



A guide for adaptation to Climate Change in La Ceiba, Honduras

OCTOBER 2016

EXECUTIVE SUMMARY

CityLinks is a program of the International City/County Management Association (ICMA) that helps build capacity of urban systems in developing and transitioning countries by drawing on the resources of U.S. local governments. With funding from USAID, CityLinks established a program of exchange among the cities of La Ceiba, Honduras and Somerville. In this partnership UCCRN served as the key science knowledge provider for CityLinks.

The city of La Ceiba is a complex scenario to face both, the challenges associated with a growing urban population and its geographic location that makes it highly vulnerable to the impacts of climate variability and change. The city is highly vulnerable and permanently faces risks that can lead to the loss of human lives, the damage of infrastructure and to lower the quality of life of the population.

There are many threats associated to climate change in La Ceiba: Temperature increase, storm surge and coastal flooding, sea level rise, coastal erosion, saline intrusion and reduction of annual rainfall and urban flooding.

Additionally, the city faces a series of environmental problems that are not climate-related but that increase the vulnerability of the city to prevent and respond to the impacts of such threats. The lack of land use planning, inadequate waste management, poverty and increase pressure on natural resources are growing concerns that need to be addressed by the city.

Alternatives for adaptation to climate change have been identified and discussed with the participation of stakeholders and city officials and include the construction of infrastructure to prevent further damage, particularly in the coastal area, the development and implementation of a land use plan for the city, the establishment of ordinances to regulate activities that exacerbate issues, and awareness-raising with the general public to understand climate change and environmental management. In addition, a local strategy for adaptation was proposed based on the National Strategy for Climate Change.



Teams from La Ceiba's and Somerville during a meeting as part of the the initial exchange trip in La Ceiba.

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INTRODUCTION

City Links TM is a program of the International City/County Management Association (ICMA) that allow city officials in developing and transitioning countries to draw on the resources of U.S. local governments to find sustainable solutions tailored to the real needs of their communities. The CityLinks framework was conceived by the ICMA, and has a three-fold goal of addressing interrelated development issues such as climate change among others. The ICMA, through CityLinks, developed climate adaptation partnerships for local governments in developing countries' looking to address the ways that climate change is impacting urban systems. The key source of technical assistance is provided by the resource cities themselves, which ICMA identifies through its extensive membership and networks. In order to provide additional targeted technical support to the CityLinks partnerships, ICMA draws on expertise from the Urban Climate Change Resource Network (UCCRN), which is a consortium of over 600 individuals dedicated to the analysis of climate change mitigation and adaptation from an urban perspective.

As part of this initiative, CityLinks partnered La Ceiba in Honduras, and Somerville, Massachusetts in the United States as the two cities that face similar challenges in flooding and storm water management. Somerville has overcome problems derived from inadequate decisions of city development in the past through political involvement, public participation and city planning. Although climate change poses new challenges for Somerville, lessons from the past guide development strategies that take into account the prevention and management of the impacts associated to extreme events. In La Ceiba, on the other hand, short term actions could prevent further impacts of flooding and extreme events, however there are many issues and priorities that need to be address for the city to be more resilient to climate change.

The purpose of the partnership was to develop a city-to-city exchange between the cities of La Ceiba, Honduras and Somerville, Massachusetts, during which both cities shared key challenges and approaches from a technical and operational point of view. Along with climate change challenges, the team had the opportunity to have a better understanding of the city's dynamics, the current initiatives to solve environmental issues and opportunities to address the topic in the near future. A series of activities were carried out during the partnership:

- Exchange trips between the municipalities of La Ceiba and Somerville.
- Development of climate change projections specific for the city of La Ceiba on temperature, rainfall and sea level rise.
- Training and awareness raising workshops to local authorities and general public on climate change.
- A workshop to identify vulnerability scenarios and alternatives for solution with local stakeholders.
- A visit to the Ministry of Environment to leverage support from the Central Government of Honduras to adaptation initiatives in the city of La Ceiba.

This report is intended to provide guidance for city planners, local authorities and other organizations working in La Ceiba on how to address adaptation to climate change. The document is structured in three main sections in order to guide decision-making: **Part I** explains what is already known about climate change and its related threats for the city based on a literature review of all studies on the subject and current projections by UCCRN, **Part II** describes in a general manner the underlying issues that exacerbate the problem and create vulnerability scenarios that must be addressed, **Part III** consists of a compilation of ideas from local stakeholders and Somerville experts on how the main threats could be addressed in la Ceiba, and **Part IV** reviews the Honduran Strategy for Climate Change highlighting/adapting the objectives that are more relatable to La Ceiba based on the analysis carried out during the exchange.

PART I: UNDERSTANDING LA CEIBA'S CLIMATE CHALLENGES

The city of La Ceiba, founded in 1835, is located in the Caribbean Coast of Honduras and is the third largest city in Honduras. La Ceiba is a geographically unique town in terms of its location since it is inserted in an alluvial floodplain area between a mountain range and the Caribbean Sea. It is divided into three main areas, corresponding to the areas encompassed by three major river that cross the town from South to North: Section 1 from Bonito to Danto River, Section 2 from Danto River to Cangrejal River and Section 3 from Cangrejal River to Juan Leandra Creek. Elevations in the municipality range from sea level to 2,435 meters above sea level at the Pico Bonito Mountain.

The main economic activity in the area is agricultural production. Historically and since the early 1900's, Standard Fruit Company has been an important source of employment and has also supported the development and planning of the city. Tourism is also a driver of economic activities, since La Ceiba serves as a hub for ecotourism to the Bay Islands and other surrounding National Parks.

La Ceiba has a tropical rainforest climate with rainfall episodes throughout the year. Average rainfall in La Ceiba is 4,300 mm which makes it one of the wettest cities in Central America. Average temperature is 25°C and average annual relative humidity is 74%. Due to its location and proximity to the Caribbean Sea, La Ceiba is frequently impacted by high intensity rainfall events. Higher and even more frequent intense rainfall events, will increase the risk of the neighborhoods in the lower areas of the city.

Urban flooding

Streams that cross La Ceiba are short due to their proximity to the *Nombre de Dios* mountain range and to the coast. Headwater streams are located in areas with great slopes and irregular topography and quickly flow into the valley causing flash floods. In addition, the capacity of the streams to contain peak flows is hindered by the erosion and deposition of sediment on the streambeds.

Rainy season in the La Ceiba occurs from May to November in most of the country due to the rise of the Inter-tropical Convergence Zone (ITCZ). In the northern coast of Honduras, once the rainy season and hurricane season are over, flooding continues to be a threat due to the occurrence of cold fronts from the North that leave heavy rainfalls on an already saturated soil profile, which results in flooding.

The city faces three major flooding risks:

- Flooding of the urban area due to the problems associated to storm water drainage and low slopes in the city,
- Occasional major flooding of the Cangrejal River that crosses the city, and
- Flooding from heavy rainfall events and storms associated with tropical cyclones of cold fronts¹.



Upper watershed area of Cangrejal river. Area of critical importance for La Ceiba's hydrological dynamics.

FACTS ON LA CEIBA

Total population: 204,140 inhabitants.

Average rainfall: 4,300 mm.

Density: 321 hab/Km²

Mean elevation: 3 masl

Main watersheds: Cangrejal, Juan Leandra and Río Bonito.

Major events: Hurricane Mitch, 1998.

¹ Smith, J.B., K. Strzepek, J. Cardini, M. Castañeda, C. Quiroz, T.M.L. Wighley, J. Herrero, P. Hearne, and J. Furlow-Sf. Coping with climate variability and Climate Change in La Ceiba, Honduras.

The Cangrejal Watershed has been the most studied catchment because of its flooding risk. However, local authorities point out that one of the major threats in the city’s poorest neighborhoods is Adan’s creek, a low order stream that crosses town and whose margins are heavily populated.

CLIMATE CHANGE PROJECTIONS FOR LA CEIBA

The most severe climate event to hit La Ceiba was Hurricane Mitch in 1998 which resulted in a rainfall event of four days that flooded two thirds of La Ceiba and destroyed major infrastructure for the city. According to local authorities a more recent tropical storm in November of 2014 resulted in a rainfall event of 260 mm in less than 24 hours which caused flooding in 80% of the city and this year, flooding occurred in large areas of the city due to a heavy rainfall season and a “La Niña” year. No lives were lost but damages to houses and property affected a great number of the population.

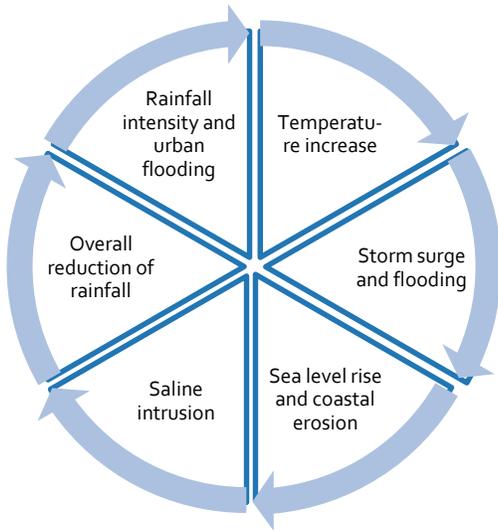


Figure 1. Expected alterations under climate change scenarios in La Ceiba.

Impacts of climate change are already observed in La Ceiba, although not clearly understood and disseminated by the general public. The increase in global temperature is linked to several alteration of atmosphere and oceanic dynamics and therefore, a list of potential impacts is expected for this area.

A few studies have looked into the projections of temperature, rainfall and sea level rise in La Ceiba. In addition, other studies have translated general projections into potential areas affected by flooding, sea level rise, peaks in streamflow, and urban areas under risk and groundwater quality alterations. A summary of the main observed/expected impacts of climate change will be described below (Figure 1).

Rainfall

Another threat posed by climate change in La Ceiba is the increase of rainfall intensity during hurricanes and tropical storms. Trenberth *et al.* (2003) cited by Smith *et al.*, (2011) concluded that the intensity of rainfall can increase 7% for every increase of degree Celsius in the atmosphere which could result in greater impacts during extreme events. It is also predicted that with an increase of 1.6°C of sea surface temperature, wind velocity would increase by 3.75% and rainfall by 11.25% during these kind of events.

While intensity of rainfall is expected to increase during extreme events, Argeñal (2010)² predicts the reduction of 5% of annual rainfall for the North coast of Honduras. This variation is more significant during the dry season of the Northern hemisphere when rainfall could be reduced by 10% and the temperature can increase in 0.9°C in this area. This reduction poses challenges in terms of water availability from surface sources and for the supply of potable water systems in La Ceiba that depend on surface streamflow in El Danto River.

Table 1. Precipitation and temperature projections for La Ceiba, Honduras over the coming century (UCCRN, 2016).

| | 2020s | 2050s | 2080s |
|----------------------|----------------------------|-----------------------------|------------------------------|
| Temperature | +0.7 (0.8 to 1.1) 1.3°C | +1.2 (1.5 to 2.4) 2.8 °C | +1.5 (1.9 to +3.6) 4.6 °C |
| Precipitation | -10% (-6% to +4%) +9 % | -18% (-16% to +3%) +6% | -31% (-18% to +2%) +14% |

Note: Low-estimate, middle range of projections (in parenthesis) and high-estimate based on the 33 GCMs and 2 RCPs are shown. Temperature projections rounded to the nearest tenth of degree Celsius, and precipitation projections rounded to the nearest percent. Projections are relative to the 1979-2000 base period, and represent 30-year timeslices.

² Argeñal F. 2010. Variabilidad Climática y Cambio Climático en Honduras.

Based on the application of 33 Global Circulation Models (GCMs) and two scenarios of greenhouse emissions (RCPs), UCCRN (2016) has projected changes in rainfall from a reduction of 18% to an increase of 2% considering the period of 1979 – 2000 as baseline (Table 1).

Temperature

The increase in temperature is the most direct effect of the increase of greenhouse gases. For La Ceiba, as well as for the rest of the country, the expected increase is approximately of 1°C for the next decade. Smith et al, (2005) estimated an increase in temperature of 0.5 °C for year 2025 and up to 1° - 2°C for the year 2050. Argeñal (2010), projected temperature changes based on both pessimistic and optimistic scenarios for GEI. For both scenarios, temperature is expected to increase at least 0.5°C in the Caribbean coast of Honduras for year 2020. These estimates do not take into account additional increases in temperature due to heat island effect for the city.

Flooding

Two main factors must be considered when predicting flooding in the rivers that cross the city and particularly in the Cangrejal River: i) Land use changes in the upper watershed area that reduce infiltration and increase the fraction of rainfall that becomes runoff, and ii) the changes in the intensity and amount of rainfall due to climate change. A study by Vega *et al.* (2015)³ evaluates four possible scenarios of flooding for La Ceiba and three return periods⁴: 20, 50 and 100 years. Under the scenarios with climate change and increased deforestation in the watershed, the floodplain for La Ceiba covers an area of 3.19 Km² for a return period of 100 years. This same projection predicts the water to rise up to 4 meters in some margins of the river. This would cause tremendous damages for the infrastructure and serious threat to human lives if proper warning systems and response mechanisms are not in place.

Previously, in 2002, Kresch *et al.*⁵ developed flooding maps for the city with return periods of 50 years. The study estimated a peak flow of 1030 m³/s for the river, stream velocities of up to 3.9 m/s and elevation of up to 2 meters above the stream levels in several parts of the city. With regards to urban flooding, Vega *et al.* 2015, developed participatory maps that show the areas of greater risk to flooding due to inefficient storm water drainage. The study also lists a series of other factors that aggravate this problem and that will be further discussed.

Salt water intrusion

Saline intrusion is the process that results in the connection of water from the aquifers of coastal areas with the sea, which results in irreversible salinization of the aquifer. The water table in La Ceiba is highly vulnerable to this phenomenon which hinders the availability of water for human consumption particularly when demand increases due to population growth and other economic activities and when there is a reduction of groundwater recharge due to shortages of rainfall or changes in land use. A combination of characteristics make this area particularly vulnerable to salt water intrusion (Figure 2) (Vega et al, 2015).



Flooding in La Ceiba's San Isidro market during the rainy season of 2016.

³ Vega, A., R. Jimenez, F. Miralles-Wilhelm, R. Muñoz. 2015. Adaptación al cambio climático y gestión integrada de recursos hídricos en La Ceiba, Honduras. Monografía del Banco Interamericano de Desarrollo (BID).

⁴ Return period is an estimate of the likelihood of an event based on historic records measured at that site.

⁵ Kresch, D.L., Mastin, M.C., y Olsen, T.D. 2001. Fifty-year flood-inundation maps for La Ceiba, Honduras. USGS. Open file report 02-254. U.S. Department of the Interior. U.S. Geological Survey.



Vega et al., 2015 applied the model CQUAL-W2 to identify the risk for the Cangrejales River to saline intrusion with a minimum streamflow of 4.8 m³/s under current conditions and under climate change scenarios that would increase the sea level to 60 cms above current levels in year 2050. The study confirms that saline intrusion could reach up to 3.2 km inland from sea shore and salinity could peak concentrations of 35 ppt. Tamayo and Fuentes (2013) also used models (Ghyben-Herzberg) to predict the impact of sea level rise on saline intrusion. They concluded that under climate change scenarios there would be a “serious socioeconomic crisis” in La Ceiba and therefore water resource management plans must be implemented in the area⁶. Even though this is an important issue for sustainable potable water supply in La Ceiba, the subject is not well known by the public and the authorities, and needs to be immediately considered when granting new permits for groundwater exploitation in the area.

Sea Level Rise and Coastal Erosion

Coastal erosion is already an issue of great concern in La Ceiba. Infrastructure and local economic activities are threatened by the loss of beaches and there is great uncertainty for the future and affected businesses demand rapid intervention from the local authorities. Increases in sea level are expected due to the increase in sea water temperature, melting of glaciers and changes in hydrological patterns from the land.

La Ceiba has had an increase in sea level of about 3.1 mm/year over the last years. Cardini and Richards (2005)⁷ predict an increase of 5 – 20 cms by year 2025 and up to 60 cms by year 2050. Smith *et al.* (2005) estimated that the increase in sea level could erode 20- 30 cms for year 2050 and that erosion could be worse in area near Danto River.

As part of this initiative, UCCRN⁸ used 24 global circulation models (GCM’s) and scenarios of Greenhouse gas emissions (GEI) to predict sea level rise in La Ceiba. The projections are developed using both local and regional components, based on global climate models and expert assessment of scientific literature. A total of four components are considered: changes in ocean height (local), thermal expansion (global), loss of ice from glaciers, ice caps, and land-based ice sheets, and land water storage (global) (Table 2.).



Parthenon Hotel. Properties in the coastline are rapidly losing beach front area.

Table 2. Sea level rise projections for La Ceiba, Honduras over the coming century in cms.

| 2020s | 2050s | 2080s |
|-----------------------|-------------------------|--------------------------|
| +5 (8 to 15) 18 cm | +15 (22 to 43) 59 cm | +21 (38 to 84) 121 cm |

Coastal flooding and storm surge

Both, sea level rise and the increase in storm intensity and strength result in more exposure of coastal areas to storm surge and flooding. Smith (2005) estimated that if an event of the magnitude of hurricane Fifi would occur, the waves would increase between 0.3 – 0.6 meters. These estimates do not consider the harmful potential of increases in wind speed during such an event, which would aggravate the scenario for the communities in the coastal urban areas of La Ceiba and particularly those with the highest growth. The areas that would be more at risk are the ones between Bonito and Danto rivers and the port area.

⁶ Tamayo, C. y H.R. Fuentes, 2013. Modeling Seawater Intrusion and Sea Level Rise effects on the Coastal Aquifer of Northern Honduras (Abstract). National and International Conference on Groundwater.

⁷ Cardini (Serman&Asociados) y Richard y Nicholls (University of Southampton).

⁸ UCCRN. Urban Climate Change Research Network from Columbia University (USA)

PART II: FACTORS THAT INFLUENCE VULNERABILITY IN LA CEIBA

La Ceiba faces a very complex scenario to address issues associated to climate variability and change. A combination of climatic and geo-morphological threats along with the particular socioeconomic dynamics of the city result in a scenario with both: high climatic threats and high intrinsic vulnerabilities. While climate change poses new threats to La Ceiba, the municipality and all stakeholders need to be aware of intrinsic characteristics of the context that make the city more vulnerable to climate variability and change. This understanding is essential to the development of an adaptation strategy.

A revision of these scenarios was carried out during this exchange and some examples are listed as follows:

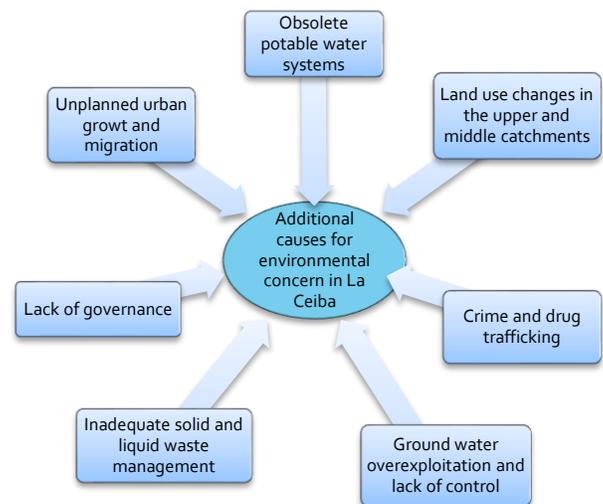
- **City planning:** The urban growth of the city in the last decades has mostly been unplanned, which has resulted in additional environmental and social problems as well as higher vulnerability to climate variability and change. Illegal settlements have been established in the most vulnerable areas of the city (i.e. near the stream or in steeper areas) and local government has not been able to enforce the law or offer alternatives for relocation. Twenty two communities in La Ceiba have been identified as high risk flooding areas. The CODEM estimates that no less than 63,700 people are at high risk of flooding in La Ceiba.

- **Land use changes:** Migration from the central and southern areas of the country and the expansion of agricultural crops pose pressure on the hillsides of the mountain range surrounding the city and on the headwaters of the major watersheds that are part of the municipality and that provide potable water for La Ceiba. These land use changes affect the hydrologic dynamics and water quality of the streams. The city has lost its natural defenses to reduce the areal extent of flooding. Some wetlands and natural channels have been filled-in by urban development and there are still no regulations to prevent further reduction of wetlands.

- **Waste management:** The inadequate disposal and management of solid waste in the city translates into a hydraulic concern. Disperse trash is washed down with rainfall and aggravates obstruction of drainage systems which increases the risk of flooding. Local authorities lack the personnel and resources to carry out preventive clean-outs and communities are not yet aware of the consequences of inadequate disposal of their garbage and its linkage to flooding.

- **Climate-related health threats.** The lack of land use planning, zoning and law enforcement also results in the increase of other environmental and health issues such as scarce potable water and sanitation alternatives for the communities. There have been reports that demonstrate a higher incidence of vector or insect-borne diseases associated to poor drainage and storage of water (i.e. Dengue fever and Chikungunya).

- **Infrastructure:** Despite the high availability of water from rainfall in the area and the existence of several streams and springs, the lack of infrastructure for water storage results in rationing of potable water and dependence on the exploitation of the underlying aquifer. There is high exploitation of the shallow aquifer by local communities and particularly by the local industry. In terms of wastewater treatment, only 46% of the population of La Ceiba is connected to the sewerage system⁹. The remaining population has septic systems and the majority is discharging waste-water into channels, streams or estuaries posing a threat to the health of the community. The Municipal entity for managing waste water, OMASAN, faces



⁹ Personal communication with Morán G. General Manager OMASAN, 2016.

many challenges due to the lack of personnel, equipment and financial resources to repair or provide maintenance to the sewer system. There are additional challenges with new urbanizations that build waste water treatment plants. Once the urbanizations are sold the new owners, they are not able to manage the waste water treatment plants and demand that OMASAN takes charge and solves their issues. Collapse of sewerage systems is frequent even with low rainfall events because of the illegal connections of pluvial waters into the system. This also increases sedimentation of the water treatment plants, damages pumping systems and increases the costs of water treatment. There is little control on the connections and no awareness among the population on the implications of the mixed connections.

- **Security:** In recent years La Ceiba has had a spike in criminal activities and high homicide rates. Its location is also a scenario for drug trafficking from South America to the North and there is an increasing number of gang members involved in illegal activities in the Northern coast of Honduras. This scenario make it even more difficult for local authorities to deal with environmental issues due to the lack of governance and the high risks associated to law enforcement for the protection of natural resources. On the other hand, the perception of “risk” by the population in La Ceiba is far more linked to insecurity due to crime than to any other threat, which makes environmental issues or climate threats not be identified as a priority.

PART III: FINDING SOLUTIONS THROUGH A PARTICIPATORY APPROACH

The population in La Ceiba is very aware of the impacts of extreme events and how that affects every day life and local development. Community leaders are also conscious of the threats that are associated to governance, lack of education and behavioral patterns in the population that exert pressure to their natural resources and hinder the preparation or prevention to disasters, city planning and proper environmental management. As part of the exchange, a workshop was conducted with different community leaders and representatives of local organizations (both, NGO's and Government). The objective of the event was to identify the major areas of vulnerability associated to climate change in La Ceiba and summarize alternatives for adaptation from the point of view of such stakeholders. In addition, the Somerville team revised the alternatives and proposed adaptation policies and strategies that could support an adaptation initiative in La Ceiba. Three major threats were analyzed:

- Urban Flooding
- Coastal Erosion and sea level rise
- Flooding from Cangrejal River



Discussions during workshop on finding alternatives for adaptation in La Ceiba with stakeholders. July 27th, 2016.

The results of the workshop are presented in the tables below and reflect the ideas of everyone who participated. Each table was developed around three vulnerable areas identified as priorities by La Ceiba's municipal technical staff: Urban Flooding, Coastal Erosion and Sea Level Rise, and Flooding of the Cangrejal River. Vulnerabilities within each area are separated by sectors of the population or economic activities that are impacted. Columns follow with a list of adaptation alternatives, potential adaptation policies, and potential programs and design strategies

URBAN FLOODING

Table 4. Proposed adaptation alternatives to reduce the vulnerability to urban flooding in La Ceiba.

| VULNERABILITY | ADAPTATION ALTERNATIVES | POTENTIAL ADAPTATION POLICIES | POTENTIAL PROGRAMS AND DESIGN STRATEGIES |
|---|--|--|---|
| RESIDENTIAL SECTOR | | | |
| Minimal education on the issue of management of solid waste results in litter and dumping that exacerbates drainage concerns. | Implementation of an effective educational institutional system in all neighborhoods. | Create anti-littering ordinance and enforcement schedule. | Public education campaign against littering, signage, education. Designation of a clean-up demonstration zone. |
| Absence and/or failure of stormwater system in many residential districts. | Establishing a program for permanent cleaning and maintenance / periodic preventive stormwater system. | Require permitted development to pay impact fees that can cover district-wide/neighborhood-wide flooding protection (including informal settlement areas). | District-level and citywide storm water plan, modelling, and greater accountability for developers. |
| Absence of regulation for storm water systems in residential areas | Creation and implementation of ordinances on the subject of rainwater systems | Require that stormwater systems exist before residential development is permitted. | Develop design standards that make the storm water systems uniform and connectable to municipal system Storm water connection requirements. |
| SANITATION | | | |
| Absence of integrated solid waste management system | Official closure of current landfill site and procurement of a new landfill site. | Require waste management plan before development is permitted. | Offer waste collection service incentive (reduced price, more convenient collection) for reduced waste generation. Use cost savings to increase litter reduction efforts. |
| | Promotion of recycling companies | Over the long-term, evaluate whether recycling is possible as a market-based | Release competitive solicitation for overall waste management service that includes litter, trash, and recycling |

| VULNERABILITY | ADAPTATION ALTERNATIVES | POTENTIAL ADAPTATION POLICIES | POTENTIAL PROGRAMS AND DESIGN STRATEGIES |
|---|--|---|---|
| | | service or a traditional municipal service. | |
| SOCIO-ECONOMIC ASPECTS | | | |
| Temporary suspension of economic activities, including tourism and education, during flooding events. | Preventive measures to reduce flooding | All businesses must have a stormwater plan and are given incentives for reduction of water into the storm system. City planning must consider potential increase in rainfall intensity and update a Land use Plan. | Early warning systems, education to businesses, promote no-regret protection solutions. Rainwater retention. (Capture and reuse may not be cost effective in La Ceiba.) Promote rain barrels, rain gardens and water reuse practices Offer technical assistance on business continuity |
| INFRASTRUCTURE | | | |
| Absence of rainwater infiltration that increases the risk of flooding | Regulation of percentage use of urban land | Required percentage of permeability for all projects | Through land use planning and soil/watershed analysis, determine pervious surface requirements for city districts. |
| | Construction of alternative urban drainage (gardens and ponds) | | Pilot infiltration and green infrastructure designs |

COASTAL EROSION AND SEA LEVEL RISE

Table 5. Proposed adaptation alternatives to reduce the vulnerability to coastal erosion and sea level rise in La Ceiba.

| VULNERABILITY | ADAPTATION ALTERNATIVES | POTENTIAL ADAPTATION POLICIES | POTENTIAL PROGRAMS AND DESIGN STRATEGIES |
|---|---|--|---|
| COASTAL INFRASTRUCTURE | | | |
| Disorganized construction and development in high-risk areas. | Application of existing land use plan with climate change adaptation adjustments Construction of hard infrastructure (breakwaters) and restore ecological natural barriers such as mangroves. Establish environmental committees to support adaptation processes. | Develop land use plan that incorporates new flood risk zones, no-development zones, new elevation standards. Buy-back and relocation programs. Ecological solutions prioritized over hard infrastructure Permitting/permissions are approved by independent parties and puts coastal protection at the forefront of planning. | Educate politicians and residents on the importance of enforcing a land-use plan. Identify highest-risk areas and institute a phased buy-back program To increase the use of ecological restoration as cost-effective solution to hard coastal protection, all new proposed projects must be screened for suitable ecological alternatives. If alternatives are found, they must be implemented first. Create committees of citizens that are not developers or politicians to vote on projects with the goal of protecting the coast. Example: Somerville Conservation. |
| Absence of information on degree of erosion, causing lack of response | Create a monitoring system (generation of indicators) | | Study effects of development (e.g., jetties) on erosion. |
| NATURAL RESOURCES | | | |
| Dependence on the coastal marine resource as driver for economy and development of the city | Governance education programs, climate change and heritage Establish an independent committee that approve any projects in coastal areas to reduce political influence on infrastructure permits. Promote sustainable tourism | Educate people on the importance of the coast and allow them to see that the issues affecting the coastal resources are important to everyone. Permitting/permissions are approved by independent parties and puts coastal protection at the forefront of planning. Leverage marine sector for environmental protection investments | Partner with universities and NGO's to create a public education campaign to let people know how important the coastal areas are. In the schools, and general public campaign. Create committees of citizens that are not developers or politicians to vote on projects with the goal of protecting the coast. Create committee or group among marine industry businesses to focus on one particular environmental issue, for example fisheries conservation or clean beaches. Eventually expand scope of group to advocate for national level investment. |

| | | | |
|--|---|--|---|
| Saline intrusion in wells used for public supply | To identify critical areas/wells for saline intrusion and restrict groundwater exploitation | Adoption and implementation of regulations for groundwater extraction. Compliance with current legislation regarding the use and access to water. | Update well permitting assumptions to include drought and sea level rise projections. |
|--|---|--|---|

CANGREJAL RIVER FLOODING

Table 6. Proposed adaptation alternatives to reduce the vulnerability to flooding in Cangrejal River in La Ceiba.

| VULNERABILITY | ADAPTATION ALTERNATIVES | POTENTIAL ADAPTATION POLICIES | POTENTIAL PROGRAMS AND DESIGN STRATEGIES |
|--|---|---|--|
| INDUSTRIAL (RURAL) | | | |
| Gravel and stone material mining that affects the streambed and hydrologic dynamic of the River. | Regulations that limit extraction | Recognize that Cangrejal River is at the center of La Ceiba's adaptation strategies. Increase City control on resource extraction. | Sign a memorandum of understanding with national government on shared understanding of natural resource conservation in riparian zone. In lieu of greater permitting authority, City should link climate change funding from national government to river conservation. |
| INDUSTRIAL (URBANO) | | | |
| Filled land in wetlands that reduces infiltration and water storage | Implement of regulatory standards | Land use plan that identifies no-growth and conservation areas. | Prohibit land filling in current flood zones and projected long-term flood risk areas. |
| Construction of infrastructure in natural channels | Cleaning and Maintenance Engagement: reaching out to current organizations (civil society) in the area | Ordinances to preserve natural drainage system Highlight urban riparian corridor as both a resource and a risk. | Map and identify natural drainage system. Education campaign on benefits of reduced encroachment on river banks. |
| Collapsed drainage systems | Political action | Identify no-regret improvements, e.g., infrastructure along evacuation route corridors | Prioritization of repairs, factoring in CC adaptation potential |
| AGRICULTURAL | | | |
| Loss of crops | Implementation of Plans for watershed management in the upper Cangrejal basin. Training of farmers on adaptation practices | Promotion of climate resilient agriculture | Planting crops that are climate resilient or adapted to changing climate (examples?) |
| Deforestation | Reforestation and prevention of further forest loss | Reforestation as flood mitigation | Link reforestation projects to national government funding opportunities. |
| TOURISM | | | |
| Interruption of roadways between city and rural tourism destinations | Maintenance of roads highways | Prioritize corridors for safety and economic growth | Identify key transportation links and identify back-up routes, create priorities for response |
| Loss of landscape | Land Use Plan | Development plans that simultaneously conserve. | Land use plan that identifies protection areas |
| Reduction of water availability in recreational areas | Training/Water harvesting | Promote water reuse and conservation | Education campaign to raise awareness that water availability will shift with climate change. |
| Encroachment | Land Use Plan | Development plans that simultaneously conserve. | Land use plan that identifies protection areas |
| Drought | Reforestation and ecological restoration | Climate tolerant planting | Engage tourism industry to consider changing climate in landscaping as well as ecotourism |

PART III: DOWNSCALLING THE NATIONAL STRATEGY FOR CLIMATE CHANGE ADAPTATION TO LA CEIBA

The Honduran Government has developed a National Strategy for Climate Change. This strategy provides a framework of objectives to promote both, adaptation and mitigation to climate change in the country and lists a series of specific objectives to respond to the issues in seven main areas: i) Water resources, ii) Agriculture, soil and food security, iii) Forests and biodiversity, iv) Coastal-marine resources, v) Human Health, vi) Disaster risk reduction and vii) Hydroelectric power. Based on the National Climate Change Strategy, three of those areas or topics are described and adapted to La Ceiba's scenario. The proposed selection is based on the linkage between the climate change projections and the issues prioritized during the workshop with stakeholders and discussed during the partnership. In the following table there is a description of the main objectives of the National Strategy applied to La Ceiba.

Table 7. Main Adaptation Objectives for the city of La Ceiba based on the National Climate Change Strategy.

| OBJECTIVE | SPECIFIC OBJECTIVES |
|--|--|
| WATER RESOURCES | |
| To prevent the impairment of water bodies and to guarantee its water quantity and quality. | <ul style="list-style-type: none"> - To promote best management practices in agriculture in the upper watershed areas to reduce pollutant loads and maintain water availability in streams. - To prevent further saline intrusion of the aquifer by regulating overexploitation of groundwater. |
| To reduce the impacts of frequent and intense droughts due to the reduction of rainfall and to promote the recharge of aquifers | <ul style="list-style-type: none"> - To promote sustainable land use at a watershed level, and proper land use planning in order to promote hydrologic regulation of fluvial systems under climate change scenarios. |
| SEA-COSTAL SYSTEMS | |
| To preserve the structure and dynamics of sea-coastal ecosystems, considering the effects of climate change, particularly sea level rise and changes in the sea level and temperature. | <ul style="list-style-type: none"> - To establish mechanisms to prevent and control coastal erosion and protect existing infrastructure based on analyses of coastal dynamics under climate change scenarios. - To support national initiatives to preserve wetlands in coastal areas. - To strengthen the sustainability of the communities that depend on sea-coastal ecosystems. |
| DISASTER PREVENTION AND RISK MANAGEMENT | |
| To reduce the risks and impacts associated to hydrological/weather events, whose frequency, duration and intensity are increasing due to climate change. | <ul style="list-style-type: none"> - To restore fluvial ecosystems, by improving streamflow control and flooding in order to prevent damages and losses due to extreme rainfall events. - To regulate urban settlements and promote land use planning in the city and vicinities. |
| To promote the design, development and construction of proper infrastructure in order to adapt to current and projected impacts of climate change. | <ul style="list-style-type: none"> - To promote the establishment of regulations for the design and construction of infrastructure that are better adapted to the threats posed by climate change in La Ceiba. |

FINAL RECOMMENDATIONS

- Even though many challenges have been identified in La Ceiba, there are great opportunities to implement actions that will lead to more resilient scenarios. There is a particular interest in the current local Government to address these issues, which is a window of opportunity to develop planning exercises and enforce regulations.
- As part of the exchange, a series of workshops were carried out to raise awareness about climate change and vulnerability in La Ceiba. It is important to continue efforts to better communicate climate change in a way that is relevant to all local stakeholders and it supports decision-making.
- The city of La Ceiba has been proclaimed the “Eco-tourism capital of Honduras” and the local economy is highly dependent on tourism. This sectors appears to be the most belligerent in finding alternatives for sustainable tourism because of its dependence on providing adequate destinations for visitors. Although not all the entrepreneurs of this sector fully understand the causes and consequences of climate change, they are organized and have the technical support and financing to increase their understanding of the topic. The results of this initiative should be disseminated to the general public and its efforts for fundraising for environmental initiatives could be scaled into schemes where the private sectors and the communities create alliances to increase resilience.
- As presented in this document, a series of studies have already been carried out in La Ceiba to address climate threats. A discussion of such documents with local authorities is a good starting point for better understanding of environmental issues and climate change.
- As perceived by the community and described above, many of the environmental issues in La Ceiba are rooted in the lack of land use planning and law enforcement (i.e. land use changes in the upper watershed, urban settlements in high risk areas in the city, constructions in affected coastal areas etc.). A priority for addressing and preventing further damages from climate change in La Ceiba must consider the development and implementation of a Land Use Plan that considers both, the ongoing environmental issues and future projections of climate change for La Ceiba. Once approved and in place, making those documents available to the general public will also make more efficient the use of the information and avoid the duplication of efforts by new donors.
- The legal framework for disaster risk mitigation, adaptation to climate change and integrated water resource management exists at a national level, along with national strategies for implementation approved by the Government. The revision and dissemination of such framework in La Ceiba for different target audiences has also the potential of resulting in awareness-raising by the public and support decision-making within the municipality.
- Climate and sea level data collection and management for La Ceiba has also great potential for improvement. Although external cooperation has made substantial investments in establishing a Regional Center for Environmental Data Collection and Interpretation (CREDIA), there are still scientific inputs needed to support the understanding of climate change in La Ceiba. The strengthening of local universities in this area would help provide data for decision-making in La Ceiba and would also improve technical capacities within the municipality.
- The city has recent experiences that prove that the strengthening of local Emergency Committees (CODELs) in the most vulnerable neighborhoods has resulted in rapid response during recent flooding events, and the prevention of major damages. This is a valuable experience to plan for future rainfall scenarios and evidence that the strengthening of local communities through training increases resilience. The municipality should continue working with these communities and expand to other vulnerable areas. These committees would also benefit from having a better understanding of climate change and what to expect in the future.