

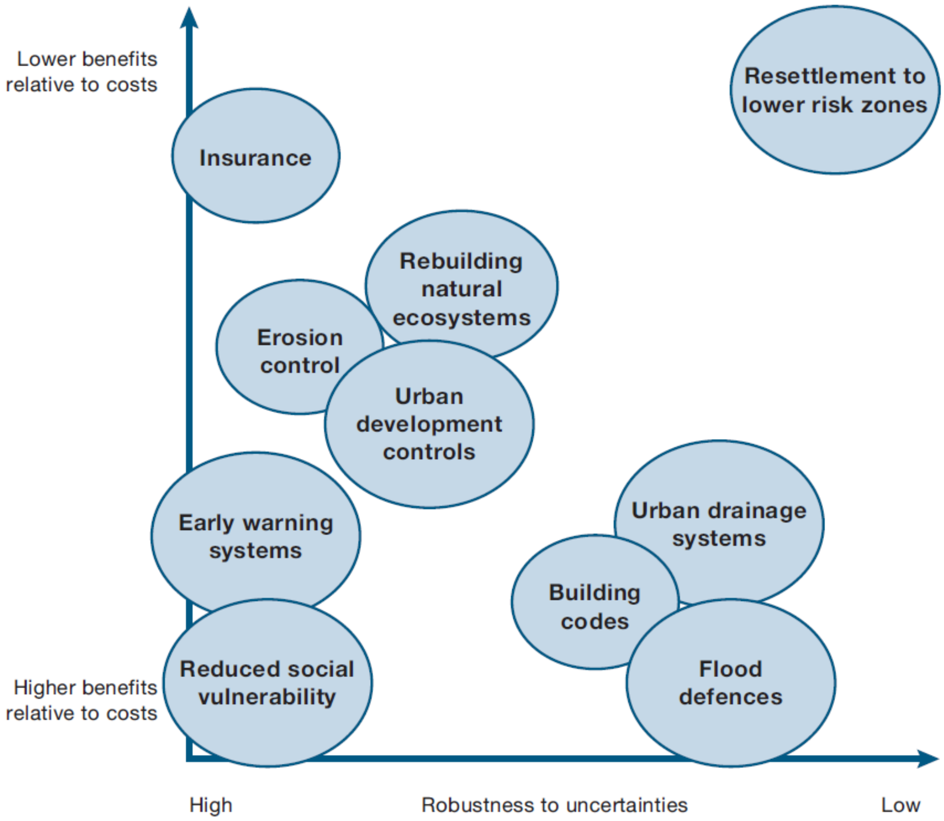


Figure 6.1 **Relative costs and benefits of flood management options (based on findings for Guyana, Mozambique and UK). Source: Adapted from Ranger and Garbett-Shields 2011, in Jha, A., Bloch, R., and Lamond, J. (2012).**

Table 6.1 Structural measures

Climate changes	Potential impact	Measure	Challenge/Response	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	**Develop a water and sewage masterplan in order to improve water management and quality in El Progreso**	Stakeholders acknowledged that El Progreso suffered from drainage problems and that efforts should be put in enhancing the city's water management system. Rain water doesn't always have an issue, as pumping areas do not exist throughout the city. Hard-engineering infrastructure for the improvement of water management and quality was advanced as a strategy: ■ Stakeholders agreed that the major initiative from which the city could benefit would be the development of a water and drainage masterplan for El Progreso. The water masterplan should be used as a planning tool: it could be used to support urban expansion by identifying suited areas for development given the availability and management of water flows. ■ A major concern that was also raised was the management of the Ulúa River: given its importance in the regional water structure, the control of River flows would be essential for managing future flood risk. In this, stakeholders mentioned that supporting the central government in the construction of two dams, the Llanito and Jicatuyos dams, would be essential. One of the major concerns raised in this was funding: stakeholders recognized that the city would need considerable financial resources to implement and assure the vialability of hard-engineering infrastructure.	■ Improvement of water management and quality in the city ■ Integrate the presence and management of water flows in urban expansion ■ Increased control of watersheds: environmental protection	Moderate	Low
		Development of housing policies specifically targeted to low-income populations	Stakeholders mentioned that a possible complimentary solution to guide urban expansion and avoid the location of low-income populations in high-risk areas would be the development of housing policies. These would be targeted specifically to marginalized groups, who suffer most commonly of housing shortages, and are often compelled to settle in high-risk areas given the affordable prices. The establishment of housing policies would not only improve the living conditions of low-income populations in El Progreso, but could also contribute to diminish exposure to climate change impacts: better quality housing stock would improve the overall resilience of the city, through more resistant construction materials, better provision of public services, and locating settlements in appropriate areas.	■ Address housing shortages of low-income groups: improved living conditions ■ Contribution to resilience: better quality housing stock, increased access to public services, location of settlements in appropriate areas	Moderate	High

Table 6.2 Non-structural measures

Climate changes	Potential impact	Measure	Challenge/Response	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	**Enhancement of zoning and land use planning to guide urban development away from high-risk areas and establish a pattern of sustainable urbanization**	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. El Progreso has been marked by a pattern of unplanned urban expansion. Due to the strong economic dynamism of the Sula Valley, the region attracted numerous newcomers, which gave rise to a conurbation process. Industrialization went hand in hand with urbanization. However, municipalities in the Sula Valley often lacked the accurate planning instruments to cope with the new flows of population. In El Progreso, this meant that settlements emerged in high risk areas, notably along the Pelo and Ulúa Rivers. Stakeholders agreed that efforts should be put in enhancing zoning and land use planning regulations. This would enable the establishment of a more sustainable pattern of urban development, ultimately resulting in improved urban resilience. During the workshop, four main points were raised in this: ■ Stakeholders acknowledged the need to **accurately identify high-risk neighbourhoods and areas, and design planning instruments accordingly**, in order to guide urban expansion away from them. ■ **The enhancement in the application of land use ordinances**: a better zoning and more regulated zoning system would guide urban development away from high-risk areas. ■ Stakeholders also recognized the necessity of **developing strong controls along river banks**, as they are the areas where risk is concentrated the most within the urban core. Efforts should be put in developing planning regulations and enforcement capabilities to guide expansion away from river banks. ■ The **Municipal Zoning Proposal**, forming part of the Municpal Development Plan (PDM-OT), should be prioritized, as it **integrates risk within planning and the spatial configurations it proposes for the Municipality**. The Municipal Zoning Proposal and the PDM-OT are the result of cooperation and support from the World Bank funded Land Management Programme PATH II.	■ Identify high-risk areas ■ Guide urban development away from high-risk areas: develop strong controls along river banks ■ Integration of risk in land use planning ■ Increased resilience and establishment of a pattern of sustainable urbanization	High	High

	Develop a Management Plan for the Mico Quemado Mountain in order to minimize the risk of hazards through watershed management and the enhancement of governance frameworks	Although the urban fringe does not expand in the Mico Quemado mountain and the Mico Quemado is designated as a protected natural reserve, **stakeholders seemed concerned by the potential risk the Mountain could represent**: if urban expansion is not controlled and settlements start to appear in hilly slopes, they could be strongly exposed to floods and landslides. During the workshops, it was strongly emphasized how **the city and the Mico Quemado are deeply interrelated**, and stated that the appropriate management of the Mountain would be essential for the long-term sustainability and resilience of the city. ■ Stakeholders mentioned **that a Management Plan for the Mico Quemado Mountain is needed**. The Plan should comprise an area diagnosis and measures to guide both urban expansion away from high-risk areas and the management of the various natural resources present in the Mountain. ■ **Resisting deforestation as well as the management of watersheds, were put forward**. Deforestation of surrounding hillsides is also a potential contributing factor for flood risk in El Progreso: flood risk and water supply in El Progreso are directly affected by water basin and slope management of the Mico Quemado mountain range, and its protection and restoration is crucial for managing water availability for the city. ■ **Governance poses a major challenge in developing a comprehensive management plan** for the Mico Quemado. The mountain's jurisdiction falls under 3 municipalities in 2 different departments: El Progreso, Santa Rita and El Negrito. This raises the issue of low levels of coordination between municipalities, and the problems that a fragmented institutional setup could represent for future risk reduction and water management in El Progreso. Overall, **disaster risk management and adaptation planning for the city needs to be aligned with land management practices and institutional arrangements governing water basin management in the surrounding region**.	■ Improve the interrelationship between the city and the Mico Quemado Mountain ■ Guide urban development away from high-risk areas in the Mountain ■ Improvement in watershed management ■ Contention of deforestation ■ Enhance governance structures in disaster risk reduction and climate change adaptation ■ Increased control of natural resources: environmental protection	High	High

	Launch educational campaigns aimed to raise awareness amongst the local population on climate change adaptation	Stakeholders agreed on **the need to raise awareness amongst the local population on climate change adaptation, and the potential hazards** it could have in terms of floods and landslides. They emphasized the idea of launching a massive educational campaign to transmit knowledge about risk areas and how the population should be prepared for a potential hazard. Two measures that could support the campaign were advanced: ■ **Establishment of educational focal points or groups throughout the Municipality:** this would help to support the creation of a mechanism of massive dissemination of knowledge concerning climate-related hazards. ■ **Establish an educational program at schools to familiarize students with climate change** and potential climate-related effects. This would enable to establish an educational norm and increase the school's educational capacity regarding climate change adaptation. The ultimate objective of these measures would be **the formation of an integral approach to climate change adaptation, in which public engagement and participation are constitutive elements**. Through awareness raising, climate change adaptation and the attached risks would be integrated in people's minds, which **would facilitate public participation and follow-up of measures** meant to address it.	■ Mainstream awareness on climate change adaptation ■ Capacity-building: enhancement of public engagement and participation in climate change adaptation activities ■ Contribute to the formation of an integral approach to address climate change adaptation ■ Institutional strengthening: engagement of a wider range of stakeholders in the DRM system and climate change adaptation activities	High	High

	Develop a water and sewage master plan in order to improve water management and quality in El Progreso	Stakeholders acknowledged that El Progreso suffered from drainage problems and that efforts should be put in enhancing the city's water management system. Rain water doesn't always have an issue, as pumping areas do not exist throughout the city. **Hard-engineering infrastructure for the improvement of water management and quality** was advanced as a strategy: ■ Stakeholders agreed that the major initiative from which the city could benefit would be **the development of a water and drainage master plan for El Progreso. The water master plan should be used as a planning tool:** it could be used to support urban expansion by identifying suited areas for development given the availability and management of water flows. ■ A major concern that was also raised was **the management of the Ulúa River**: given its importance in the regional water structure, the control of River flows would be essential for managing future flood risk. In this, stakeholders mentioned that supporting the central government in the construction of two dams, the Llanito and Jicatuyos dams, would be essential. One of the major concerns raised in this was funding: stakeholders recognized that the city would need considerable financial resources to implement and assure the viability of hard-engineering infrastructure.	■ Improvement of water management and quality in the city ■ Integrate the presence and management of water flows in urban expansion ■ Increased control of watersheds: environmental protection	Moderate	Moderate
	Creation and/or improvement of mechanisms for data collection, storage and dissemination for better climate monitoring, risk planning, and information sharing.	Stakeholders saw as a challenge the development of local skills and knowledge in climate change adaptation in the absence of relevant technical information: critical information and data to orient decisions at the sub-national and local level, as well as for the elaboration of climate change induced socio-economic scenarios, is still missing in El Progreso. Without this information, it is impossible to undertake local adaptation activities that rely on the downscaling of climate change models and climatic data. Various points were raised to address these shortcomings: ■ The establishment of a research and statistics unit: the presence of a permanent institution responsible for collecting data related to climate change impacts would strengthen knowledge on the matter and the development of related strategies. ■ Improve coordination between institutions with a mandate in climate change action: this would help share the transmission of knowledge and innovative ideas, as well as the development of best practices.	■ Development of local skills and knowledge in climate change adaptation ■ Access to appropriate data that would inform the decision-making process and the formulation of appropriate measures and policies ■ Institutional strengthening: better coordination between institutions to share knowledge and the development of best practices	Moderate	Moderate

	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 El Progreso 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 El Progreso. Strategies that would lead to a long-term reduction of risk could then be properly developed.	■ 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	High	High
	Creation of a legal framework aimed at regulating building control	Stakeholders acknowledged that the application of building controls remains weak in El Progreso: there is no regulatory legal framework for controlling construction and development. Further, there is also a lack of coordination between agencies for effective risk management, which results in a lack of planning control. For instance, private developers regularly create housing schemes in areas that do not have basic public infrastructure, creating problems for the municipality. The creation of a legal framework specifically aiming at regulating building control could thus prove beneficial. This would ensure the quality of new buildings, enhance the planning application system, and contribute to land use regulation, ensuring that new developments have access to basic public infrastructure and services. All these measures would ultimately contribute to building up El Progreso's adaptive capabilities.	■ Enhancement of planning control and regulations ■ Contribution to adaptive capacities: ensure the quality of new buildings and access to basic infrastructure	Moderate	High

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 in each neighborhood	
		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: from measures to action

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/s responsible for putting it in place and giving it life, the expected time-frame (short, medium, or long-term), as well as the relative costs. The purpose of this is to present planning initiatives that the city could consider and how these could be implemented.

Table 6.4 El Progreso 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	Identify high-risk neighbourhoods and areas	■ City-wide; focus on: ■ Neighborhoods prone to landslides: col. Las Golondrinas, col. Corocolito, col. Juventino Barahona, col. Rodolfo Cárcamo; neighbourhoods adjacent to the Mico Quemado Mountain. ■ Neighborhoods prone to flooding: neighborhoods adjacent to the Ulúa and Pelo rivers	■ CODEM ■ Urban Planning Department ■ Environment Department				Moderate
	Increase the application of land use ordinances						
	Develop strong controls along river banks						
	Prioritize the suggestions of the Municipal Zoning Proposal						
Develop a Management Plan for the Mico Quemado Mountain in order to minimize the risk of hazards through watershed management and the enhancement of governance frameworks	Develop a diagnosis of the area and attached measures to guide urban expansion away from high-risk areas and management of natural resources in the Mountain.	Neighbourhoods to the West of the city adjacent to the Mico Quemado Mountain.	■ CODEM ■ Urban Planning Department ■ Environment Department ■ Municipality of El Negrito ■ Municipality of Santa Rita ■ Civil society organizations: Fundación Mico Quemado (FUNDAMIQUE), CARITAS				Moderate
	Establish measures to stop deforestation						
	Work towards developing a governance framework for the management of the Mountain, as the mountain's jurisdiction falls under 3 municipalities : El Progreso, Santa Rita and El Negrito						

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)	
Launch educational campaigns aimed to raise awareness amongst the local population on climate change adaptation	Establishment of educational focal points or groups throughout the Municipality	■ City-wide	■ CODEM ■ CODELES ■ Department of Education				Low
	Establish an educational program at schools to familiarize students with climate change						
Develop a water and drainage master plan for El Progreso and the attached hard-work engineering projects	Develop a water and drainage master plan for El Progreso to be used as a planning tool	■ City-wide	■ Urban Planning Department ■ Environment Department ■ National Sewage System				Very high
	Increase efforts in the management of the Ulúa River: support the construction of two dams, the Llanito and Jicatuyos						
Increase El Progreso's housing stock	Development of housing policies specifically targeted to low-income populations: marginalized groups, who suffer most commonly of housing shortages, and are often compelled to settle in high-risk areas given the affordable prices.	■ City-wide	■ Urban planning Department				High
	Integrate housing policies with existing planning priorities and instruments						
Creation and/or improvement of mechanisms for data collection, storage	Establishment of a research and statistics unit responsible for collecting data related to climate change impacts	■ City-wide	■ CODEM ■ Urban Planning Department ■ Environment				Low

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)	
and dissemination for better climate monitoring, risk planning, and information sharing.	Improve coordination between institutions with a mandate in climate change action: transmission of knowledge; development of best practices		Department				
A shift from disaster management to long term risk reduction and climate change adaptation	Efforts into changing the local population's perception of climate change: frame climate change as a daily process with consequences occurring every day	■ City-wide	■ CODEM ■ Urban Planning Department ■ Environment Department				Moderate
	Shift from a reactive and response-led system to a proactive system						
Creation of a legal framework aimed at regulating building control	Work towards incorporating risk into building control policies	■ City-wide	■ CODEM ■ Urban Planning Department ■ Environment Department				Moderate
	Ensure cooperation between authorities responsible for the implementation of building controlpolicies						

6.5 Conclusions

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 El Progreso *Strategic Climate Adaptation Investment and Institutional Strengthening Plan* presents an overview of the strategies that the city can adopt to strengthen its capabilities in climate change adaptation planning.

As discussed in this report, a key challenge to climate change adaptation In El Progreso appears to be the relatively weak institutional capacity to undertake such action. Although disaster management capacity is of a reasonably good standard in the city, integration of climate adaptation into development activities requires creating new knowledge and skills, for example, to undertake comprehensive vulnerability assessments and to develop climate change scenarios, as well as to incorporate climatic variables into their relevant decision and planning processes.

To some degree, the development of local skills and knowledge is impeded by the absence of relevant technical information. Critical information and data to orient decisions at the sub-national and local level, as well as for the elaboration of climate change induced socio-economic scenarios, is still missing in El Progreso. Without this information, it is impossible to undertake local adaptation activities that rely on the downscaling of climate change models and climatic data. Lack of financial resources and legislative capacity of city level public institutions is also a challenge for local risk management and planning. This capacity deficit is exacerbated by a rapid rate of urbanization and population growth in El Progreso, placing stress on the system for urban risk management.

The Municipality, with support from the World Bank, has recently developed a Municipal Development Plan with focus on Territorial Planning. Aimed at directing sustainable and resilient urban growth away from high risk areas, the Plan also incorporates projects for risk and vulnerability reduction.

Framing adaptation in line with overall development priorities can prove to be crucial. If adaptation is mainstreamed within the existing institutional structures and developing objectives, notably including poverty alleviation, vulnerability to climate-related hazards can be significantly reduced.

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

- Adam, J. C. and Lettenmaier, D. P.: Adjustment of global gridded precipitation for systematic bias, J. Geophys. Res., 108, 1–14, 2003.
- ASP Consultores, 2012. El Progreso – Yoro: Diagnóstico Integral Multidimensional (Translation: El Progreso – Yoro: Multidimensional Diagnostic). 174 pp.
- Available at: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/enso_cycle.shtml
- Ayuntamiento de Oviedo, 2007. Abastecimiento de Agua Potable en la Aldea de Santa Ines, El Progreso-Yoro (Translation: Potable Water Implmentation in the Village of Saint Ines, El Progreso). 19 pp.
- Brabb, E.E., 1984. "Innovative approaches to landslide hazard and risk mapping". 4th Internationational Symposium on Landslides, Toronto. Vol.1: 307-323.
- Cardona, Omar Dario. "CAPRA: Mapas de Amenazas y De Riesgos, Aplicaciones en la Gestion del Riesgo: Informe Tecnico Subtarea 4.2c, Evaluacion del Riesgo de Desastre en el Progreso". World Bank. No publication date.
- Carrara, A., Cardinali, M., Guzzetti, F. and Reichenbach, P., 1995. "GIS technology in mapping landslide hazard". En: Carrara, A. y Guzzetti, F. (eds.). Geographical Information Systems in Assessing Natural Hazards. Kluwer Academic Publisher. The Netherlands. 135-175.
- Castellanos, E.A. and Van Westen, C.J., 2008. "Qualitative landslide susceptibility assessment bymulticriteria analysis: A case study from San Antonio del Sur, Guantánamo, Cuba". Geomorphology, 94: 453-466.
- CATIE, CINET, FUNDEMUN, 2004. Diagnóstico general de buenas prácticas en municipios seleccionados de Honduras. Informe técnico. 176 pp.
- DesInventar 2012. Database (version 2012.05.1065) (1970-2011).http://online.desinventar.org/ accessed on 29/06/2012
- Diagnóstico Ambiental El Progreso; Préstamo BID No. 1478/SF-HO
- Diagnóstico Integral Multidimensional (DIM), 2012. El Progreso – YORO. Development of Municipal Development Plans to Focus on Land Management (PDM-OT) with emphasis on the Territorial Land Base Catastradas, regularized and legalized, Gender, Risk Management, Early Recovery and Climate Change Adaptation. Municipios de La Lima y Pimienta, Departamento de Cortés, Municipio de El Progreso y Olanchito, Departamento de Yoro.
- El Mundo, 2005. La tormenta tropical 'Gamma' deja al menos nueve muertos en Honduras y amenaza con azotar Cuba. Available at: http://www.elmundo.es /elmundo/2 0 0 5 /1 1 /1 9 /s oc iedad/1 1 3 2 4 2 2 9 9 3 .html
- ERN América Latina, 2010. Central America Probabilistic Risk Assessment: Honduras. Informe Técnico subtarea 4.2c: Evaluación del riesgo de desastre en El Progreso. 50 pp.
- Fundación para el Desarrollo Municipal (FUNDEMUN), 2008. Estudio de Zonificación Urbana, Alcaldía Municipal de El Progreso.
- Girvetz EH, Zganjar C, Raber GT, Maurer EP, Kareiva P, et al. (2009) Applied Climate-Change Analysis: The Climate Wizard Tool. PLoS ONE 4(12): e8320. doi:10.1371/journal.pone.0008320
- Gui lyardi, E., W. Cai, M. Collins, A. Fedorov, F. Jin, A. Kumar, D. Sun, and A. Wittenberg. (2012) New Strategies for Evaluating ENSO Processes in Climate Models. Bulletin of American Meteorological Society

- Government of Spain, et al. n.d. Proyecto de Herramientas Estrategias de Planificacion Territorial para Fortalecer el Gobierno Municipal (Translation: Territorial Planning Strategies in order to Fortify the Municipal Government).
- Hawkins, E. and R. Sutton. 2009. The Potential to Narrow Uncertainty in Regional Climate Predictions. Bulletin of the American Meteorological Society. pp1095-1107.
- Hijmans et al. 2005. Very High Resolution Interpolated Climate Surfaces for Global Land Areas. International Journal of Climatology. 25: 1965–1978 (2005)
- http://archivo.laprensa.hn/Apertura/Ediciones/2010/06/01/Noticias/Miles-de-afectados-en-El-Progreso-por-Agatha
- IPCC. 2007. Summary for Policy Makers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds)]. Cambridge University Press, United Kingdom and New York, NY, USA. 996pp.
- Knutson, T., J. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J. Kossin, A. Srivastava, and M. Sugi. 2010. Tropical Cyclones and Climate Change. Nature Geoscience 3:157-163.
- Knutti, R., G. Abramowitz, M. Collins, V. Eyring, P. Gleckler, B. Hewitson, and L. Mearns. Good Practice Guidance Paper on Assessing and Combining Multi Model Climate Projections. IPCC Expert Meeting on Assessing and Combining Multi Model Climate Projections. Available at: https://www.ipcc-wg1.unibe.ch/guidancepaper/IPCC_EM_MME_GoodPracticeGuidancePaper.pdf
- Kresch, David L., Mark C. Mastin, and Theresa D. Olsen. 2001. Fifty-Year Flood-Inundation Maps for El Progreso, Honduras. U.S. Geological Survey Open-File Report 02-252.
- Knutson, T. J. (2010). Tropical Cyclones and Climate Change. Nature Geoscience, 157-163
- La Prensa (2010). Miles de afectados en El Progreso por Agatha.
- Lin, Jia-Lin, 2007: The Double-ITCZ Problem in IPCC AR4 Coupled GCMs: Ocean–Atmosphere Feedback Analysis. *J. Climate*, **20**, 4497–4525
- Maurer, E.P., J.C. Adam, and A.W. Wood: Climate Model based consensus on the hydrologic impacts of climate change to the Rio Lempa basin of Central America, Hydrology and Earth System Sciences 13, 183-194, 2009 (connect to online version).
- McSweeney, C. M. New, G. Lizcano et al.. 2010. The UNDP Climate Change Country Profiles: improving the accessibility of observed and projected climate information for studies of climate change in developing countries. Bulletin of the American Meteorological Society, 91, 157–166.
- Meehl, G. A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer, and K. E. Taylor: The WCRP CMIP3 multi-model dataset: A new era in climate change research, Bulletin of the American Meteorological Society, 88, 1383-1394, 2007.
- Mejía-Navarro, M., and García L.A., 1996. “Natural hazard and risk assessment using Decision Support Systems. Application, Glenwood Springs, Colorado”. Journal of Environmental and Engineering Geoscience, 2 (3): 299-324.
- MITIGAR-COPECO, 2012
- Municipalidad del El Progreso, 2012 Plan de Desarrollo Municipal con Enfoque de Ordenamiento Territorial (PDM-OT), El Progreso. Anexo 6. Informe Especial Gestión de Riesgo
- Municipio De El Progreso, Yoro Asociación de Municipios de Honduras, Comisión Permanente de Contingencias Secretaría de Recursos Naturales y Ambiente.

- NASA Earth Observatory, image of the Honduran city of El Progreso acquired May 30, 2009. Formosat-2 image provided by Dr. Cheng-Chien Liu, National Cheng-Kung University (NCKU) and Dr. An-Ming Wu of the National Space Organization (NSPO) of Taiwan. Image processing also provided by Emil Cherrington, Water Center for the Humid Tropics of Latin America & the Caribbean (CATHALAC). Caption by Holli Riebeek. Available at: http://earthobservatory.nasa.gov/IOTD/view.php?id=38851
- National Aeronautics and Space Administration (NASA). 2012. Goddard Earth Sciences Data and Information Services Center. U.S. government.
- National Oceanic and Atmospheric Administration (NOAA). 2012a. El Nino. U.S. government. http://www.education.noaa.gov/Weather_and_Atmosphere/El_Nino.html
- National Oceanic and Atmospheric Administration (NOAA). 2012b.The ENSO cycle U.S. government.
- National Strategy of Climate Change Honduras (ENCC). 2010. Government report.
- National Weather Service (NWS). 2012. Inter-Tropical Convergence Zone. http://www.srh.noaa.gov/jetstream/tropics/itcz.htm
- New York City Panel on Climate Change (NYCPPCC). 2009. Climate Risk Information.
- Perdigón, V. and Vásquez, J.F., 2007. Abastecimiento público de agua potable a la aldea Santa Inés. El Progreso, Yoro-Honduras. Informe Técnico. 81 pp.
- Plan de Mitigación de Desastres Naturales (PMDN), 2002.
- Plan de Prevención y Mitigación de Amenazas por Inundaciones y Terrenos Inestables, 2012.
- Research Program in Climate Change, Agriculture and Food Security. Available at: http://www.ccafs-climate.org/data/
- Santacana, N., 2001. Análisis de la susceptibilidad del terreno a la formación de deslizamientos superficiales y grandes deslizamientos mediante el uso de sistemas de información geográfica. Aplicación a la cuenca alta del río Llobregat. Tesis Doctoral. Universidad Politécnica de Cataluña. 399 pp.
- Soluri J., 2005. “Banana Cultures: Agriculture, Consumption, and Environmental Change in Honduras and the United States.”
- United Nations Framework Convetion on Climate Change – UNFCCC. Non-Annex I national communications. Available at : http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php
- United Nations Development Programme (UNDP), Bureau for Crisis Prevention and Recovery (BCPR). 2013. *Climate Risk Management for Smallholder Agriculture in Honduras.* New York, NY: UNDP BCPR
- Velasco, Virginia Perdigon. “Abastecimiento Publico de Agua Potable a la Aldea de Santa Ines. El Progreso, Yoro, Honduras 2006-2007”. Ayuntamiento de Oviedo. 2007
- World Bank, 2009. Honduras: Country notes on Climate Change Aspects in Agriculture.
- World Bank, 2011. “Urban Risk Assessment: An Approach for Understanding Disaster & Climate Risk in Cities.” Urban Development & Local Government Unit; Finance, Economics and Urban Department, The World Bank.
- World Bank. n.d. “Plan de Prevencion y Mitigacion de Amenazas por Inundaciones y Terrenos Inestables Municipio de El Progreso”. No publication Date.

ANNEXES

Annex 1 Methodology of climate-related hazard assessment

This analysis utilized existing resources used by the El Progreso municipal 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 describe the current hazard level and to consider how the 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 El Progreso 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/adaptation planning.
4. Assess available future precipitation and temperature data for mid-century.
5. Assess the application of three distinct approaches that consider how climate change may impact the tools investigated in Step 3.

Each step is discussed in greater detail below.

Step 1: Review the physical system. It is important first to understand the physical system specific to El Progreso 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 El Progreso government were reviewed.

To investigate local climate, two data sources were analysed:

- To consider how meteorological conditions vary month by month in the region, observed precipitation and temperature data from WorldClim (Hijmans et al., 2005) were collected. Worldclim data was generated through the interpolation of average monthly climate data from weather stations at a 1 km^2 resolution.[17]
- Literature review summarizing observed trends for Honduras.

The lack of meteorological data limits this analysis. Given observational data for El Progreso was not made available, 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) DesInventar database and other online material including local newspaper reports. This information was collected to explore answers to these specific questions: Do floods 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 El Progreso.

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

[17] For observation data, this dataset uses a number of major climate databases such as the Global Historical Climatology Network (GHCN), the FAO, the WMO, the International Center for Tropical Agriculture (CIAT), R-HYdronet, and a number of additional minor databases for Australia, New Zealand, the Nordic European Countries, Ecuador, Peru, Bolivia, among others. It also uses the SRTM elevation database. The ANUSPLIN program interpolates noisy multi-variate data using thin plate smoothing splines (using latitude, longitude, and elevation as independent variables). At a minimum, averages were calculated for 1960 to 1990 where at least 10 years of data where available. After removing stations with errors, WorldClim used precipitation records from 47,554 locations.

Step 3: Review flood and landslide resources. As this analysis is to inform planners, planning tools used by the local stakeholders to gage landslide and flood hazards were collected. Using these tools allows this analysis to be developed drawing from sources of information that local planners are intimately knowledgeable with. The resources collected for El Progreso include flood and landslide maps. 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? In addition, this analysis conducted an independent landslide susceptibility analysis to further quantify the hazard.

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 choose the optimum data sources and develop robust projections to inform this analysis (see Box 1 for term definitions and additional discussion of uncertainty in climate projections):

- **Time period:** This analysis required mid-century data centered around the 2040s.
- **Spatial scale:** The data sources of climate projections available include statistically downscaled global climate model projections of 15 global climate models used to inform the IPCC Fourth Assessment Report. The use of downscaled data was preferred given the location and terrain surrounding El Progreso.
- **Natural Variability:** To reduce this uncertainty, 30-year averages were used centered at the 2040s.
- **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.

Given the disagreement amongst climate models regarding the direction of future precipitation (i.e., will precipitation increase or decrease), additional tools were used to assess confidence in the climate model ensemble mean used in this analysis. The following ranking was applied (this example is based on a total of 15 climate models) to consider how many of the models agreed in the direction produced by the climate model ensemble average: “very high” if 13 or more climate models were in agreement, “high” if 11 or 12 climate models were in agreement, “medium” if between 6 and 10 climate models were in agreement, “low” if between 3 and 5 climate models were in agreement, and “very low” if less than 3 climate models were in agreement. This ranking was applied in our evaluation of precipitation projections in the 2040s where there can be strong directional disagreement across the models.

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 25th %ile (i.e., 25 % of the climate models suggest a value lower than this) and 75th %ile. If the 25th %ile and the 75th %ile are far from the climate model ensemble average, then there is a large spread across the projections.

Box 6 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 the ability of climate models to project precipitation. This difference in confidence should be qualitatively considered when incorporating vulnerability and risk 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 7).[18] 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 7 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 the following set of projection data:

- Monthly precipitation and temperature projections for the 2040s for each of the 15 climate models were collected from the climate wizard tool for the two scenarios considered (Givertz, 2009) (see Table A.1).[19]

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

Dataset / Report	Precipitation Projections	Downscaled?	Spatial Resolution	Emission Scenarios	Climate Models
Climate	Monthly	Yes	50 km	B1	Statistically downscaled

[18] 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. (IPCC, 2007).

[19] 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.

Dataset / Report	Precipitation Projections	Downscaled?	Spatial Resolution	Emission Scenarios	Climate Models
wizard[20] (Girvetz, 2009)	(2040s)			A1B A2	15 global climate models used to inform the IPCC Fourth Assessment Report

The projected changes in climate based upon this dataset 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.
- **Approach 2.** This approach uses information on regional storm events that have caused floods and/or landslides to develop precipitation event thresholds. For example, for a series of storm events that caused significant flooding in El Progreso, 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 El Progreso. 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 site-specific, 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 El Progreso 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 for El Progreso, we largely adopted Approach 3 to investigate how landslides and floods may change in the future. Future work should develop flood and landslide precipitation indicators based on today's relationships; the projections of these indicators would provide some insight regarding potential changes in floods and landslides. However, the lack of existing meteorological observations is an immediate challenge for El Progreso to conduct such an analysis.

[20] http://www.climatewizard.org

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

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. Though the landslide maps are not informed by precipitation, one of the flood maps that was developed by USGS is based on one dimensional hydrologic modelling and informed by annual precipitation. In an optimal case, the predicted precipitation patterns should be used to rerun the model. However, it was not possible to reproduce these maps associated with future climate (i.e., request USGS to drive the hydrologic model with climate projection data).
2. Identify precipitation thresholds. Consider how these precipitation thresholds may change	Use past events described in research/academic/government literature and local newspapers to identify the dates of past flood and/or landslide	■ Collection of past flood events ■ Collection of past landslide events	This approach assumes that the identified precipitation thresholds represent a consistently	Government and international reports along with local newspaper articles provide a survey of flood events in El Progreso. However, this information

Approaches to Investigate Future Changes in Floods and Landslides				
Approach	**Description**	**Requirements**	**Assumptions**	**Discussion/Limitations**
in the future.	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.	■ Local meteorological data ■ Daily downscaled precipitation projections	strong driver for lfloods 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.	does not provide the precipitation rates and environmental conditions that led to the flooding. Unfortunately, daily precipitation and environmental data collected by the National Weather Service was not made available for purposes of this study. 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 consider the impact on local flood hazard maps.	Identify sources of recent precipitation projections for El Progreso (i.e., projections developed ideally using modelling of IPCC AR4 or later) and the associated metrics (e.g., time periods, emission scenarios, climate models).	■ Precipitation projections	As this analysis is intended to separate the climate change component from the other influencing factors to consider how climate	Precipitation and temperature projections provide some indication of how landslides and floods may change in the future. As these data are not developed specifically focusing on tailored precipitation flood and landslide

Approaches to Investigate Future Changes in Floods and Landslides				
Approach	**Description**	**Requirements**	**Assumptions**	**Discussion/Limitations**
	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-%ile of precipitation; changes in the 100 year precipitation return period).		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.	drivers in El Progreso, the resulting assessment has a large degree of uncertainty related to the downscaling and homogenization of information and environmental variables.

Annex 2 Disasters that have impacted El Progreso

Table A2.1 provides a description of disasters that have impacted the municipality of El Progreso. The urban area events are those that have been explicitly reported to have impacted the city or its neighbours, or are events that have impacted the entire municipality (including the urban area). It is assumed that all events relating to crops have occurred only in rural areas and have not affected the city (unless the report suggests differently). Recently, the city of El Progreso has adopted a successful response plan to protect the population from fatalities during flood events. Because of this, this table may underrepresent total flood events that have recently occurred (i.e., flood events with minimal damage may not be reported).

Disasters (natural and not natural) reported in the municipality of El Progreso Data from 1968-2011. Source: DesInventar Database (Version 9.5.12-201).

Event	Municipality events	Urban area events
Flood	176	98
Epidemic	34	21
Windstorm	13	7
Rain	9	5
Plague	9	0
Structural collapse	8	3
Drought	6	3
Landslide	6	0
Earthquake	4	4
Contamination	2	2
Hurricane	2	2
Forest fire	1	0
Heat wave	1	1
Other	1	0
Storm	1	1
Total	272	147

Annex 3 El Progreso neighborhoods

Table A3.1 El Progreso neighborhoods

No.	Name	No.	Name	No.	Name
1	Lotificacion Aurora	35	Col. El Progreso	69	Col. Nueva Suyapa
2	Col. Quebrada Seca	36	Bo. San Jose	70	Bo. Suyapa
3	Col. Marvin Reyes	37	Col. Santa Elizabeth	71	Col. 5 de Diciembre
4	Col. 6 de Julio	38	Residencial Panchame	72	Col. Melgar
5	Col. Kennedy	38	Lotificacion El Bosque	73	Col. Sitraterco
6	Col. La Libertad	40	Col. Las Acacias	74	Bo. El Pino
7	Col. Berlin	41	Lotificacion Nelson Hall	75	Bo. Brisas Del Ulúa
8	Col. Juan Carias	42	Col. Panchame	77	Bo. San Miguel
9	Urbanizacion Cobitral	43	Bo. San Juan	78	Bo. La Sirena
10	Col. 7 de Abril	44	Residencial El Progreso	79	Bo. Montevideo
11	Tr. Barrio Las Golondrinas	45	Bo. Los Angeles	80	Bo. San Francisco
12	Col. 12 de Junio	46	Bo. El Barro	81	Bo. Las Mercedes
13	Col. 29 de Enero	47	Bo. Fatima	82	Col. Los Jasminez
14	Col. Corocolito	48	Bo. San Martin	83	Col. 18 de Septiembre
15	Col. Juventino Barahona	49	Bo. San Antonio	84	Residencial Pires
16	Col. Los Laureles O Nueva Jerusalen	50	Col. Fraternidad De La Paz	85	Bo. Penjamo
17	Col. 19 de Julio No. 2	51	Col. Palermo	86	Lotificacion Kattan
18	Residencial Alfonso Guillen Zelaya	52	Col. Centenario	87	Lotificacion Etupsa
19	Col. 19 de Julio No. 1	53	Lotificadora Las Palmas	88	Lotificacion Tubsa
20	Col. 1 de Marzo	54	Col. Monte Fresco	89	Col. Katan
21	Col. Roberto Suazo Cordova	55	Col. Alameda	90	Lotificacion Moya
22	Tr. Marvin Reyes Lotificacion	56	Col. Municipal	91	Col. Estandar
23	Col. Corocol	57	Col. Santa Fe #1,2,3	92	Col. 19 de Junio
24	Altos Del Progerso	58	Col. Paty	93	Residencial Hondupalma
25	Col. El Porvenir O Manuel Sevilla	59	Bo. Las Delicias	94	Lotificación Paredes
26	Col. Rodolfo Carcamo	60	Bo. Cabañas	95	Col. Española
27	Col. Esperanza De Jesus	61	Col. 27 de Octubre	96	Col. Los Castaños
28	Col. 2 de Marzo	62	Lotificadora Mendieta	97	Palermo Invasion

No.	Name	No.	Name	No.	Name
29	Col. Enmanuel	63	Col. Dionisio	98	Bo. Las Golondrinas
30	Col. San Jose No. 2	64	Col. Rodas Alvarado	99	Urbanizacion La Rioja
31	Bo. Buenos Aires	65	Col. Sinai	100	Lotificadora Perla
32	Col. Jersen	66	Col. Rancho Luna	101	Col. 2 de Julio
33	Col. Mangandi	67	Col. Bendeck	102	Col. Centroamericana
34	Col. Ramirez Reina	68	Col. 1º de Mayo	103	Col. Policarpo Paz García

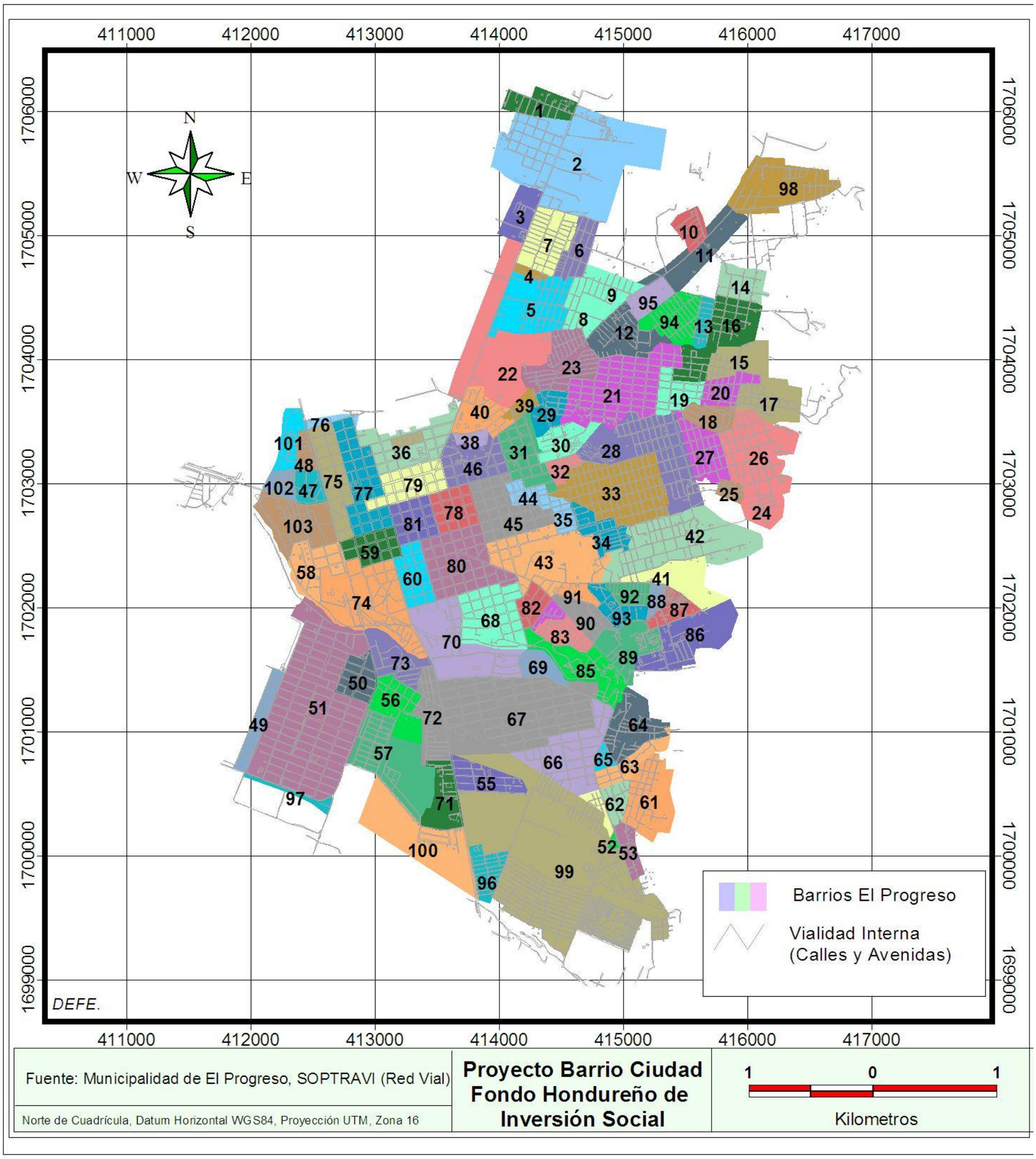


Figure A3.1 **El Progreso neighborhoods map. Source: Proyecto Barrio Ciudad, FHIS.**

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