February 2016
Las Terrenas, Dominican Republic

The production of this assessment has been possible thanks to the generous contribution of the people of the United States through the United States Agency for International Development (USAID). The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government.
FRONT COVER
Beach erosion in Playa Nina, Las Terrenas. Photo credit: Alejandro Herrera (ICMA)

ABOVE THESE LINES:
Flooding in Las Terrenas in November 2012. Photo credit: Las Terrenas Live courtesy of Sylvain Maufrais.
Las Terrenas without flooding in November 2015. Photo credit: Andrea Vogel (ICMA)

RESEARCH, WRITING AND SUPPORT TEAM

ICF
Michael Savonis, Molly Hellmuth, Joanne Potter, Angela Wong, Tara Hamilton

ICMA
Alejandro Herrera Moreno, Andrea Vogel, Andrés Cepeda, Erick Dorrejo, Indhira De Jesús

FEDOMU
Dionys de la Cruz, Angel Mercedes, Beatriz Alcántara, Yamilks Flores, Elaine Germán

Las Terrenas Technical Team
Mariana Vanderhorst, Roberto Reyes, Argenys Hernández, Patricia Fermin, Ramón Rafael Frías

February 2016

The production of this assessment has been possible thanks to the generous contribution of the people of the United States through the United States Agency for International Development (USAID). The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government.
CONTENTS

EXECUTIVE SUMMARY

Executive summary .................................................................................................................................................. iii
1 Introduction ........................................................................................................................................................... 3
2 Municipal Context ..................................................................................................................................................... 4
   2.1 Population ....................................................................................................................................................... 6
   2.1 Geography and Natural Resources .................................................................................................................. 6
   2.2 Economy ........................................................................................................................................................... 7
3 Strategic Municipal Priorities and Challenges ....................................................................................................... 8
   3.1 Participatory Governance ................................................................................................................................. 9
   3.2 Appropriate Land Use with Harmony Between the Natural and Built Environment ......................................... 9
   3.3 Quality Municipal Services .............................................................................................................................. 10
       3.3.1 Water services ........................................................................................................................................... 10
       3.3.2 Sewage and storm water drainage .............................................................................................................. 10
       3.3.3 Transportation .......................................................................................................................................... 11
       3.3.4 Solid waste management ........................................................................................................................... 12
       3.3.5 Electricity .................................................................................................................................................. 12
       3.3.6 Human health and safety ........................................................................................................................... 12
   3.4 Sustainable Tourism and Natural Resources .................................................................................................. 13
   3.5 Well-educated and Skilled Citizenry ............................................................................................................... 15
4 Climate-related Vulnerabilities .............................................................................................................................. 16
   4.1 Exposure to Climate Hazards .......................................................................................................................... 18
       4.1.1 Temperature .............................................................................................................................................. 19
       4.1.2 Rainfall ..................................................................................................................................................... 20
       4.1.3 Drought .................................................................................................................................................... 21
       4.1.4 Hurricane frequency and Intensity ............................................................................................................ 23
       4.1.5 Extreme rainfall, riverine flooding, and landslides ..................................................................................... 24
       4.1.6 Sea level rise, storm surge, coastal erosion .............................................................................................. 26
   4.2 Sensitivities and Potential Climate Impacts to Municipal Services and Objectives ........................................ 29
       4.2.1 Participatory governance .......................................................................................................................... 30
EXECUTIVE SUMMARY

The municipality of Las Terrenas is located on the north coast of the Dominican Republic. Part of the Samaná peninsula; Las Terrenas is one of the major tourism spots in the country. With an economy based fundamentally on tourism, with some contribution from fishing and agriculture, the municipality’s strategic development plan prioritizes objectives in local governance, social development, environment, natural resources, sustainable use of the territory and the guarantee of quality basic services. At the same time, Las Terrenas is very vulnerable to current and future climate variability and change, particularly the intense rainfall and flooding in its urban center, and the rise in sea level and storm surge in its coastal area, resulting in a significant impact on natural resources, infrastructure and population, essential for development. The International Association of Cities and Municipalities (ICMA), ICF International, the Dominican Federation of Municipalities (FEDOMU) and the City of Las Terrenas, sponsored by the United States Agency for International Development (USAID), implement the Planning for Climate Adaptation Program. The objective of this program is to increase resilience of Dominican communities by improving land-use planning processes.

Within this objective, the Climate Vulnerability Assessment is an essential step to identify the present and future vulnerabilities that threaten municipal development in the face of climate change, in order to extract adaptation measures that can be used for decision making in land-use planning. Under a development approach, this evaluation is developed in coordination with the Technical Team and the Working Groups of the City Council and the contribution of the communities, in a participatory process designed to develop capacities at all levels. The components of vulnerability (exposure, sensitivity, and adaptive capacity) are described separately, in order to clarify the underlying causes of vulnerability.

In terms of its current and future climate situation, the average annual temperature in Samaná is 26.2 °C and has increased since 1960 at a rate of ~ 0.1 °C per decade. Topography goes from 0 to more than 500 meters above sea level from the coast to the Sierra de Samaná. This changes in altitude determine a thermal gradient with coastal values between 24 and 26 °C to between 22 and 24 °C 125 meters above sea level. By 2050 it is projected that the average annual temperature will rise by 1.56 °C. The municipality has some of the highest average rainfall in the country, with an average annual contribution of about 1,924 mm. At higher altitudes, rainfall levels are even higher, varying between 2000 and 2500 mm. The projection for average annual precipitation indicates reductions rates from -1.2% to -2.3% (by2030) to -13.7% to -17.9% (by 2050).

There are no registered droughts in the disaster inventory for Samaná. The Standardized Precipitation Index indicates the occurrence of drier periods in 2000-2001 and 2010 and although it is expected that the aridity and the annual deficit in the humidity of the climate will increase in mid-century due to the increase in temperature, evapotranspiration potential and the decrease in rainfall, the values of the projected aridity index indicate that Las Terrenas will still be considered wet in the future. From 1851 to 2014, 22 cyclones or hurricanes crossed within a 50 km radius of Las Terrenas, with two touching land in the municipality, most recently Hurricane Jeanne in 2004. Global warming is projected to make hurricanes more intense and with higher precipitation rates which will increase flooding. Projections of sea level rise between 0.20 to 0.58 m by 2050, with higher storm surges will increase coastal flooding and beach erosion.

The present assessment reveals that the territory is vulnerable to several climatic threats and stressors: temperature increase, changes in rainfall pattern, drought, greater intensity of extreme events with intense rainfall and floods, rise in sea level with higher storm surges and coastal flooding and beach erosion. Intense rains are particularly relevant, because in such conditions the population and urban infrastructure is vulnerable to fluvial and pluvial floods, which are caused by the floods of the Las Terrenas and Caño Seco rivers; or by the accumulation of water in low-lying areas naturally prone to flooding (areas of flooding) or
where -product of uncontrolled urbanization- the topography and drainage have been altered, causing conditions of stagnation.

The vulnerable areas in the city include practically all its neighborhoods with an important incidence in the downtown area, where the most important commercial area is located. Vulnerability is increased by non-climatic impacts such as the dispersion of solid waste that exacerbates the problem by clogging the drains. In the coastal zone, the population and infrastructure (urban and tourist) is very vulnerable to the entry of extreme weather events with storm surges that cause sea penetration and floods. The floods and their negative consequences on the population and the coastal infrastructure may be greater in the future under the scenarios of more intense extreme weather events with storm waves of greater reach due to the rise in sea level. It is estimated that low-lying areas in Las Terrenas at risk of coastal flooding cover around 19 km², extending approximately 20.7 km from the coast of Punta Balatá to the eastern end of the municipal border. At least 17% of the coast shows severe erosion aggravated in part by human activities such as coastal constructions, vehicular traffic, mangrove losses and sand extraction, where the coast has moved up to 100 m in some places (inward or outside). The affected areas include between Punta Bonita and Caño de Jobo, Punta Bobilanza and between Calolima and El Anclón. Currently there are areas with severe erosion on the beaches of several hotels: Casablanca, Allegro, Dolce Vita, Casa Nina and Balcones del Atlántico.

Many of the projects and activities proposed in the Municipal Development Plan will contribute to the adaptation of Las Terrenas to climate change. The fundamental challenge of any effort to strengthen the reduction of vulnerability and adaptation to climate change is to achieve inter-institutional coordination and collaboration between the public and private sectors. This evaluation is a starting point for the Las Terrenas municipality to explore how the effects of climate, non-climatic impacts, and adaptation capacity contribute to the current vulnerability of its development objectives, and how the change can exacerbate these vulnerabilities. The analysis and refinement of this assessment by local planners and stakeholders will help to make decisions about whether adaptation measures should focus on reducing exposure, sensitivity, and / or increasing adaptive capacity, as well as its adequate insertion in a new model of territorial ordering on the way to the final goal of more resilient cities in the Dominican Republic.
I INTRODUCTION

The coastal city of Las Terrenas, located on the northwest end of the Samaná Peninsula in the Dominican Republic, is flanked by a striking mountain range on its southern end and the Atlantic Ocean to the north. This small, vibrant city has recently experienced rapid population growth, primarily due to increased private sector investments in tourism. The municipality has struggled to expand its services to keep pace with this growth, and the living conditions of the local population have deteriorated even as residents have seen increases in employment opportunities associated with the upsurge in tourism. The development challenges confronting Las Terrenas are compounded by climate stresses. Las Terrenas is highly vulnerable to current and future climate variability, particularly heavy rainfall events and coastal erosion, which result in significant impacts on roads, housing, and beaches. The steady increase in new development investments—sometimes constructed in vulnerable areas or without regard for the climate-related impacts on the investments and surrounding areas—is exacerbating this vulnerability and the sustainability of new development.

This preliminary climate change vulnerability assessment for Las Terrenas identifies current and future vulnerabilities to municipal priorities that can be used to inform decision-making, including land use planning. Las Terrenas is one of four USAID Planning for Climate Adaptation Program pilot cities\(^1\) that are undertaking participatory climate change vulnerability assessments with support from the International City/County Management Association (ICMA). ICMA is collaborating with local municipal councils to conduct climate change vulnerability assessments that engage local communities and technical experts in a participatory process that is designed to build capacity at all levels. The vulnerability assessments are part of a larger objective of the Climate Adaptation Program to develop a replicable process to integrate climate change vulnerabilities into land use planning.

This report provides preliminary information about climate vulnerability as input into this broader participatory process. The process will engage a range of municipal actors to consider: 1) municipal development objectives and how they may be vulnerable to current and future climate, and 2) how these vulnerabilities can be taken into account in land use planning to improve the resilience of Las Terrenas now and in the future. As such, the general results documented in this assessment must, in subsequent steps, be synthesized with the results from the participatory process, and be verified by local stakeholders. Through this process, these results may be improved by the provision of greater detail\(^2\) about the locations of anticipated impacts and their potential severity, and by the undertaking of more complete analyses to determine the most critical vulnerabilities. Where necessary, the Planning for Climate Adaptation Program will support this work by providing training on climate change vulnerability and assessment.

---

1 The three other pilot cities include National District, Santiago de los Caballeros and San Pedro de Macorís.

2 Supplemental detail and information can be found in the Las Terrenas vulnerability and adaptation base document of ICMA (2015), which may be useful to land use planning context.
This vulnerability assessment follows the USAID Climate-Resilient Development (CRD) Framework’s “development-first” approach (USAID 2014), by identifying important municipal development goals and objectives, and then considering how these objectives are vulnerable to current and potential future climate hazards. The components of vulnerability (exposure, sensitivity, and adaptive capacity) are described separately in this assessment in order to better illuminate the underlying causes of the vulnerability. This approach also allows planners to better determine what adaptation measures will be most effective, and whether adaptations should be focused more on reducing exposure, reducing sensitivity, and/or increasing adaptive capacity. All results from workshops on vulnerability with the City Hall Technical Team and the local community’s groups are incorporated herein.

2 MUNICIPAL CONTEXT

Las Terrenas is a municipality of the Province of Samaná, located on the northwest end of the Samaná Peninsula. Las Terrenas borders the municipality of Sánchez to the west and the municipal district El Limón to the east. Las Terrenas is divided in five districts: Las Terrenas Urban Zone, El Cosón, La Barbacoa, El Naranjito, and El Jamito (Figure 1). The urban area of Las Terrenas, El Cosón, and La Barbacoa are coastal sections with frontage on the Atlantic Ocean while El Naranjito and El Jamito are mostly mountainous sections defined within the Sierra of Samaná.
Figure 1. Location of the municipality of Las Terrenas and its five districts in the Samaná Region context (source: ONE 2016).
2.1 POPULATION

According to ONE (2016), the population of Las Terrenas was 18,829 in 2010, with approximately 60% of the inhabitants concentrated in the coastal urban zone (1931.25 inhabitants/km²). Table 1 shows the population distribution across the five districts, comprised of 26 neighborhoods.

Table 1. Population data for the Sections of Las Terrenas Municipality (source: ONE 2016)

<table>
<thead>
<tr>
<th>DISTRICTS</th>
<th>BARRIOS/PARAJES</th>
<th>SURFACE (KM²)</th>
<th>POPULATION</th>
<th>DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Las Terrenas Urban Zone</td>
<td>10</td>
<td>5.76</td>
<td>11,124</td>
<td>1931</td>
</tr>
<tr>
<td>El Jamito</td>
<td>4</td>
<td>22.89</td>
<td>2,726</td>
<td>119</td>
</tr>
<tr>
<td>La Barbacoa</td>
<td>3</td>
<td>28.16</td>
<td>2,055</td>
<td>73</td>
</tr>
<tr>
<td>Los Naranjitos</td>
<td>2</td>
<td>25.08</td>
<td>1,519</td>
<td>61</td>
</tr>
<tr>
<td>El Cosón</td>
<td>7</td>
<td>30.00</td>
<td>1,405</td>
<td>47</td>
</tr>
<tr>
<td><strong>Total Municipality Las Terrenas</strong></td>
<td><strong>26</strong></td>
<td><strong>111.90</strong></td>
<td><strong>18,829</strong></td>
<td><strong>168</strong></td>
</tr>
</tbody>
</table>

Between 2002 and 2010, population grew by 35.8%. The percentage of poor people\(^3\) is highest in the urban zone (90%) compared to the rest of the municipality (72%). Population is projected to increase to 21,500 by 2020 (Deverchere 2011).

2.1 GEOGRAPHY AND NATURAL RESOURCES

The municipality is bordered to the south by a mountain range, Sierra de Samaná, which reaches an altitude of over 400 meters above sea level (masl). The mountains gradually descend northward toward the coast, forming a narrow strip between the base of the mountains and the coastline where development is concentrated. Most of the area of the municipality of Las Terrenas is located in the Samaná North Coastal Basin (93%). Municipal water courses include the rivers Las Terrenas and Cosón, and the Caño Seco, El Jobo, Salado, and El Portillo streams. Local hydrology is heavily influenced by the geomorphology of the peninsula. The waterways that flow into the Atlantic are usually short in length but run with a great amount of water due to the contribution of runoff from the hills. Water accumulates at the edge of the mountain range before flowing into the ocean. This peculiarity of the hydrologic system promotes the presence of marshes that extend between the higher elevations and the waterfront, such as at Coson, Mar Gorda, and La Barbacoa as well as the coastal lagoons at Marico (see Figure 2).

---

\(^3\) Poverty is defined by through the weighting of 17 variables related to the material conditions of life of the population (e.g., quality of housing, schooling, or sanitary services) (MPyD 2014).
Figure 2. Elements of the hydrological system of the Municipality Las Terrenas in the geomorphological context (sources: topographic sheets and field information).

The municipality of Las Terrenas includes important terrestrial, coastal, and marine biodiversity resources. The municipal coastline spans about 27 kilometers (km), and is a mix of sandy beaches (18 km), high rocky beaches (6 km), mangroves (solely 2 km in La Barbacoa), and the mouths of rivers and streams (~1 km). The Samaná Peninsula is home to a large number of terrestrial and marine species of flora and fauna, including a great number of endemics (Ministerio Ambiente 2012). Extensive coral reefs occupy the insular shelf off the coast of Las Terrenas (ReefBase 2016) with more than 30 km².

2.2 ECONOMY

The municipality’s primary economic sectors—tourism, fishing, and agriculture—are reliant on the region’s land, coastal, and marine natural resources. Tourism is an important economic driver in Las Terrenas, which has become one of the country’s tourist hotspots, aided by increased accessibility due to the construction of a new international airport at El Catey and a new highway from Santo Domingo.

The municipality has more than 70 hotels (and more are under construction), distributed primarily along the coastal areas of the urban zone and the district of El Cosón. Sport fishing and diving are popular recreational tourist activities. Fishing and agriculture represent traditionally important economic activities for communities in Las Terrenas. Reef, demersal, and pelagic fishing have historically provided income to local communities and are increasingly supporting the tourism industry for consumption and sport fishing (see photo next page). Main fishery resources include about 80 species of fish and shellfish, with spiny lobster, snappers, grouper, dolphinfish, and tuna among the most commercially valuable. Agriculture is mainly subsistence farming (outside of coconut farming) and includes crops such as yams, taro, cassava, cubanelle pepper, and cilantro. Agricultural products are sold mainly in Santo Domingo.
3 STRATEGIC MUNICIPAL PRIORITIES AND CHALLENGES

Las Terrenas Municipal Development Plan (2013–2016) sets several strategic goals, including the realization of:

- Transparent and participatory governance,
- Appropriate land use with harmony between the natural and built environment,
- Adequate, sustainable, and regularly maintained municipal services,
- An enterprising city, with comprehensive development based on sustainable tourism,
- A safe city, committed to the conservation of its natural resources and compliance with health standards, and
- An educated population and skilled workforce, who value their cultural identity.

These strategic objectives are critical to building and maintaining a secure, beautiful, and prosperous municipality that reflects the interests of its citizens. However, Las Terrenas faces some challenges in realizing these objectives, as outlined in the following sections.
PARTICIPATORY GOVERNANCE

Approximately 71.1% of the population participated in the municipal elections in 2010 (ONE 2016). Las Terrenas has recently undergone a period of rapid growth and change, primarily due to investments in tourism, which have in turn resulted in many new environmental and social impacts. The municipal government has struggled to keep its services at pace with this growth. The Municipal Development Plan strives to achieve transparent and participatory governance, in part by encouraging investment in new accounting systems, allowing free access to information, and creating a community advisory unit on sustainable development. However, overcoming special interests and enforcing regulations to protect the natural environment remain a continuing challenge as the deterioration of the beaches, habitat, and biodiversity combine to undermine the potential successes brought about by increased tourism. Furthermore, the lack of agreement among public institutions undermines the pursuit of effective solutions to environmental and social problems. In fact, the technical group of the City Council considers this lack of accord as one of the main factors contributing to the vulnerability of the territory.

The Municipal Development Plan aims to achieve transparent and participatory governance, updating the City’s organizational structure and training staff, creating new accounting systems, making city management more efficient, including increasing city’s revenue, guaranteeing free access to public information, better disseminating their activities and creating a community advisory unit for sustainable development (FEDOMU, 2013). However, overcoming interests and enforcing regulations to protect the natural environment continues to be a challenge since the deterioration of beaches, the cutting of mangroves, sand extractions and damages to biodiversity combine to minimize potential benefits of tourism development. In addition, the lack of agreement among public institutions weakens the search for effective solutions to environmental and social problems. The Municipal Development Plan is the result of a participatory process in which 48% of participating institutions corresponded to community associations and tourism companies. The rest are institutions of the risk management system (12.2%), trade associations (10%), professionals (7.8%), education centers (6.7%), press (5.6%), religious institutions (4.4 %) and public institutions (4.4%). If we consider that public institutions, in addition to being poorly represented, were only represented by the Ministries of Women, Sports and Tourism, the absence of key institutions such as the Ministry of the Environment or the National Institute of Drinking Water and Sewage is an obvious weakness. These institutions are directly responsible for controlling and solving many serious environmental problems of the municipality, such as the destruction of wetlands and beaches, or the contamination of groundwater resources.

APPROPRIATE LAND USE WITH HARMONY BETWEEN THE NATURAL AND BUILT ENVIRONMENT

The last national study on coverage and land use (Ministerio Ambiente 2014) revealed that 55% of the land of the municipality Las Terrenas is occupied by terrestrial ecosystems (forests and bushes) and 4% by aquatic and marine ecosystems (marshes and mangroves). About 39% of the land is used for agriculture and about 2% is populated area. Urban sprawl occupied less than 0.5 km² in 2000 and by 2010 had extended to more than 1 km² (Deverchere 2011). The Las Terrenas Office of Urban Planning performs several functions under Law 6232-63, including tax collection and assessment, and land use approval. The office has produced maps that outline administrative and political boundaries and natural resources by census polygons, but the municipality has not yet developed a comprehensive land use plan. Under Resolution No. 06/2011, the National Ministry of Tourism developed a Tourist Sector Land Use Plan (2012) that outlines three main land categories in Las Terrenas: a tourist area, an urban commercial and residential area, and an area of urban expansion and rural areas (MITUR 2012). The Tourist Sector
Land Use Plan should be taken into consideration in the formulation of the new Municipal Land Use Plan, in order to decrease existing and anticipated land use conflicts between residential, commercial, and tourism development goals, and environmental protection goals. Deverchere (2011) summarizes important criteria useful in developing a Plan of Municipal Management, which include a transparent and participatory process in order to ensure sustainable planning development of the territory.

### 3.3 QUALITY MUNICIPAL SERVICES

An important municipal goal is the provision of adequate and effective services to all citizens. These critical services (some of which are not managed by the municipality) include safe water supply, sanitation, transportation, solid waste management, and electricity. Other services important for the municipality include the slaughterhouse, cemeteries and funeral services, public parks and spaces, public libraries, and sports and recreation facilities.

#### 3.3.1 Water services

The National Institute of Potable Water and Sewers (INAPA) is responsible for water supply to the city. Water supply for the municipality comes from the Cosón River and the water intake and water treatment system are located in the Section of El Cosón. The water supply system has two storage tanks with a capacity of 1,480,000 and 300,000 gallons of water and a water treatment system with a capacity of 260 liters/second. The municipality built an aqueduct in 2011, which is designed to service the nearly 45,000 residents in the urban and tourist areas, as well as the towns of Carolina, Abra Grande, Atravesado, El Buen Pan, El Cosón, La Bonita, La Ceiba, and La Barbacoa (Ministerio Ambiente 2012). However, water service in the municipality is poor, as only 20.3% of households receive water into their houses from the public network (ONE 2016) and the pipes frequently crack due to high pressure. The municipality would like to expand the service coverage connections of the aqueduct throughout the municipality but several communities currently have no connection to the aqueduct drinking water including Hoyo del Cacao, La Granja, Come Pan, El Almendro, Jamito, Los Puentes, Abra Grande, Monte Adentro, El Manantial, La Barbacoa, El Naranjito, and Las Guázaras (FEDOMU 2013). The aqueduct has capacity to supply water to the entire population but more distribution facilities are needed, and those that are in place need to be upgraded or replaced.

#### 3.3.2 Sewage and storm water drainage

The municipal goals are to make the sewer system functional, expand sewer connection coverage throughout the municipality, and construct a storm water drainage system for the urban zone. Although the municipality has a sewage treatment plant, the plant is not functioning properly, connections to the sewer system are incomplete, and untreated water is discharged in the mangroves creating a serious local sanitary problem that can threaten groundwater reserves. The municipality does not have a storm water drainage system. Currently, roads act as (unplanned) drainage channels and flood during the rainy season; this leads to destruction and damage of roads and surrounding assets, disruption of services, and interruption of tourism activities. Dumping of wastewater into the waterways causes pollution and landscape degradation, threatens public health, and harms marine life. Damage to coral reefs from exposure to untreated wastewater increases the vulnerability of coastal areas to extreme events, stresses the marine ecosystem, and results in adverse effects on the economy.
3.3.3 Transportation

The main access roads to the city are the Tourist Boulevard of the Atlantic; Northeast Highway or Highway John Paul II, which connects to Santo Domingo; Calle Las Terrenas-Sánchez; Calle Nagua-Puerto Plata; and Calle Arenoso-San Francisco de Macoris (FEDOMU 2013). There is no municipal entity that manages public transportation, but there are public transport services that connect the city with other cities and towns. Within the urban zone of the municipality, Calle Duarte and Calle Nuestra Señora del Carmen are the major paved roads that lead to the coast. Hotels and local businesses line the coastal roads of 27 de Febrero and Coronel Francisco Alberto Caamaño Deño (see Figure ).

The municipality plans to improve the quality of urban and rural roads in the municipality, including through the development of a network of roads in the hills to better bridge rural areas of the municipality; investment in sidewalks and curbs in the urban zone; and development of trails in the peripheral sectors. The municipality also plans to improve the management of vehicular and pedestrian traffic in the urban area by implementing road signs in the town and in areas of high traffic, labeling the town streets of the town, and improving public transport service in the city (FEDOMU 2013). When planning the road network in Las Terrenas, it should be considered that the roads near the coastline can have an influence on coastal erosion.

Figure 3. Roads in the urban zone of Las Terrenas (source: [http://www.las-terrenas-live.com/las-terrenas/mapa.html](http://www.las-terrenas-live.com/las-terrenas/mapa.html)).
3.3.4 Solid waste management

Solid waste is collected by trucks from both the council and small private and independent businesses (FEDOMU 2013). The open-air municipal landfill is located close to the Maria Alcalá River and does not have a perimeter fence. The waste is burned, but the municipality has begun compaction during collection in some areas. Key challenges related to solid waste management include the limited amount of equipment, inadequate landfill management, lack of containers in some areas of the city, and the lack of community awareness about proper disposal. Approximately 20.3% of private households did not subscribe to garbage collection services in 2010 (ONE 2016). Individuals’ burn garbage to reduce its volume, which produces harmful and carcinogenic smoke, and garbage is deposited in driveways, streets, streams and rivers. Improper garbage disposal (approximately 21 tons/day) and makeshift dumps contribute to accumulation of solid waste during rain events, blocking the flow of Las Terrenas and Caño Seco rivers and increasing the possibility of overflow and flooding. The municipality plans to relocate the municipal landfill, and to expand and improve the system of collection. The deficiencies in the management of solid waste and the lack of public awareness for proper disposal is one of the most serious problems facing Las Terrenas, with serious implications for environmental health, climate vulnerability, and the cultural and economic (via tourism) strength of the municipalities.

3.3.5 Electricity

The private company responsible for the distribution of electricity, Luz y Fuerza, has contracts with approximately 9,500 households, of which 80% are active. However, there are a number of burned out street lights, overhead power distribution lines are disorganized and unsightly, poles are poorly located in the middle of sidewalks, and the price of electricity is high (FEDOMU 2013). High electricity tariffs have resulted in past protests, including a large scale protest in 2014 that led to 2 deaths, and the collapse (due to vandalism) of more than 20 power line posts. This event led to depressed tourism, and power outages lasting over five days in some areas. In September of 2015 electricity tariffs of Las Terrenas substantially decreased due to a government supported interconnection of the Luz y Fuerza to the National Interconnected Electric System (SENI). The municipality plans to work with private companies to improve street lighting in order to provide better services and present a better image to visitors.

3.3.6 Human health and safety

The 2013 Tourist Sector Land Use Plan includes the following goals for Las Terrenas: ensuring safety of citizens, conserving natural resources, and complying with health standards. Primary concerns regarding citizen security include micro-trafficking of drugs, theft and robberies, organized crime, limited control of migration, and vulnerability of certain areas to landslides and floods. Las Terrenas is subject to natural disasters including earthquakes, tsunamis, hurricanes, cyclones. The health and safety impacts of these natural disasters include loss of shelter, damage to and loss of critical services and infrastructure such as telecommunication, and increased incidents of injury and disease, among many others. The municipality is


served by the departments of Municipal Police, Fire Department, Civil Defense, and the Dominican Red Cross; however, challenges to ensuring public safety in Las Terrenas include a lack of trained staff, necessary equipment, and adequate training.

The leading causes of hospitalization in the municipality include motor vehicle accidents, acute respiratory infections, urinary and intestinal infections, acute diarrhea, abdominal pain, dengue, amoeba system diseases, and hypertension. The public hospital in Las Terrenas is located in the center of the urban area, and there are several private hospitals and health centers. However, the municipality is lacking adequate hospital services, primary care facilities, and local pharmacies, as well as skilled health care providers; this is particularly a concern during peak tourism season.

The 2013 Tourism Sector Plan outlines the need to improve police and public security and suggests the development of a community awareness program on crime prevention. It also calls for the creation of a Municipal Committee for Disaster Prevention, Mitigation and Response; implementation of a community environmental awareness program; improvement of medical services and infrastructure; and development of interagency coordination for the enforcement of hygiene and environmental quality standards (MITUR 2012).

### 3.4 SUSTAINABLE TOURISM AND NATURAL RESOURCES

A critical municipal goal included in the Tourist Sector Land Use Plan is to foster entrepreneurship and holistic development based on sustainable tourism practices, taking advantage of the attractive and accessible natural areas of the region (MITUR 2012). Ecosystem services from the waterways, beaches, marshes, forests, mangroves, and coral reefs are essential for successful sustainable development, tourism-focused services, and adaptive capacity.

Data from the Tourism Ministry for 2011 for Las Terrenas indicated 57 hotels and 1903 rooms. For 2016, the Hotel Booking Portal presents (online) 113 hotels of various types for Las Terrenas, mostly distributed in the coastal zone of the urban area of Las Terrenas and the Cosón Section. There are a number of hotels proposed and under construction. Diving is in high demand, and currently there are more than ten specialized activity centers covering more than 20 dive sites north of the peninsula (see Figure 4). Sandy beaches are being impacted by unsustainable tourism practices including pollution, frequent driving of vehicles on the beach, and construction of structures within the 60 meter coastline buffer zone. Existing infrastructure, built within this 60-meter buffer (in violation of the Law 64-00), have altered the natural dynamics of the beach promoting erosion problems, increasing the stress over the coastal ecosystems. Furthermore, the ongoing development along the coast is contributing to the modification of the whole coastal system. Regulations pertaining to development and use of beaches are needed, as well as for public pedestrian streets and optimum services in the coastal areas (Reyes and Mieses 2014).

---


Figure 4. Distribution of shallow reefs and location of some hotels and tourist diving sites in the municipality of Las Terrenas. Sources: ReefBase (2016) and Planning for Climate Adaptation Program field work.

Mangrove and other coastal forest lands have been cleared for tourism infrastructure development. These forests play a critical role in the maintenance of ecological processes in surrounding marine, estuarine, and terrestrial ecosystems, including maintenance of reef fish populations (see photo below). Clearance of mangroves has also lead to sedimentation of coral reefs, causing mortality and reef degradation. Development in marshes is also reducing the ability for the ecosystem to serve as a natural buffer against flooding. Deforestation and illegal sand mining is contributing to loss of natural buffer zones and slope destabilization.
Uncontrolled fishing practices and diving are stressing the marine ecosystem, particularly coral reefs, and the ecosystem services they provide. Increasing fishing to meet higher demands have resulted in unsustainable fishing practices (such as small net sizes in fishing gears, no respect for the minimum size of capture or the closed seasons), that have wide-ranging ecological consequences. Likewise, the selective removal of key ecological species from reef communities (such as herbivorous fish) has adverse ripple effects on the reef ecosystem, which is aggravated by local river pollution.

Implementation of long-term strategies that protect these natural resources and the welfare of the local community and visitors to the area is a critical need. Accordingly, the municipality plans to better define “sustainable tourism” by the larger community to encourage support of this goal by a broader cross-section of the municipality; enforce mangrove conservation and develop a mangrove reforestation program at river outlets; and construct a tourist jetty for boat trips, scuba diving, and fishing.

### 3.5 WELL-EDUCATED AND SKILLED CITIZENRY

The municipality is striving to develop an informed and educated citizenry who value their cultural identity and who comprise a skilled workforce. The municipality plans to upgrade public schools and invest in training teachers, and construct a technical training center for tourism vocations, including gastronomy and hospitality. There are 13 public and two private schools in Las Terrenas, many of which are located in the coastal urban zone. As of 2010, 1,386 people over the age of 5 in Las Terrenas had not received any formal education; 1,134 had received a preprimary education as the highest level of educational attainment; 8,058 completed primary school; 4,773 finished secondary school; and 1,441 had attained university or higher. In 2010, approximately 12.9% of the population over 15-years-old was illiterate.

---

8 Ministry of Education. Educational Centers GIS. Available at: [http://apps.see.gob.do/MapsMINERD/Default.aspx](http://apps.see.gob.do/MapsMINERD/Default.aspx)
Climate variability and change can have substantial impacts on local development sectors, services, and people, impeding efforts to achieve development objectives. In order to reduce these impacts and promote climate-resilient land use planning, municipal planners need to understand the climate vulnerabilities of their population, economic sectors, and services.

Following the approach taken by the IPCC (2014), climate vulnerability is determined by exposure, sensitivity, and adaptive capacity (Figure 5). The concept of climate vulnerability recognizes the potential for people or businesses to reduce climate impacts through actions designed to reduce exposure and/or sensitivity, or to increase adaptive capacity.

![Figure 5. The components of vulnerability: exposure and sensitivity combined indicate potential impact, while potential impact and adaptive capacity indicate vulnerability.](image)

Exposure is the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by a climate hazard or stressor. These climate stressors and hazards include hydro-meteorological and oceanographic variables and phenomena with the potential to cause harm to human health, livelihoods, systems, or natural resources. In this report, climate stressors include current and potential future rainfall, temperature extremes, drought, riverine and coastal flooding (sea level rise and storm surge), tropical storms, erosion, and landslides.

Sensitivity is the extent to which a system, asset, or species will be positively or negatively affected if it is exposed to a climate stressor. The effect may be direct (e.g., a change in crop yield in response to temperature change) or indirect (e.g., damages caused by severe coastal flooding and sea level rise). The more sensitive the asset, resource, or population is to one or more climate stressors, the more vulnerable it tends to be. For example, older poorly constructed infrastructure tends to be more sensitive to flooding compared with infrastructure constructed with flooding in mind (i.e., roads with adequate drainage), and certain types or varieties of crops are more sensitive to drought. Together, exposure and sensitivity determine the potential impact that climate and non-climate stressors will have on important assets, infrastructure, or populations relevant to municipal services and economic sectors.
The potential for harm from climate change can be minimized through reductions in exposure and sensitivity, which is referred to as adaptive capacity. Adaptive capacity highlights an ability to take actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities from current climate extremes such as droughts, heavy precipitation events, storms, and heat waves, as well as longer-term climate change impacts. The adaptive capacities of individuals, households, and organizations vary according to their access to information, ownership or access to resources, the skills of the people within these systems, and the ability to assess climate issues and make informed decisions. Adaptive capacity can be increased not only by taking measures to prepare for and adjust to climate stressors, but also by promoting growth in GDP, implementing policy reforms, undertaking other development actions, and strengthening governance.

Climate vulnerability represents the potential for consequences where something of human value (including humans themselves) is at stake and where the outcome is uncertain. Taken together, exposure, sensitivity, and adaptive capacity of people, assets, and systems represent vulnerability. Describing each component separately allows planners to better determine what adaptation measures will be most effective, and whether adaptations should be focused more on reducing exposure, reducing sensitivity, and/or increasing adaptive capacity.

This section analyzes the degree to which municipal objectives and underlying factors supporting them (including people and assets) may be harmed or unable to cope with a climate stressor. It involves the collective analysis of exposure, sensitivity, and adaptive capacity. First information is provided that improves understanding of the exposure of Las Terrenas to current and potential future climate stressors. Second, the current and potential future impacts of climate stressors on the critical development objectives of Las Terrenas are evaluated, based on the sensitivity of the exposed people and assets. The third step considers the potential adaptive capacity of Las Terrenas to be able to moderate or avoid these impacts. Finally, the overall vulnerability of important municipal objectives is evaluated, based on the combination of exposure, sensitivity, and adaptive capacity.
4.1 EXPOSURE TO CLIMATE HAZARDS

The climate of the northern Atlantic coast of the Samaná peninsula is influenced primarily by its proximity to the ocean and its topography, which rises from the coast inland to more than 500 meters above sea level over a distance of about 7 km. This section begins with a summary of current and potential future climate at 2050, including changes in temperature and rainfall extremes, hurricanes and storm surges, and associated flooding, drought, erosion, and landslides.

These stressors are consistent with those identified by municipal council staff during a Planning for Climate Adaptation Program Workshop (2015), where the river overflows, floods, coastal erosion, and hurricanes were identified as most significant. The overview is followed by brief descriptions of the historical climate conditions and trends, and potential changes at 2030 and mid-century (see box, below.)

In summary, annual average, minimum, and maximum temperature, and the frequency of hot days and nights have been increasing in Las Terrenas. By 2050, average annual temperature is projected to increase by 1.1°C to 1.6°C. Las Terrenas experiences an average annual rainfall of about 1924 millimeters (mm), with year to year variability strongly influenced by El Niño (drier than average conditions) and La Niña (wetter conditions) episodes. Average annual rainfall is projected to decrease by mid-century by -10.9 to -13.7%. Historically, the occurrence of hurricanes and tropical storms have contributed significantly to annual rainfall totals.

Although the total number of tropical storms may decrease, the number of very intense (Category 4 and 5) hurricanes are projected to increase by 2100. Riverine flooding has occurred frequently in the past ten years as a result of moderate to heavy rainfall events. The proportion of total rainfall that falls in extreme or heavy events is projected to slightly increase by mid-century. The mean rate of sea level rise in the Caribbean region over the last 60 years was ~1.8 mm/yr. The current area of Las Terrenas at risk to coastal flooding is about 19 km² and includes the low elevation urban zone of Las Terrenas. Global sea level is projected to rise by 0.20 to 0.58 meters at mid-century, increasing storm surge heights, flooding and erosion.
CLIMATE SCENARIOS, MODELS AND EMISSIONS SCENARIOS. Underlying risk and vulnerability assessments are climate scenarios, projections and models, and emissions scenarios. To better respond to climate change risks and vulnerabilities, it is critical to understand climate change information, including its uncertainties, for a given time frame and location. A climate scenario is a plausible representation of future climate that has been constructed for explicit use in investigating the potential impacts of climate change. Climate scenarios often make use of climate projections (descriptions of the modelled response of the climate system to scenarios of greenhouse gas and aerosol concentrations) (IPCC 2014). Emission scenarios represent numerous alternatives of how the future can unfold and the associated implications of human emissions of greenhouse gases (GHG) to the atmosphere. For example, the level of future emissions depends upon different scenarios regarding the path humanity takes in terms of social and economic development and growth, and political and technological choices. These scenarios range from "optimistic" lower emissions scenarios to "pessimistic" higher emissions scenarios. Climate models are mathematical representations of the climate system and interacting processes that can reproduce key features found in the climate of the past century. Climate models “run” emission scenarios and produce projections of future climate. Both models and emissions scenarios contain uncertainties—these uncertainties increase as they are projected further out in the future. Despite uncertainties, model information can be useful to decision making.

4.1.1 Temperature

Current temperature. The temperature modeling maps shows that average temperatures decrease as one moves from the low-lying coast to higher altitudes in Las Terrenas (JICA/ONAMET 2004). The average annual low temperature occurs mid-winter (January, 22°C), and the high in mid-summer (August, 28°C). Across the entire Dominican Republic, mean annual temperature increased by about 0.45°C from 1960–2003 (McSweeney et al. 2012) and at an average rate of ~0.1°C per decade in the area of Las Terrenas (Climate Wizard 2015). This warming since 1960 in Las Terrenas was most rapid in the cooler months of January and February. In addition, the frequency of hot days and hot nights has increased significantly since 1960. The average number of “hot days” per year in the Dominican Republic increased by 63 (or 17.4% more hot days) between 1960 and 2003 (McSweeney et al. 2012).

Future temperature. By 2030, under low and high emissions scenarios, annual average temperatures are projected to increase by 0.7°C and 0.8°C, respectively; by mid-century, annual average temperatures are projected to increase by 1.13°C to 1.56°C for the low and high scenarios, respectively. The magnitude of change of annual minimum and maximum temperatures is similar to the projected changes for the annual average. At mid-century the hottest annual temperatures are projected to increase by

9 “Hot day” is defined by the temperature exceeded on 10 percent of days in current climate of that region and season.

10 Low emissions scenarios refer to SRES B1 or RCP 4.5, and high emissions scenarios to SRES A2 or RCP 8.5, typically for the median ensemble of the models, unless otherwise stated.
1.5°C and 1.8°C for the low and high emissions scenarios.\textsuperscript{11} Confidence in temperature projections is high (Climate Wizard 2015).

\textbf{4.1.2 Rainfall}

\textbf{Current rainfall}. Las Terrenas has some of the highest rainfall averages in the country, with an average annual amount of approximately 1924 mm (from 1950–2000).\textsuperscript{12} Las Terrenas’ rainfall distribution is shown in Figure 6,\textsuperscript{13} along with nearby local station data, at similar altitudes. At higher altitudes, rainfall levels are even higher, varying between 2000 and 2500 mm (JICA/ONAMET, 2004).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6.png}
\caption{Gridded monthly rainfall estimates for Las Terrenas from WorldClim (1950–2000), and data from nearby stations (source: ONAMET).}
\end{figure}

Monthly rainfall is unevenly distributed, with peaks in May and November, and a rainfall low in February. Rainfall in the Dominican Republic shows strong inter-annual and decadal variability. Inter-annual variability is influenced strongly by El Niño Southern Oscillation (ENSO); El Niño typically brings drier than average conditions between June and August, and La Niña episodes bring wetter conditions at this time. Results of an analysis of long-term changes in monthly rainfall for several stations in the Semaná Peninsula were rarely statistically significant, and varied given station location.\textsuperscript{14} However, a separate analysis of mean annual rainfall over the entire Dominican Republic indicated a decrease of 5 mm per year (4.5\%) per decade since 1960. This decrease is due mainly to decreases in rainfall from June through November (McSweeney et al. 2012).

\textsuperscript{11} Climate Wizard, Semaná Peninsula downscaled (11 GCMS).
\textsuperscript{12} Taken from WorldClim gridded data, there are no meteorological stations in Las Terrenas.
\textsuperscript{13} WorldClim gridded data, 2.5 arc minutes (4.2 km x4.2 km grid at the equator).
\textsuperscript{14} The analysis of long-term rainfall changes is assessed through a comparison of rainfall patterns for two non-overlapping periods, 1960–1985 and 1986–2012 (USAID 2013).
**Future rainfall.** Generally, the low and high emissions scenarios indicate a higher confidence towards projected reductions in mean annual rainfall, particularly in the months June through October for the median model ensembles. Projected annual average rainfall indicate reductions from 2030 (-1.2% to -2.3%) toward midcentury (-13.7% to -10.9%), with slight increases in November and December rainfalls in the 2030 time period for low and high emissions scenarios.\(^{15}\) The number of days with "extreme rain" (90th percentile rainfall) is projected to decrease in the summer months, and increase slightly in September and November.\(^{16}\) Note that projected potential increases in summer rainfall associated with tropical cyclone activity, which may not be captured in the GCM projections, may counteract the projected decreases in rainfall in the region (IPCC 2013).

### 4.1.3 Drought

**Current drought.** There are no recorded droughts in the disaster inventory for the Semaná Peninsula.\(^{17}\) Drought was not identified as a critical climate-related risk to the municipality.\(^{18}\) A Standardized Precipitation Index (SPI)\(^{19}\) analysis of Semaná station rainfall data indicates the occurrence of drier periods in the period 2000–2001, and 2010 (see Figure 7).\(^{20}\)

\(^{15}\) World Bank Group CCKP.

\(^{16}\) World Bank Group CCKP.

\(^{17}\) Available at: [http://online.desinventar.org/desinventar/#DOM-20101111/](http://online.desinventar.org/desinventar/#DOM-20101111/).

\(^{18}\) Input from USAID Planning for Climate Adaptation site visits and workshop.

\(^{19}\) The Standardized Precipitation Index (SPI) is a widely accepted index for the quantification of drought. The SPI specifically addresses the intensity of meteorological drought, or precipitation deficit. The shortage of precipitation is a fundamental, intuitive metric for drought—perhaps the most basic description possible. However, it is important to note that this only reflects precipitation, not the ability of municipalities to hold and manage their water. See more at: [https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi#sthash.LiLNO1Hr.dpuf](https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi#sthash.LiLNO1Hr.dpuf).

\(^{20}\) Note that 30 years of data are recommended for SPI analysis, results should be interpreted with caution as only 20 years of data were available for this analysis.

Future drought. Annual aridity and deficits in climate moisture are expected to increase in Las Terrenas under both high and low emissions scenarios at mid-century due to increasing temperature and potential evapotranspiration, and reduced rainfall; however, projected aridity index (AI) values indicate that Las Terrenas would still be considered humid in the future. Annually, the number of consecutive dry days is projected to increase, although confidence in these projections is low (Climate Wizard).
4.1.4 Hurricane frequency and Intensity

Current hurricane frequency and intensity.
Cyclone and hurricane landfall frequencies over the Dominican Republic are variable with an average of one every two years, but can occur as frequently as two per year. There have been periods of inactivity of five to ten years (USAID 2013). They occur primarily during the months of August, September, and October; with greatest intensity in the southeast and southwest regions of the country. Analysis of inter-annual variability of hurricanes shows an increase in hurricane landfall probability for the whole Caribbean during La Niña years and a decrease during El Niño years, with a more than 3:1 ratio of hurricane landfalls between the two periods, per season (Figure 8).

Heavy rainfall associated with hurricanes and tropical storms can contribute significantly to rainfall totals (especially August to September). From 1851 to 2014, 22 cyclones or hurricanes have come within 50 km of Las Terrenas, with two making landfall in the municipality (Figure 9). Of these, the most recent to make landfall was Hurricane Jeanne in September 2004 (NOAA 2016). Analysis of inter-annual variability of hurricanes shows an increase in hurricane landfall probability for the whole Caribbean during La Niña years and a decrease during El Niño years, with a more than 3:1 ratio of hurricane landfalls between the two periods, per season (USAID 2013). The available data on historical hurricane frequency and intensity shows no clear pattern or relationship to climate change.²¹,²²

Future hurricane frequency and intensity. Potential future changes in frequency and tracks of tropical cyclones are uncertain. However, it is likely that, on a global basis, climate warming will cause hurricanes in the coming century to be more intense and to have higher rainfall rates (20% more rainfall within 100 km of the storm center) (USAID, 2013) than present-day hurricanes. In addition, there is some evidence in the Atlantic Basin that the numbers of very intense (category 4 and 5) hurricanes will increase by a substantial fraction, but that the total number of tropical storms may decrease in frequency by the end of the century.²³ The uncertainty in potential changes in tropical cyclones contributes to uncertainties in future wet-season rainfall.

---

²¹ Available at: http://stormcarib.com/climatology/ for western Caribbean.
Figure 9. Hurricane paths that have passed within 50 km (light gray circle) of the center of the municipality of Las Terrenas during the period 1851–2014 (source: NOAA 2016).

In addition to inter-annual hurricane variability, multi-decadal changes in frequency have also been observed. Hurricane activity is above average during the phases when the tropical North Atlantic is warmer. If the current SST conditions in tropical North Atlantic persist, high levels of hurricane activity may prevail for the next decade (Pielke et al. 2003) irrespective of climate change linked to changes in atmospheric composition (USAID 2013).

4.1.5 Extreme rainfall, riverine flooding, and landslides

Current extremes, riverine flooding and landslides. Historical trends in daily rainfall extremes cannot be determined at present for Las Terrenas due to lack of rainfall data for the city. Changes in frequency of extreme rainfall events at Samaná Peninsula and Alto Yuna stations (see Table 2) between the periods 1960–1985 and 1986–2012 were analyzed to assess trends, although the results were inconsistent, with some stations showing an increase and some a decrease in frequency of extreme rainfall events (USAID 2013).
Table 2. Results on the frequency changes of extreme (10% and 5%) rainfall events, comparison from the time period 1960–1985 to the time period 1986–2012 in Samaná Peninsula and Alto Yuna region (source: USAID 2013)

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Extreme 10%</th>
<th>Extreme 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nagua</td>
<td>Decrease</td>
<td>Decrease</td>
</tr>
<tr>
<td>Sánchez</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Samaná</td>
<td>Inconclusive</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>La Vega</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Salcedo</td>
<td>Decrease</td>
<td>Decrease</td>
</tr>
</tbody>
</table>

The Northern Coastal Basin is highly influenced by the geomorphology of the peninsula, so although the length of the rivers and streams appear small in length, the drainage area is larger and includes the steep mountains that experience high rainfall. There is one recorded reference to historical flood events in Las Terrenas that resulted from “torrential rainfall”24 for an event on November 5, 1968. More recent reports of flooding in Las Terrenas were referenced in the local press in the years 2004, 2008, 2009, 2012, and 2014. The floods of 2004 were associated with Hurricane Jeanne; however, the remaining reported flood events were caused by moderate to heavy rains that resulted in the overflow of the Caño Seco and Las Terrenas rivers. In the 2012 event, landslides were also reported due to heavy rainfall. A community mapping exercise conducted in 2015 by the Planning for Climate Adaptation Program combined local flood knowledge and topographic information to develop a flood risk map of areas surrounding Las Terrenas River (see Figure 10).

A landslide hazard map of the Dominican Republic (IDB 2010) identifies potentially vulnerable areas by combining data from slopes greater than 32% with areas of high rainfall (greater than 1400 mm). Aside from the landslides during a heavy rain event in November 2012,25 other documented landslide events within the municipality of Las Terrenas have not been documented, although the conditions for landslides (steep slopes, loose soils, and intense rainfall) do exist.

---

24 Available at: [http://www.desinventar.org/](http://www.desinventar.org/).
Future extremes, riverine flooding, and landslides. Projected changes for five-day maximum rainfall and daily rainfall intensity indicate low confidence in the area surrounding Las Terrenas (Climate Wizard). The proportion of total rainfall that falls in heavy events is projected to slightly increase in the median ensemble (3.15 to 1.87 percent), with changes ranging from -21% to +27% by the 2060s. Maximum one- and five-day rainfall projections tend to indicate decreases, particularly in May, June, July, and September when reductions in total rainfall are projected (McSweeney et al. 2012).

4.1.6 Sea level rise, storm surge, coastal erosion

Current sea level, storm surge, and coastal erosion. Between 1901 and 2010, global average sea level has risen by ~0.17 meters, averaging about 1.7 mm year in that time period (IPCC 2013). The rise in global average sea level has accelerated in recent decades to approximately 3.2 millimeters per year.
from 1993 to 2010 (similarly high rates likely occurred between 1920 and 1950). Sea level rise is not uniform across the globe due to local factors including uplift and subsidence. However, understanding local sea level trends in the Dominican Republic, and specifically in Las Terrenas, is difficult due to lack of local data. According to the Permanent Service for Mean Sea Level (PSMSL), there are only two tide gauges located in the Dominican Republic: Barahona (10 years of interrupted data) and Puerto Plata (14 years of interrupted data), respectively.

The mean rate of sea level rise in the Caribbean region over the last 60 years was similar to the global average of approximately 1.8 mm/year (IPCC 2014).

According to IDB (2010), the current extent of the area of Las Terrenas at risk to coastal flooding is about 19 km², extending roughly 20.7 km of coastline from Punta Batala to the eastern edge of the municipal boundary (Figure 11). The at-risk area is associated with low elevations, and extends inland up to 2.5 km at its widest point, encompassing the urban zone of Las Terrenas. Estimates of 100-year return period storm surges were developed for the Dominican Republic, indicating storm surges of about 1.5 meters for Las Terrenas.

Erosion has occurred in some parts of the coastal areas of Las Terrenas, as shown in Figure 12, accelerated in part by human activities (e.g., coastal construction, vehicular traffic, mangrove loss and sand extraction). Bourne et al. (2016) evaluated historical changes in about 17 km of shoreline in Las Terrenas using aerial photography from six years (1979, 1989, 1998, 2004, 2010, and 2015). Three large areas (~17% of the coastline) suffered some erosion. About 35% of the coast experienced accretion and 48% remain with minimal changes. Shoreline has moved by as much as 100 m in some places (in or out). The affected areas include between Punta Bonita and Caño de Jobo, Punta Bobilanza and between Calolima and El Anclón (Figure 13). The causes of these changes are being analyzed but some relation with mangrove loss was preliminary found. Currently areas of severe erosion are observed in the beaches in front of several resorts (Casablanca, Allegro, Dolce Vita and Casa Nina) through Punta Popi and in Balcones del Atlántico.

---

26 According to the Permanent Service for Mean Sea Level (PSMSL), PSMSL.com.

27 The U.S. Agency for International Development (USAID) implemented the Caribbean Disaster Mitigation Project (CDMP), which developed the TAOS model that numerically simulates return periods of different storms surge heights in the Caribbean (1999).
Figure 11. Flood Area Municipal Las Terrenas (preparation: Planning Program for Climate Adaptation, from flood vulnerability map of Dominican Republic IDB 2000).

Figure 12. Storm surge computed by the TAOS model for the Dominican Republic (source: IDB 2014).
Figure 13. Shoreline change in Las Terrenas from 1979 to 2015. The analysis shows mostly stable shoreline (yellow), with accretion (green) in some areas, and erosion (red) in three large areas (source: Bourne et al. 2016)

**Future sea level, storm surge, and coastal erosion.** Simple linear interpolations of IPCC end-of-century sea level rise projections indicate that global sea level could rise by 0.13 m to 0.4 m by 2030 for low and high emissions scenarios, and by 0.20 and 0.58 m at mid-century.\(^28\) In addition to sea level rise, increased storm surge heights are expected over the coming decades, exacerbating flooding and erosion problems in coastal areas, and in effect magnifying the impact of weaker storms. A more detailed study of potential impacts of the sea level rise, including changes in storm surges, requires detailed observational data that are not available for the Dominican Republic (USAID 2013).

### 4.2 SENSITIVITIES AND POTENTIAL CLIMATE IMPACTS TO MUNICIPAL SERVICES AND OBJECTIVES

In this section, information on the current and potential future exposure (Section 4.1) and sensitivity of the municipal objectives and services (Section 3) will be considered together to identify current and potential future climate impacts. Current climate impacts, particularly those associated with flooding, have significantly disrupted municipal activities, and undermined investments. Climate change may exacerbate these impacts, or create new impacts, as a result of projected higher temperatures, more intense hurricanes, and higher sea level and storm surges. In addition, non-climate stressors, such as environmental degradation, corruption, population growth, development

---

\(^{28}\) IPCC, 2014. Interpolation of end of century projections, for RCP 4.5 and 8.5 median emissions scenarios.
patterns, and pollution can harm the functioning of a system, leading to increased sensitivity to climate exposure. This ultimately increases impacts and hinders municipal development progress.

In particular, Las Terrenas has experienced significant crosscutting impacts from flooding— including physical damage to assets, disruptions to services, reductions to quality of life, and increased maintenance and repair costs as a result of rainfall events and storms (Table 3). The urban zone of Las Terrenas is particularly sensitive to flooding impacts, given its low-lying coastal location and proximity to Las Terrenas River that runs through its center. In the urban zone, there is a high concentration of assets and people at risk. Climate change may exacerbate these impacts.

Table 3. Collection of information from different media, regarding some local flood events and impacts in Las Terrenas

<table>
<thead>
<tr>
<th>DATE</th>
<th>DESCRIPTION OF IMPACTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>18/09/2004</td>
<td>Winds and heavy rainfall associated with Hurricane Jeanne led to flooding, damages to trees and power lines—disrupting electricity, loss of businesses, and housing (including severe damages to Barrio Los Pescadores), and disruptions of water supply.</td>
</tr>
<tr>
<td>17/04/2008</td>
<td>Heavy rainfall caused Las Terrenas River to overflow, resulting in inundation of parts of the community, including Taino Square and Kappa Plaza.</td>
</tr>
<tr>
<td>22/01/2009</td>
<td>Heavy rains caused Las Terrenas River to overflow, disrupting traffic, including transport systems.</td>
</tr>
<tr>
<td>10/11/2012</td>
<td>Heavy rains caused the overflow of the Caño Seco and Las Terrenas rivers, inundating Kalinda Square, areas between the police station and Plaza Colonial, and the Plaza Milano. Heavy rainfall also caused landslides from the top of Calle El Carmen and Duarte Codetel level. Casualties and damage were reported in businesses and homes.</td>
</tr>
<tr>
<td>5/11/2014</td>
<td>Heavy rainfall and a malfunction of the waste water treatment plant caused inundation of the hospital, and Sector Barrio Fino. Access to major tourist areas was restricted.</td>
</tr>
</tbody>
</table>

In this section, current and potential future impacts to the municipal objectives and services outlined in Section 3 are discussed. A more comprehensive set of potential impacts by municipal sector or service is detailed in Table 4, below.

4.2.1 Participatory governance

Climate impacts to natural resources, livelihoods, and municipal services can indirectly affect the governance of the municipality of Las Terrenas. Community members have noticed an increase in flood impacts, which they blame on poor municipal planning and services. For example, flooding and erosion of roads, businesses, and housing have directly affected the livelihoods and properties of the community; these problems have increased demands for more transparent and participatory municipal governance. The municipality has been unable to meet these demands because of the rapid development and

29 Sources: Live Las Terrenas, Dominican Today and DRI.
30 2015 Workshop on Land Use Planning and Climate Vulnerability, USAID
population growth underway in the city, which compounds the challenge. Taken in combination, these challenges—the high pace of development, the reliance of its population and economy on climate-sensitive natural resources, and climate change—will likely result in increased climate impacts and exacerbate existing pressure on the municipality to better include community members in its governance and decision-making processes.
<table>
<thead>
<tr>
<th>MUNICIPAL PRIORITIES</th>
<th>SUPPORTING SECTORS</th>
<th>TEMPERATURE INCREASE</th>
<th>SEA LEVEL RISE</th>
<th>CHANGES IN RAINFALL PATTERNS</th>
<th>EXTREME WEATHER EVENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participatory governance</td>
<td>Various</td>
<td>Climate impacts to livelihoods and disruptions to municipal services; increasing pressure on the municipality to better include the community in its governance and decision making processes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harmonious land use</td>
<td>Various</td>
<td>Undermine the efficiency and effectiveness of investments and spatial planning that do not take changes in climate into account</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sewage systems and storm water drainage</td>
<td>Lower wastewater quality due to increased algal blooms and pathogen concentrations, and lower dissolved oxygen.</td>
<td>Flooding of roads that serve as drainage. Potential inundation of sewage system.</td>
<td>Flooding of roads that serve as drainage. Sewer overflows that pollute the environment and expose the population to pathogens.</td>
<td>Damage to infrastructure. Increase of debris that can further block drainage.</td>
</tr>
<tr>
<td>MUNICIPAL PRIORITIES</td>
<td>SUPPORTING SECTORS</td>
<td>TEMPERATURE INCREASE</td>
<td>SEA LEVEL RISE</td>
<td>CHANGES IN RAINFALL PATTERNS</td>
<td>EXTREME WEATHER EVENTS</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase of flies around organic waste, increasing risk of infectious diseases.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td>Thermal expansion of power lines, reducing the amount of power that can be securely transported, risk of line sag and power outages. Increase energy demand for cooling.</td>
<td>Downed power lines, inundated generation, transmission, and distribution assets.</td>
<td>Restricted access for transport of alternate energy supplies. Potential reductions in cooling water. (If hydropower, changes in generation potential).</td>
<td>Downed power lines. Energy service disruption. Increased capital and maintenance costs.</td>
</tr>
<tr>
<td>Built infrastructure</td>
<td></td>
<td>Higher cooling costs.</td>
<td>Inundation or physical damage.</td>
<td>Inundation or physical damage.</td>
<td>Damage to tourism infrastructure.</td>
</tr>
<tr>
<td>Natural resources</td>
<td></td>
<td>Coral bleaching due to ocean acidification. Heat stress on vegetation and wildlife. Increase of seaweed on the beach (especially Sargassum).</td>
<td>Submersion of coastal forests. Loss of wetlands. Increased erosion on the beach. Possible reduction of reef growth.</td>
<td>Possible alteration of natural forest structure and composition. Potential changes in nutrient balance and increased sedimentation.</td>
<td>Physical damage to forests, with greater impact on coastal forests by large storm waves. Physical damage to marshes and mangroves. Physical damage to coral reefs, especially barriers and shallow reefs.</td>
</tr>
<tr>
<td>Tourist activities</td>
<td></td>
<td>Reduced volume and demand for diving due to loss of coral reefs.</td>
<td>Loss of beach area for recreational use.</td>
<td>Reduced activity due to loss of coral reefs resulting from changes in salinity, nutrient</td>
<td>Reduced activity due to loss of coral reefs or reef degradation landscape by storm surges.</td>
</tr>
<tr>
<td>MUNICIPAL PRIORITIES</td>
<td>SUPPORTING SECTORS</td>
<td>TEMPERATURE INCREASE</td>
<td>SEA LEVEL RISE</td>
<td>CHANGES IN RAINFALL PATTERNS</td>
<td>EXTREME WEATHER EVENTS</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------</td>
<td>----------------------</td>
<td>----------------</td>
<td>-----------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Fishing and agriculture</td>
<td>Fishing</td>
<td>Heat stress on fish and marine ecosystem.</td>
<td>Reduced activity due to loss of reefs whose vertical growth rate does not exceed that of sea level rise.</td>
<td>Possible reduction of reef growth. Physical damage to fishing landing sites.</td>
<td>Potential changes in nutrient balance and increased sedimentation. Physical damage to fish breeding sites, and coral reefs, especially barriers and shallow reefs. Reduction of fishing time.</td>
</tr>
</tbody>
</table>

Reduced activity due to loss of reefs whose vertical growth rate does not exceed that of sea level rise.

Physical damage to fishing landing sites.

Heat stress on fish and marine ecosystem.
Impacts to productivity of fisheries.
Impacts to corals and shellfish due to ocean acidification.

Possible reduction of reef growth.
Physical damage to fishing landing sites.

Potential changes in nutrient balance and increased sedimentation.

Physical damage to fish breeding sites, and coral reefs, especially barriers and shallow reefs. Reduction of fishing time.
4.2.2  Appropriate land use
A main goal of the municipality is to develop its first Municipal Land Use Plan. Without an adopted, authorized plan that indicates how and where to develop, and where the major (current and potential future climate-related) risk zones are, the municipality may make poor planning decisions that could put people and assets at risk, increase conflicts, and undermine the efficiency and effectiveness of investments over the long run. For example, the main urban zone of Las Terrenas frequently experiences flooding already, and the coastal areas are subject to erosion. The risk of coastal flooding—including its extent—is projected to increase as a result of climate change in Las Terrenas. Temperature and temperature extremes are projected to increase, with the hottest annual temperatures projected to increase by 1.5°C and 1.8°C by mid-century. An effective land use plan can take current and future climate changes into consideration when delineating land use zoning (no build zones, green spaces, etc.), and in developing regulations (e.g., setbacks). It will be important that the land use plan adequately reflects the changing climate, particularly planning surrounding coastal development and resource management, as sea levels and temperatures will continue to rise.

4.2.3  Water supply
Historically, water supply and treatment facilities have been impacted by past flooding. Since the new water treatment facility was built in 2011, it is less sensitive to climate stressors due to its new elevated and inland location. However, the water distribution network continues to experience difficulties as a result of exposed and cracked pipelines that leak water, leaving them sensitive to flood and contamination impacts.

In the future, climate change may affect the quantity, quality, and reliability of water services. Future storm events may contribute to further damage of the water distribution network, as hurricane storm intensity is projected to increase under climate change over time. Flooding of the water distribution network, or of access roads to the water treatment plant, may impede operations and maintenance, including delivery of diesel to the on-site diesel-powered generator. Because the mean annual rainfall is projected to decrease and the number of consecutive dry days is projected to increase, water supply may be reduced (and further stressed as population increases), potentially leading to acute or long term reductions in water security. Increases in mean and maximum temperatures may decrease water quality and increase water treatment requirements and costs.

4.2.4  Sewage systems and storm water drainage
The municipality does not have a reliable system of storm drains, relying instead on streets to act as conduits for water drainage. The streets habitually flood during the rainy season. Flooding is exacerbated by debris and solid waste, which clogs river ways and leads to overflows even from moderate rainfall events. Further, the sewer system is not currently functioning due to technical issues and also overflows during heavy rains.

31 More detailed hydrologic and water systems modeling is required to better understand potential water security impacts.
Future increases in sea level, storm surge, and heavy rainfall from storms will likely continue to cause sewer overflows and urban flooding, which will exacerbate pollution of coastal waters and beaches, damages to infrastructure, and further expose people to pathogens.

### 4.2.5 Transport

Roads in the urban area of Las Terrenas are critical because they provide access to businesses and services required for the tourism industry, goods movement, and emergency evacuation and disaster response. Flooding and storm surge have inundated roads in the past, which are constructed along flood-prone areas of the Samaná Peninsula. The area’s roads face particularly high impacts from flooding when the Las Terrenas River overflows. Coastal roads have been temporarily inundated from storm surge and the road base is increasingly sensitive to erosion from sea level rise.

Climate impacts to transportation will continue to impede services that are dependent on these roadways. Increases in sea level, storm surge, and riverine flooding will exacerbate flooding of roads, leading to destruction and flooding of roadways and service disruption, affecting the local economy and emergency services. For example, flooding of roads surrounding the hospital reduces the ability to provide emergency service during extreme events and reduces access for tourists visiting the area. Increases in sea level and storm surge will also continue to temporarily inundate and erode the road base of coastal roads, potentially requiring repair or relocation. Increases in temperature may deteriorate road asphalt and increase maintenance costs.

### 4.2.6 Solid waste management

Improper garbage disposal blocks the flow of Las Terrenas and Caño Seco Rivers, increasing overflow, and contributing to other flooding and health impacts.

The impacts of projected increases in hurricane storm intensity will be exacerbated if solid waste continues to obstruct and pollute the Las Terrenas River. Heavy rainfall could cause debris and leachate to escape from the open perimeter landfill, and further pollute the urban area. Additionally, flooding of roads may temporarily limit access for collection of waste. Increases in temperatures can lead to overheating of collection vehicles and may increase odor, requiring more frequent waste collection and more rigorous management of the open-air landfill. Workers and the greater population may also be at greater health risk, including infectious diseases associated with pests (e.g., flies) attracted to uncovered organic waste under warmer temperatures.

### 4.2.7 Electricity

The historically high cost of electricity has led to protests and erosion of trust between the Las Terrenas community and the Luz y Fuerza power company. Power outages are already a routine occurrence in Las Terrenas, and they have led to negative effects on tourism, and health care. Heavy winds and rainfall in the past have downed trees and power lines in Las Terrenas, leading to power outages, which exacerbate existing tensions and economic impacts.
Potential increases in hurricane intensity in the future could lead to increased damages to electricity infrastructure and disruptions to service, broadly impacting the economy, but also leading to higher capital and maintenance costs of energy systems. Flooding of roads may restrict access for transport of energy supply to buildings that rely on backup generators, such as hotels. Flooding and inundation of generation, transmission, or distribution systems can lead to direct damages and power outages. Increases in extreme temperatures can cause thermal expansion of power lines, leading to line sag and potential service disruption. Additionally, increases in extreme temperatures can increase municipal and tourism energy demand for air conditioning, potentially stressing the system. Finally, elevated water temperatures due to extreme heat can significantly impact thermoelectric generation.

### 4.2.8 Human health and safety

The health and safety impacts of past climate extremes (such as flooding and hurricanes) have included loss of shelter, loss of critical services, injuries, and loss of life in Las Terrenas (see Table 2, above). The main public hospital is located in a flood plain (see Figure 10, above), and has recently experienced flooding that resulted in service disruptions.

Vector-borne disease, such as malaria, dengue, and chikungunya, can spread more easily under some conditions created or exacerbated by climate change. Both increased dry and wet weather can lead to increased incidence of these diseases. Though dengue transmission occurs year-round, it has a seasonal peak in most countries during months with high rainfall and humidity. However, the recent spike in dengue incidence throughout the Dominican Republic has been attributed in part to the drought affecting the country, which leads people to store water (increasing the breeding grounds for the mosquitoes that transmit the disease).32

Changes in climate may increase the need for quality health and emergency services. Increases in temperature may cause heat stress, particularly on those working outdoors, and increase the spread of pathogens. Changes in disease incidence may occur as a result of climate change, though more information is required to better understand or attribute changes in Las Terrenas. More intense riverine and coastal flooding would require enhanced emergency response services or otherwise result in more injuries. Meanwhile, future flooding may continue to limit access to the hospital in the center of town.

### 4.2.9 Sustainable tourism and natural resources

Climate impacts to the above municipal objectives and services have direct implications on tourism, as quality services, including safety and security, are important for attracting tourists and building a sustainable tourism industry. Climate impacts on natural resources (specifically beaches and marine health) severely affect the local economy and coastal livelihoods that rely on tourism. Hotels, restaurants, fishing boats, and businesses along the coast have been inundated and damaged from extreme storms in the past.33 The beaches of the municipality of Las Terrenas are eroding, including Batala, Coson, Bonita, Popi and Portillo, due to a combination of natural and human factors. Storms, cyclones and hurricanes, and associated storm surges have caused damage to property and beach

---


erosion. Closures of these facilities and resources have profound impacts on tourism and thus on the incomes and livelihoods of the citizens of Las Terrenas.

These impacts are exacerbated by non-climate–related activities, such as the removal of natural defenses (e.g., mangroves, sand mining, coral reefs), or construction on the coast. Development on marshes reduces the ability of the ecosystem to serve as a natural buffer against flooding. In addition, the capacity of beach areas is routinely exceeded (i.e., it is typical to see 15 to 20 buses of tourists per day on weekends in Punta Popi without proper sanitation or waste removal facilities), stressing the natural environment and worsening impacts.

Dumping of wastewater into the waterways has caused pollution, and landscape degradation, and harmed marine life. The reefs and, ultimately, the beaches are being degraded due to decades of overfishing and uncontrolled sediment runoff. Studies conducted in the Las Terrenas area show that local live coral coverage of the reef system is just from 5 to 11% (Reef Check 2016).

Tourism, and the natural resources it depends on, will continue to face significant impacts given future sea level rise, increasing storm surge, coastal erosion, and temperatures. Aside from permanent inundation of low-lying lands, and increased flooding impacts on assets and people within the flood plain, increases in temperature will also stress marine biodiversity and impact recreational fishing and diving. Ocean acidification due to increase in carbon dioxide concentrations, will put marine ecosystems, particularly coral reefs, at even greater risk of rapid and permanent degradation (USAID 2013). The beaches are already eroding and gradually disappearing, due to the combination of gradually rising sea levels and degrading reefs, acidification/bleaching, and human-induced impacts (i.e., inappropriate development) whose rate may increase under climate change (USAID 2013).

4.2.10 Well-educated and skilled citizenry
Flooding, sea level rise, and storm surge can damage schools and training centers, particularly the multiple education centers located along the coast in Las Terrenas, preventing them from providing intended education to Las Terrenas community members. Flooding can also reduce access to these schools and training centers, making attendance more difficult. Furthermore, climate impacts to the health of the local population can reduce the ability of students and faculty to attend school and training.

4.2.11 Fishing and agriculture
Populations that depend on fishing and agriculture for their livelihoods in the municipality of Las Terrenas are particularly vulnerable to climate impacts. Rising ocean temperatures and ocean acidification are radically altering aquatic ecosystems. Climate change is modifying fish distribution and the productivity of marine and freshwater species. This has impacts on the sustainability of fisheries and aquaculture, and on the livelihoods of the communities that depend on fisheries. The effect of sea level rise means that coastal fishing communities are in the front line of climate change, exposed to rising waters and increased storm surges. Moreover, fishing itself is contributing to the vulnerability of marine resources. Uncontrolled fishing practices and diving are increasing the sensitivity of the marine ecosystem, particularly coral reefs, and the ecosystem services they provide. Some species are being overexploited due to tourism demand. Some impacts of climate- and non-climate stressors that are
pertinent to fishing are described in the above sections, and include direct damage to fishing boats and anchors, increased pollution due to sewage runoff and increased river sedimentation.

High temperatures, sea level rise, storm surge, and ocean acidification will further stress fish populations and the marine ecosystems that support them. Changes in climate can also impact the agriculture sector; increases in temperature and a tendency for reductions in mean annual rainfall may stress crops and decrease productivity, significantly affecting the livelihood of those who depend on the income and/or food generated through agriculture.

4.3 ADAPTIVE CAPACITY

The preceding section identified current and potential future climate impacts on critical municipal objectives, sectors, and services. However, the potential for harm from climate change can be minimized through reductions in exposure and sensitivity. This ability to achieve this is referred to as adaptive capacity. The adaptive capacities of individuals, households, and institutions in Las Terrenas varies according to their access to information, ownership of or access to resources, skill sets, and the ability to assess climate issues to make more informed decisions.

The 2013–2016 Municipal Development Plan delineates the strengths, weaknesses, opportunities, and threats facing the municipality. Some of the identified weaknesses and threats currently limit adaptive capacity, including:

- Existing conflicts of interest between municipal stakeholders (e.g., private sector and community)
- Lack of community awareness on environmental conservation, especially with regard to waste
- Lack of community motivation to participate in technical courses
- Lack of coordination within the municipality
- Lack of adequate revenue transfer from the central government, and a lack of municipal budget
- Lack of skilled middle level municipal staff, difficulties in municipal staff recruitment (compounded by low wages), disorganization of council activities, and lack of internal communication within municipal departments
- Lack of available municipal land (existing land is private and very expensive)
- Lack of a technical and financial plan for the development of a land management plan and cadastral survey
- An inability to implement and enforce existing ordinances and regulations

Despite these challenges, the Municipal Development Plan also identified important strengths that indicate areas of existing adaptive capacity, including:

- Staff leading the municipal departments are trained, including some specialists
- The mayor is motivated to address the municipal problems
- The municipality has good relations with National government agencies
• The municipal council carries out activities with the participation of civil society

Further, the Plan identified external opportunities that may enable the achievement of municipal objectives. These include:

• Presence of an economically strong private sector in the city
• Major real estate and tourism development
• Global recognition of Las Terrenas as a tourist destination
• Government support for infrastructure development
• Presence of foreign investment
• Presence of resident foreign communities and associations, with a strong awareness of climatic and environmental problems

There are examples of adaptive capacity activities already underway in Las Terrenas that provide some foundation for further action. These include:

• Infrastructure and land use planning:
  – As noted in the municipal weaknesses, to date the municipality of Las Terrenas does not have a land use plan. However, Las Terrenas is one of four cities participating in the USAID Planning for Climate Adaptation project. As part of this project, participatory land use plans will be developed. This vulnerability assessment will help to inform the development of the Municipal Land Use Plan and ensure that climate vulnerabilities are taken into consideration. By integrating the consideration of climate change vulnerabilities into the land use plan, the municipality will be able to identify priority investment areas in light of current and future climate and non-climate risks, in order to build a more resilient municipality.

• Management and conservation of coastal habitats and watersheds:
  – In Las Terrenas, NGOs, the municipal government, and local businesses have formed the Alianza Arrecifal de Las Terrenas to promote protection of the coral reefs and economically viable alternatives to fishing. The hotel Balcones del Atlantico collects a surcharge of one U.S. dollar per night to fund reef conservation and dune stabilization (USAID, 2013).
  – The municipality has created a community advisory unit focused on sustainable development acknowledging that social participation and inclusivity increases the ability to respond to both climate and non-climate stressors.
  – Several local organizations (Fundación Mahatma Handhi, Samaná Smiles, Río Limpio, Basura Cero en Las Escuelas) are already taking actions to reduce solid waste to solve an environmental situation that in turn exacerbates problems associated with flooding.

• Disaster risk reduction, early warning, and early action:
  – As part of the ongoing USAID Improved Climate Information Program (2015-2018), improvements in development of and access to climate information, characterization of extreme weather, and early warning systems for Las Terrenas are underway. The Program is part of a broader set of programs that include USAID Planning for Climate Adaptation project, and focus on building municipal capacity to manage climate risk.
  – Municipal and national actions and approaches to floods and other disasters address the current need to some extent. Further examination of these practices could enhance adaptive capacity.
While these examples do illustrate some strides toward improving adaptive capacity in Las Terrenas, to date many of the planned actions to support the achievement of the municipal objectives have not been implemented. These activities and goals (described in part in Section 2) include building community and institutional capacity through training and investments in education, increasing access to financial resources through improved tax revenue collection, improving municipal services through new investments, and increasing civic engagement in municipal planning. If achieved, these improvements will be important contributors to building a municipality with a higher adaptive capacity. This is particularly true if changes in climate are taken into consideration in the planned activities.

4.4 BROADER VULNERABILITIES

Taken together, the exposure, sensitivity, and adaptive capacity of Las Terrenas can be assessed to better understand climate vulnerabilities.

The urban zone of Las Terrenas, a main driver of development, is particularly vulnerable to climate variability and change. The area is exposed to current and future coastal and riverine flooding due to its low-lying elevation, its proximity to the coast, and proximity to Las Terrenas and Caño Seco rivers. The urban zone contains a high concentration of people and infrastructure services that are already experiencing flood impacts. These impacts are exacerbated in part due to the sensitivity of the infrastructure and services, many of which are in poor condition, and/or do not properly function. A lack of adaptive capacity contributes to this overall vulnerability, as Las Terrenas lacks resources and capacity to improve current conditions. Climate change is expected to increase both the extent of riverine and coastal flooding due to an increasing intensity of storms, higher sea levels and storm surge heights; this increases the vulnerability of Las Terrenas as a whole.

Important municipal economic sectors and services are highly vulnerable to climate variability and change. Critical infrastructure located in flood prone zones—including hotels, roads, the hospital, buildings, schools, and electricity distribution networks—have all experienced past impacts and continue to be vulnerable. The majority of tourism infrastructure assets—that are vital to the economy—are vulnerable to coastal flooding (Figure 14). Beyond flooding, temperature increases, and extreme events threaten to disrupt services, damage assets, and increase operation and maintenance costs.

34 No chronic flooding events are reported for the rest of the river and streams of Las Terrenas: Cosón, El Jobo, Salado, and El Portillo.
Beaches, reefs, fish and other marine life—the natural resources that are at the heart of Las Terrenas’ tourism-based economy—are all highly vulnerable to climate variability and change. These resources have been degraded due to a combination of climate and non-climate stressors such as polluted flood waters (flooding impacts enhanced by poor drainage, lack of wastewater treatment, lack of solid waste management), shoreline erosion (enhanced by removal of sand and mangroves, increasing exposure to sea level rise and wave action), and ocean acidification (enhanced by increasing carbon dioxide). The municipal coastal area and its supporting infrastructure and natural resources are vulnerable to impacts and damage from increases in temperature and are especially threatened by rising sea levels and future storm surge conditions. In addition, increasing demands for infrastructure services (new hotels, more services) as the tourism sector expands, will exacerbate future vulnerability of natural resources.

The population of Las Terrenas is vulnerable to climate change particularly in the urban zone where there is a greater percentage of disadvantaged community members. These residents have less access to financial resources to help recover from or adapt to climate impacts, compared to the rest of the municipality (Figure 15). The community as a whole is susceptible to increased health and safety risks resulting from climate change impacts. The people of Las Terrenas are highly dependent on the region’s natural resources for their livelihood (through subsistence fishing and agriculture and from tourist-based services), which are increasingly vulnerable to direct climate impacts. The urban center of the city, where local and tourist commercial activity is concentrated (Deverchere 2011), is highly vulnerable to flooding.
Figure 15. Percentage of poor households in the urban zone of Las Terrenas overlaid with the flood risk map of the Las Terrenas and Caño Seco rivers (indicated by the shaded area).

5 APPLICATION TO LAND USE PLANNING

Climate change adds a new dimension to developing effective land use plans, strategies, and projects. If climate change is not considered, degradation of critical resources, infrastructure, and development benefits may result over time. This vulnerability assessment takes a first step in identifying the climate vulnerability of municipal objectives, including the location of exposed assets and populations that point to critical risk areas for land use planners to take into consideration. This climate vulnerability assessment can inform land use planning in Las Terrenas by helping the municipality to assess the extent to which municipal assets and people are susceptible to and/or unable to cope with the impacts of climate variability and climate change.

It can be used to answer questions such as:

- What geographic areas are at risk? Which areas are at most risk? What geographic locations are most vulnerable to increases in sea level rise, storm surge heights, or inland flooding?
- What social and economic activities are at risk because of their location? How vulnerable are our marine fisheries to warming temperatures and ocean acidification?
- How many people in Las Terrenas are currently affected by climate-related disasters? How many more will be affected in the future without changes in land use?
• What infrastructure assets and infrastructure services are at risk? How vulnerable is our municipality’s water supply to intense or sustained drought? How vulnerable is the primary road network to severe flooding events?

This vulnerability assessment is meant to serve as a resource when applying the Dirección General de Ordenamiento y Desarrollo Territorial (DGODT) Land Use Planning Guide's climate vulnerability tool (see side bar). The Climate Vulnerability Assessment Tool is part of a set of climate tools in the DGODT's land use planning tool box. These climate tools directly support the process of integrating climate change into municipal land use planning—including identifying needed areas of technical expertise, climate information, climate vulnerabilities, and climate adaptation measures. Information on climate vulnerability is integrated directly into the land use planning territorial diagnosis and analysis—an intensive process that involves data collection, stakeholder consultations, and analysis of the municipality. The territorial analysis provides useful information for undertaking the vulnerability assessment, including identification of the “critical themes” of a municipality, and important economic sectors, services, climate and non-climate stressors, and people.

This assessment takes a first step in characterizing current and future vulnerabilities to the municipality’s development priorities that can be incorporated into the municipality's land use planning decisions and policy development. Based on this information, the municipality can consider, for example:

• How are current climate risks incorporated into land use planning/zoning? Are these zones well respected?
• What are the implications of climate change on land use planning and zoning? Are important resources, facilities, and services at risk? Could important development objectives be compromised? How might climate change affect the physical, economic, and social efficiency, health, and well-being of the municipality and its residents?
• How can land use planning better address needs of current and future vulnerable populations?

Effective land use planning can remove sensitive resources, infrastructure, and people from harm. This can be done in a variety of ways to either restrict or discourage settlement and development from areas at risk to current and future climate conditions. Economic incentives and disincentives (fees or taxes) can be employed to re-direct development and settlements from these areas to less vulnerable locations. Laws or regulations can restrict or limit activity in them to reduce the dangers to health and economic well-being. Effective plans can still make use of high-risk areas by targeting more appropriate land uses to them. Recreational facilities like baseball parks, for example, can be placed in riskier areas since they are not critical to health and livelihoods, and occasional flooding may not do them harm.
Effective land use plans can be difficult to design and implement, and established development patterns are often hard to change. However, addressing the risks directly and promoting sustainable growth will pay dividends in the longer term, particularly under a changing climate. Funds previously needed for costly repairs and rebuilding of assets and services in high-risk locations can be invested instead in sustainable improvements of municipal services and amenities. Every day that loss of life is avoided, that tourism is supported by functional services, and that assets continue to provide services during and after extreme events will enhance the welfare and well-being of the citizens of Las Terrenas.

6  RECOMMENDATIONS FOR NEXT STEPS

This report is intended to provide inputs into a participatory process that engages a broad range of municipal actors in Las Terrenas. In this process, participants will consider: 1) municipal development objectives and how they may be vulnerable to current and future climate, and 2) how these vulnerabilities can be taken into account in land use planning processes to improve the resilience of Las Terrenas now and in the future. Achieving these objectives requires strengthening this assessment through direct validation, identifying and conducting deeper analysis of critical vulnerabilities, and ensuring that climate change information is included in the land use planning process. These recommendations are provided to facilitate the process of improving the climate resilience of Las Terrenas.

**Strengthen, refine, and take ownership of this preliminary vulnerability assessment.** This preliminary assessment serves as a starting point for the municipality to explore how climate impacts, non-climate stressors, and adaptive capacity contribute to current vulnerabilities of critical development objectives of Las Terrenas, as well as how climate change may exacerbate these vulnerabilities. The results demonstrate that the economy and population of Las Terrenas is largely dependent on its natural resources, which sustain livelihoods and the key economic sector (tourism), but are highly vulnerable to climate variability and change. The municipality will draw on the knowledge of key stakeholders in Las Terrenas to bring in their own experiences, and discuss and vet the assessment’s findings on existing municipal priorities, and on the climate stressors, impacts, and adaptive capacity that contribute to (or lessen) their vulnerability. Consideration and refinement of this preliminary assessment by municipal planners and stakeholders will also assist their decisions about whether adaptation measures should be focused more on reducing exposure, reducing sensitivity, and/or increasing adaptive capacity.

**Continue to strengthen municipal capacity in climate change and climate vulnerability assessment.** Municipal technical staff, decision makers, and other stakeholders should continue to enhance their understanding of climate change and the potential impacts that climate change may have on municipal priorities and services. This report begins by identifying important municipal development goals and objectives, and then considers how these objectives are vulnerable to current and potential future climate hazards. Developing an understanding of how climate change is relevant to municipal objectives and decisions, as well as the synergistic impact of other non-climatic factors, is an important first step for municipal stakeholders seeking to build a climate-resilient municipality.
Strengthen municipal capacity to integrate the climate vulnerability assessment and adaptation findings directly into land use and municipal planning. Las Terrenas’ municipal planners and stakeholders are undertaking efforts to integrate climate change into land use planning. Resources are currently under development that will assist this integration, including guidance, training courses, tools, and documents that are being developed as part of the USAID climate programs—in partnership with Las Terrenas and other municipalities—as well as other sources. At the same time, many of the municipal activities outlined in the Municipal Plan (2013–2016) provide an opportunity to transform and increase the adaptive capacity of Las Terrenas, ultimately reducing municipal vulnerability if changes in climate are taken into consideration in the planning and implementation of these activities.

Implement an ongoing, adaptive management approach, including monitoring climate-related data, impacts, and vulnerabilities. Adapting to a changing climate is not a one-time activity; rather, as the climate changes and the municipality grows, so too will Las Terrenas’ need to adjust its strategies to ensure the safety and vitality of the municipality. Monitoring conditions is a key element of this process of adaptive management, so that decisions are grounded in the best available data and the lessons learned from previous actions. While stakeholder engagement is an invaluable source of practical information, municipal analysis and decisions can be strengthened by drawing on improved data and information (i.e., climate data, impacts data, and information on non-climate stressors). The municipality could benefit, for example, from the development of a database of information, and may consider investing in monitoring systems to improve understanding of current climate-related impacts.

Take immediate action to address climate risks, today. This assessment is useful to Las Terrenas to help the municipality identify and prioritize adaptation measures, the next step in the USAID Planning for Climate Adaptation project. A lack of complete information need not be an excuse to delay action pending further research. Some impacts and their causes are already clear, and climate change may exacerbate them. For example, Las Terrenas is experiencing today damage of coastal buildings and infrastructure due to flooding and erosion, and could implement measures now to address the elements of vulnerability. For example, the municipality could reduce exposure—e.g., by placing restrictions on shoreline development or moving structures further inland. Efforts could also be taken to reduce sensitivity: e.g., flood-proofing infrastructure and elevating structures on stilts. Exploring the individual components of vulnerability will also help planners to determine which policies, regulations, investments in hard infrastructure, ecosystem-based approaches, or other types of actions may be most effective to address a particular vulnerability.
REFERENCES


