Building Capacity in Two Vulnerable Areas of the Colombian Coastal Area

Martha Vides, Paula Sierra, Francisco Ariasis, Tahia Devisscher, Thomas E. Downing

1. Background

Adaptation was defined in 1992 by the United Nations Framework Convention on Climate Change (UNFCCC) as 'all adjustments in socio-economic systems designed to reduce vulnerability to climate change'. Since then this concept has evolved and gained relevance along with mitigation. Whereas mitigation refers to limiting global climate change by reducing greenhouse gas (GHGs) emissions and enhancing carbon sinks, adaptation aims at moderating adverse climate change effects through a wide range of system-specific actions at the local and the regional level.

The identification and implementation of sound adaptation strategies, however, is limited by the still poor understanding of the natural and socio-economic systems' responses to climate change effects. This generates uncertainties in the development of appropriate adaptation options that are economically efficient, technically and politically feasible, environmentally sound, culturally compatible and socially equitable. Adding to those challenges are that the costs and benefits of adaptation options, especially the non-technical ones, are difficult to measure and express in a common unit.

In developing countries, especially in the least developed ones and those most vulnerable to the effects of climate change, the capacity to adapt is generally much lower than in industrialized nations. This is generally due to a lack of financial resources, poor access to technological and scientific information, weak research and development capacity, the lack of highly skilled human resources, and weak institutional capacity. Moreover, national wealth and in particular its distribution play an important role in a country's capacity to adapt. In this respect, developing countries with a high poverty incidence are highly vulnerable.

The high vulnerability of developing countries is also due to the fact that climate change effects are generally not contemplated in their development planning, resulting in a visible lack of preparation to deal with the potential impacts of climate change. Sea-level rise (SLR) accelerated by climate change is one of the various effects to be considered by these countries because of the potentially negative impact it could have on their most vulnerable coastal areas.

Colombia is a developing country prone to the conditions and vulnerabilities described above. The first phase of the Netherlands Climate Change Studies Assistant Program (NCCSAP) that assessed the vulnerability of the Colombian coastal areas to potential SLR identified serious constraints for developing adaptation strategies in this country. The following summarizes these key constraints.

Firstly, legislative, institutional and organizational structures are highly vulnerable due to the lack

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of a normative framework that includes coastal zone management. Secondly, the economic feasibility of developing adaptation strategies is critically low, because the country is not prepared to assume the financial costs of implementing adaptation measures to SLR. Thirdly, the technical feasibility is also low due to the lack of technical capacity among institutions and scientific uncertainties on the subject. Fourthly, cultural and social vulnerability is high, because of the low quality of life conditions along Colombian coastal zones. Lastly, violent conflict that currently affects a large portion of the country negatively influences most of the development activities in the country.

The second phase of the Netherlands Climate Assistance Program (NCAP) was developed to identify adaptation strategies that could be successfully implemented in Colombia and build adaptation capacity considering the conditions and constraints described above. The approach of the second phase, however, varies in that it analyzes the situation from a local-level perspective. The second phase focuses on assessing the vulnerability and identifying adaptation measures to contribute towards the local adaptive capacity of two vulnerable areas of the Colombian coast: Cartagena de Indias (Caribbean coast) and San Andres de Tumaco (Pacific coast). Box 1 briefly presents the factors that need to be considered in order to build local adaptive capacity.

Box 1. Contributing towards Creating Adaptive Capacity at the Local Level

To identify adaptation strategies and contribute towards creating adaptive capacity at the local level, it is necessary to understand the local context including the state of the natural systems, the population needs and living conditions, the productive systems, the socio-cultural organizations, the institutional capacity and the local management and development strategies. Although climate change effects such as SLR, can have large impacts at the local level, there is a general lack of awareness among local decision-makers and community members about these potential impacts and consequently about how to prevent them. Therefore, creating adaptive capacity at the local level requires the participation and involvement of local stakeholders including decision-makers, companies and community members. It is also important to increase the level of knowledge concerning the vulnerability of the local territory and the potential impacts of climate change effects so that stakeholders can use this information to take the necessary decisions and actions to prevent impacts and reduce risks.

2. Objectives and Methodology

2.1 Scope and Objectives

The second phase of the NCAP follows the guidelines of the National Integrated Coastal Zone Management (ICZM) Policy which uses an integrated approach to generate effective adaptation strategies to implement at the local and national level. The objective of this study is to evaluate the vulnerability of key economic sectors to climate change effects in the Colombian coastal area and to identify strategies to build capacity to cope with potential SLR-related impacts (see table 1). To do so, the study adopts a local-level approach and focuses on two vulnerable areas of the Colombian coast identified in the first phase of the NCAP project as critical areas with the highest capital value at risk due to potential SLR. The study first conducts a sectoral vulnerability assessment in each area (considering tourism, agriculture and fisheries), with special focus on the population living in poverty conditions. It then identifies suitable adaptation measures and strategies within the framework of the National ICZM Policy. The project also generates public awareness and builds adaptive capacity through meetings and workshops with the different stakeholders. The results of the study are expected to set demonstrative pilot actions to prepare the country for the development of a National Policy on Climate Change Adaptation.

Table 1. Second Phase NCAP-Colombia Objectives

General Objective
To evaluate the vulnerability of key economic sectors to climate change effects in the Colombian coastal area and to identify strategies to build capacity to cope with potential SLR-related impacts.
Supporting Tasks
• To assess the sectoral vulnerability of two selected coastal areas, with special focus on the population living in poverty conditions. • To identify and analyze possible adaptation measures and strategies within the ICZM Policy framework. • To generate public awareness and build adaptive capacity through meetings and workshops with the different stakeholders.

According to the guidelines established under the ICZM policy, an integrated assessment of the study areas is carried out by evaluating potential biophysical, economic and social impacts due to SLR. Serving to meet both the capacity building and adaptation goals, stakeholders are engaged in the development of the project. In the study, the primary stakeholders are those considered to be the most affected and vulnerable populations to climate change risks for a specific human system. As such, they are seen as the direct beneficiaries of the project. The secondary stakeholders are those who are able to influence the success or failure of the project.

2.2 Methodology

The methodology used in the project (see figure 1) combines the adaptation framework proposed by Klein and Nicholls (1999), the UNDP-GEF Adaptation Policy Framework (2003), the DINAS-COAST project methodology, and the Framework for Planning and Decision-making Process proposed by Sharifi et al. (2004). The framework recognizes that local-scale strategies should be consistent with and inform national-scale policies. The framework also assumes that systems change over time, and that vulnerability and adaptation capacity to current experiences will not necessarily be the same in the future.

Figure 1. Methodology Framework NCAP-Colombia

Under this framework, an initial review and description of the system is first conducted. Then a vulnerability assessment is developed to analyze potential impacts upon the system. A scenario development process is also included in this stage. An adaptation decision matrix is then applied to identify and assess alternative policy options that respond to different adaptation measures to SLR. Finally, a policy exercise approach is conducted to downscale national policy options that reduce climate risks at the local level. Finally, the identified adaptation strategies are analyzed and the most suitable ones are selected.

System description: The first stage of the methodology examines the biophysical and socio-economic systems of the study areas to identify current problems and opportunities. Descriptions of current economic activities, especially those activities that increase vulnerability to climate risks are also included. In general, the system description is based on existing assessments and published and available studies, expert judgment and stakeholders' feedback. Efforts were made to use the most recent and updated information sources.

For the biophysical component of this stage, the main sources of information are previous studies carried out in the study areas. These provided sufficient information to gain a general idea of the current state of the natural systems. Stakeholders also provided feedback on this information and assisted in identifying current pressures on the natural system. These pressures were identified with the stakeholders through a problem analysis carried out for each area based on the Driving Force, Pressure, State and Impact - DPSIR methodology. As a result of this analysis, the stakeholders recognized the need to reduce the study area for Cartagena. It appeared that the administrative limits were considered to be too complicated to manage because of the large differences and variety of issues and pressures threatening the area. The study area was therefore limited to the portion of territory between La Boquilla (the northern limit of the Ciénaga de la Virgen) and the urban area of Cartagena, including the Cartagena Bay system.

The description of the socio-economic system of Cartagena is based on secondary information available on-line, as well as on statistical and analytical documents. Unfortunately, studies that analyze the current socio-economic situation of Tumaco were not found.[1]

The first stage of the methodology contributed towards the development of a current scenario for each study area that led directly into the vulnerability assessment.

Vulnerability Assessment: The second stage of the methodology focuses on the vulnerability assessment of the natural and socio-economic systems of each area. For the natural systems, the term susceptibility was preferred as it refers to the degree to which a system is open, liable, or sensitive to climate change effects. This approach considers the system's natural resilience and resistance to damage, the risk of hazards and the acquired resilience. The environmental susceptibility index model assumes that resilience is greater for a system that is less damaged. The susceptibility depends not only on the systems' characteristics, but on other pressures imposed upon the system as well. Box 2 explains the vulnerability and resilience of a natural system within the SLR context. The socio-economic vulnerability, on the other hand, refers to the society's economic, institutional, technical and cultural ability to prevent or face changes in the socio-economic system.

Box 2. Vulnerability and Resilience

Within the SLR context, vulnerability of the natural system can be referred to as the effects of an event on a given ecosystem and the capacity of this ecosystem to survive over time. This survival capacity depends upon the ecosystem's ability to recover quickly from shock, injury or depression (resilience). It is important to note that resilience can either be natural (intrinsic to a given system) or acquired (if it is gained from previous damage). Therefore a natural system's vulnerability is decreased as its resilience increases.

The vulnerability and susceptibility of the coastal areas of Cartagena and Tumaco are assessed from two different approaches: 1) considering current circumstances without taking into account the possible effects of SLR; and 2), considering different scenarios that include socio-economic changes and different levels of SLR.

1 For the vulnerability assessment this gap was complemented with primary information collected in a fieldwork campaign conducted in Tumaco.

Firstly, the natural system's susceptibility was calculated using the information obtained from the previous stage, as well as expert knowledge and local stakeholders' perceptions. The overall susceptibility index is composed of six indicators (see figure 2, annex 1) used by the Colombian Environmental Information System (SIAC in Spanish). To calculate the overall natural susceptibility index (BSI) for each area, the results of each independent indicator were computed, resulting in a general numerical value for each case. Each indicator is weighted in accordance with the perceived importance allocated to each one of them. In general, the most important indicator is considered to be ecosystem quality, followed by ecosystem coverage. The other four indicators (water quality and hydrographic processes integrity, recovery areas, land use and hazards) receive the same weight as they are considered to be equally important in defining the natural systems' susceptibility in the studied areas. It is very important to understand the entire process given that the general value does not provide as much information as each indicator does by itself. While understanding the entire process is critical in defining the measures to be taken, the susceptibility index shows the extent to which the natural system is prone to damage and degradation. The larger the general value obtained, the more susceptible the areas are from a natural system's perspective. Annex 1 presents the values for the classification of the susceptibility into: high, medium high, medium, medium low and low.

Secondly, the causality analysis of the socio-economic and environmental problems in both study areas contributed towards the recognition of relevant variables to evaluate the socio-economic systems' vulnerability. The indicators for the socio-economic vulnerability index were selected considering the results of the DPSIR analysis conducted in the first regional workshop[2], as well as available information for each area. The socio-economic vulnerability index (SVI) is composed of 5 categories (see figure 2) and the following indicators: population indicator; public investment indicator; natural disaster risk indicator; human capital factor; and life quality indicator (includes sewage disposal, water supply, waste recollection, cooking fuel, house wall materials and house floor material). The socio-economic vulnerability index values are allocated in the range 0 to 100, an increase in the value indicates that the vulnerability diminishes. Annex 2 gives the values for the classification of the vulnerability into: very high, high, medium-high, medium, medium low and low.

Figure 2. General Scheme for Vulnerability Assessment

The first susceptibility and vulnerability assessment only reflects the current state of the natural and socio-economic systems. To evaluate future possible situations, future scenarios are developed considering different changes to socio-economic and environmental characteristics and different

2 The Driving Force, Pressure, State and Impact - DPSIR analysis was conducted in Cartagena during the first regional workshop with key stakeholders in July 2005. The DPSIR was used with two purposes: 1) to prioritize, based on the stakeholders' perception, the social, economic and ecological sectors that are currently vulnerable to extreme climate events and which could be at risk in a "business as usual" scenario; and 2) to establish a set of priority impacts that could serve to guide the selection of indicators on which to develop the capacity building and adaptation measures.

levels of SLR. An important input to the scenario development process is the perception of the stakeholders in relation to the areas at risk of flooding due to an SLR.[3]

Scenarios extend to the year 2019. The reason for using this particular year is due to the Colombian national government's *Visión Colombia II Centenario 2019*. This document, which portrays the "Vision 2019", is an ambitious proposal that develops a long term vision of prosperity for the country. However, although it focuses mainly on the socio-economic aspects of development, many of these aspects have a direct or indirect effect on the environment. It is important to note that although scenarios extend to the year 2019, SLR levels are not projected for that year, but are based on the analysis of satellite images and risk maps for each area.

To summarize, while topographic characteristics are not modified for the development of scenarios, socio-economic variables and SLR levels are modified to gain a better understanding of the potential impacts of SLR on the selected study areas considering the susceptibility of the natural systems and the socio-economic system's vulnerability.

Adaptation Decision Matrix: The third stage of the methodology considers the information gained about the system's behavior in the previous stage and establishes a functional and structural relationship among major elements. The Adaptation Decision Matrix (ADM) is a tool used to relate given local circumstances to adaptation measures that are likely to be implemented in the short term, given the characteristics of the measures, the local needs and the institutional capacity. This process involves expert judgment and analysis carried out by the project team. It is implemented in an interactive manner, maintaining feedback with the stakeholders and following a step-by-step process to estimate the potential impacts for each policy adaptation strategy. The fields used in this matrix were developed based on different sources, but mainly on the Checklist and Database for Evaluating Adaptation Measures and Strategies, developed by the Stockholm Environment Institute (SEI). This tool facilitates recording the range of responses that make a policy option suitable and its implementation feasible for each specific area (see figure 3).

Figure 3. Process for the Adaptation Strategies Identification, Pre-feasibility Assessment and Prioritization

Policy Exercise Approach (Policy Option Analysis): The last stage of the methodology is based on different steps to analyze different adaptation strategies. While the DPSIR identifies root causes of environmental problems that can be directly related to the vulnerability of coastal areas to SLR, the policy options are suggested to address those roots causes. The strategies are grouped according to the subject they cover, for instance, technology, knowledge, economics, governance or demographics, among others. After establishing a clear definition for each group, the policy option analysis is carried out considering the following criteria for each alternative: effectiveness, efficiency, equity, political feasibility and implementation capacity (see figure 4). The main strategies are selected by a scoring exercise and analyzed in more detail using the criteria presented in figure 3.

3 During the regional workshop carried out in Cartagena, the stakeholders were asked to identify areas prone to flooding using as a scenario an extreme situation caused by the sum of the high tide and heavy rain that took place in the city in 2003 flooding almost 60 % of its territory. They were also asked to point out the possible effects of such an event.

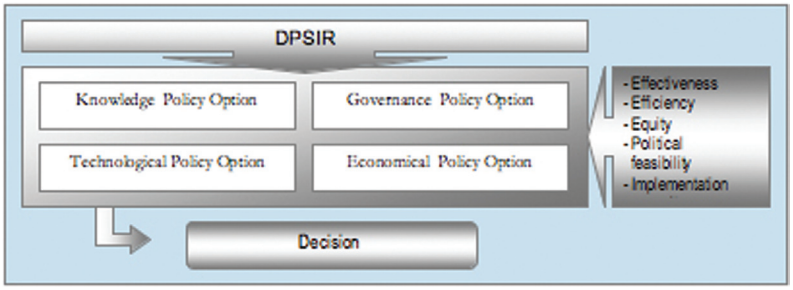


Figure 4. Scheme for the Policy Option Analysis

3. System Description

The Colombian coastal area is highly vulnerable to sea-level rise (SLR). However, the impacts of SLR may differ between the Caribbean and Pacific coasts and vary from one specific case to another. Cartagena de Indias is located on the Caribbean coast and San Andres de Tumaco on the Pacific coast (see figure 5). These areas were identified as critical areas in the first phase of the NCAP because they revealed the highest capital value at risk due to potential SLR. The different impacts that SLR may have on these two areas are explained by the distinct characteristics of each system briefly presented here.

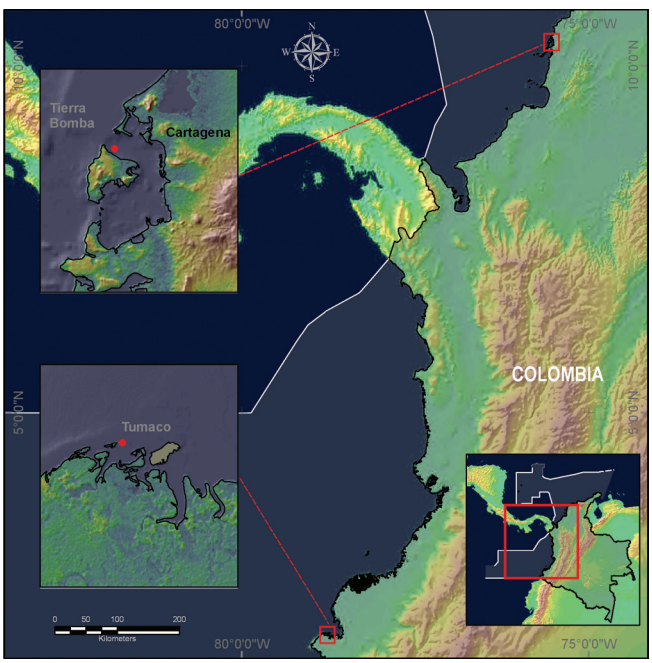


Figure 5. Case Studies: Cartagena de Indias and San Andres de Tumaco

3.1 Cartagena de Indias

The Tourist and Cultural District of Cartagena de Indias, also known as La Heroica, is a large seaport on the north coast of Colombia. Founded in 1533 it was a major center of early Spanish settlement in the Americas, and continues to be an economic hub and, a popular tourist destination.

Cartagena is the capital of the Department of Bolivar that encompasses 44 municipalities covering 6 natural regions. The territorial extension of Cartagena is 609km^2 of which 8.86% belongs to the urban area and 91.15% to the suburban and rural area. According to the National Statistical Administrative Department (DANE), in 2005 Cartagena had 1,030,149 inhabitants with 92% living in urban areas. Approximately 90% of the population of the Cartagena is located in Cartagena Bay.

The population of Cartagena is facing a transitional stage. The rural population growth rate is decreasing mainly due to population migration to the cities seeking better economic opportunities, and to forced displacements to the urban areas due to violence in the countryside. This dynamic has contributed significantly to urban expansion. According to the Network of Social Solidarity, in 2003 Cartagena received 7,138 displaced families due to armed conflict. This equals 31,136 people representing 2% of the total population displaced in Colombia. Generally, the displaced families settle in suburban areas which have had no prior urban planning. Statistics on land tenure indicate that 60% of the settlers are involved in illegal land occupation. The Nelson Mandela District, with the highest concentration of displaced families, has developed without any urban planning. Consequently, the area has poor living conditions and lacks basic amenities such as social and public services. This situation generates environmental problems and is a source of risks for Cartagena's inhabitants.

According to the SISBEN[4], since 2001 the number of people living in poverty and inequitable conditions has increased, reaching 54% of the population of Cartagena by 2003. The results of the SISBEN for education show that only 37% of the population living in poverty conditions graduates from high school, 39% only completes primary school and 22% does not have any education level at all. Despite this situation, since 2000 basic education coverage has been growing. By 2003 Cartagena reached 84% education coverage of basic education. Also, in 2003 Cartagena had 1,360 beds (public and private) available to support the health care demand of 978,000 inhabitants. That indicates a ratio of 1 bed per 720 inhabitants.

Among Cartagena's main economic activities are the commercial and artisan fisheries, trade, industry and tourism. The port of Cartagena exports 14% of the total tons of fish exported by the four main ports of Colombia, and imports 10% of the total tons that enter the country. In general, the trade balance shows an increasing tendency in tonnage handled over time due to the growth of exports and the stable behavior of imports. According to DANE, in 2003 about 34% of the employed population was working in the trade sector. In addition to trade, industry also represents an important economic activity in Cartagena. Industries located in Cartagena are characterized by a high capital/labor ratio, which restricts employment opportunities in the sector. While industrial employment makes up approximately 4% of the total employment in the city, the industrial production of Cartagena represents 6.38% of the industrial national GDP and 98% of the industrial production in the Department of Bolivar.

Weather conditions in the research area are characterized by low rainfall and mostly sunshine. Cartagena's temperature ranges from an average high of 31°C to an average low of 24°C throughout the year. The average humidity in this area is approximately 90% with a wet season that extends from May to September with higher humidity in October, and a dry season from January to April. Cartagena receives about 100cm of rain a year and the rainfall average per month is 90mm. About 30km southeast of Cartagena there is a complex of islands, peninsulas and inner water bodies that form the insular and continental areas. Within the insular area, the national protected parks Corales del Rosario and San Bernardo represent the largest protected marine area of Colombia. The principal inner water bodies within the continental area are Cartagena Bay, the Ciénaga de la Virgen and the Ciénaga de Juan Polo, all connected by a complex system of lakes and channels.

4 SISBEN (System for the Selection of Beneficiaries of Social Programs) is an index widely used by the system of social programs in Colombia. The SISBEN index is a function of a set of household variables related to the consumption of durable goods, human capital endowment and current income.

Cartagena Bay has an area of 82.6km^2 with an average depth of 16m and a maximum depth of 30m. It is connected with the Caribbean Sea through several channels. In the north, the opening between Tierrabomba Island and Lake Bocagrande has a 2km wide jetty located 0.6 to 2.1m deep. In the south, there are three channels: Bocachica, the current sailing channel, 30m deep and 500m wide; the Shipyard channel, 2m deep and 500m wide; and the channel between the islands of Draga and Abanico, 2m deep and 300m wide. The Channel of the Dike is located in the south of the bay. This channel was constructed in 1650 to connect the Magdalena River with the Cartagena and Barbacoa Bays. The Channel of the Dike is about 100m wide and between 2 and 3m deep and has a flow between 100 and 1,100m^3/s. Cartagena Bay is classified as an estuary due to the presence of the Channel of the Dike. In general, the saline stratification is the main factor that influences the dynamics of the bay, formed by the flow of water from the channel, the winds and the tide.

The waves that most frequently hit the coast of Cartagena Bay are produced by the wind coming from the northeast[5]. The average height of these waves is 0.25m. The average height of the waves produced by the wind coming from the west is 0.5m. The marine currents in Cartagena Bay are about 0.05m/s and travel parallel to the coast until Bocagrande. In Bocagrande the currents are stronger reaching 0.10m/s, causing erosion of the coastline. The coastal area of Cartagena is influenced by a semidiurnal tide regime. There are two high tides and two low tides every 24 hours. The range between these is very short (max. 60cm) which categorizes the tide regime as micro-tide. The sea-level in Cartagena is usually low at the end of April and increases during the wet season reaching its maximum level in October. This annual variation is around 40cm without considering the tide. Added to a high tide, this variation can produce an increase of almost 1m in the mean sea-level of the bay during daylight hours in October. This phenomenon causes the well-known annual floods of the low zones of Cartagena, overflowing pipes and opening the bar of the Ciénaga de la Virgen. Among the major disasters experienced in Cartagena during the 1990s, all have been related to atmospheric conditions. A total of 17 disasters were caused by the above discussed SLR.

Cartagena's coastal morphology is characterized by a deficit of sediments resulting in erosion of the coastline[6]. This erosion process was induced by the jetty of Bocas de Cenizas built in 1936, causing the deposit of the Magdalena river's sediments in a submarine canyon located in front of Barranquilla. The jetty is also a barrier to the natural coastal sediment transport between the Guajira and Cartagena. As a result, Cartagena has the problem of a deficit of sediments and erosion of the coastline[7]. The evident coastal erosion and the interest to conserve the area's historical and cultural patrimony motivated local decision-makers to implement protection measures some decades ago. However, the engineering work carried out has been developed without any specific plan and without any assessment of the potential impacts.

With regards to land use, 42% of the study area has no apparent use and is covered with natural vegetation, 14.3% is covered by an urban zone of mixed use, 12.3% by commerce, and 14% by agriculture. Cartagena Bay is completely surrounded by urban areas, except for small areas located in the south of Pasacaballos and Membrillal. The port and industrial activities are located on the east margin of the bay. This area is used for residual water disposal. Since the 1950s, residual water coming from the port and industrial activities has been dumped into the bay without any treatment, along with 40% of the city's sewage water.

As a result of human activities and settlements, the ecosystems in Cartagena show different levels of degradation. In general, and particularly in the north and in the Ciénaga de Tesca, the ecosys-

5 Waves' direction calculated using the software "OLAS" (developed by the CCCP with support from GIOC Spain).

6 Sediment transport calculated applying the methodology of Cerc and Kamphuis, using adjusted parameters proposed by Shoones and Theron (1994, 1996).

7 Throughout the last 12 years the coastal line between Galerazamba and Bahia de Barbacoas displayed important changes associated with coastal processes. This part of the coast is dominated by unconsolidated sediments and low topography. Erosion and sedimentation rates of 10m/year are considered extremely high in comparison to the global standard; nevertheless, in some sectors of Bocacanoas and Flecha de Galerazamba this rate can be as high as 18 and 53m/year. The regional accumulation and erosion processes can be associated with the Galerazamba arcillious diapirism.

tems have been highly affected by extractive processes and unsustainable practices. The ecosystems in Cartagena include coral reefs, sea grass beds, mangroves, coastal lagoons, and beaches. Among them, coral reefs are the most visible and well studied. The most affected are sandy beaches and sea grass beds. Beach ecosystems are equivalent to 90% of the coastal profile of Cartagena. The main impacts on this ecosystem come from human activities over the past decade and erosion due to the strong winds coming from the north[8]. Sea grass beds have also been seriously affected in Cartagena. Only 134ha of sea grass beds can currently be found in the area including seaweed, mollusks, crabs, sponges and sea urchins. Sea grasses are threatened mainly by the untreated sewage disposal and the continental water inflow. Mangrove ecosystems have also been heavily exploited in an unsustainable manner despite the services and resources they provide. It is possible to observe small relicts of mangroves surrounding the islands facing the industrial zone (Mamonal), on the borders of inner streams connected to the Ciénaga de la Virgen and on the borders of Tierra Bomba and Baru Islands. Mangroves also grow in some areas of the Channel of the Dike.

The largest coastal lagoon in the area is the Ciénaga de la Virgen. It is separated from the sea by La Boquilla's bar and is surrounded by mangrove areas and human settlement. Additionally, it is gradually losing area due to the constant inflow of sediments that result from the continental erosion. Sedimentation processes have favored urban expansion towards the inner part of the lagoon. On the eastern flank it receives streams that carry water coming from nearby human settlements, farming and cattle areas. South and west flanks are occupied by human settlements and the construction of a new road along its border. In this area waste water drains from some of the most densely populated areas of Cartagena. The western flank is constantly under pressure from the population of La Boquilla where settlements are constantly growing and causing erosion. Juan Polo's marsh is in the northern part of the Ciénaga de la Virgen. This area is well preserved and is the most influenced by the ocean dynamics within the complex. The central part of the Ciénaga de La Virgen complex shows an island formation, caused by sediment deposition, where mangroves are growing. In general, the environmental degradation in the Ciénaga de la Virgen has affected all the productive activities, especially fisheries, aquaculture and small-scale agriculture.

3.2 San Andres de Tumaco

The Colombian Pacific basin is nearly 80,000km^2 and is located in the western region of the country. San Andres de Tumaco is the second largest city of the Colombian Pacific coast and covers three small islands at the south end of Tumaco Bay: The Viciosa, Tumaco and El Morro.

According to the 2005 census, the municipality of Tumaco had 161,490 inhabitants, 56% living in the urban zone, 36% in the urban peripheries and 10% in the rural areas. Urbanization in Tumaco has increased over time with a 6% increase between 1993 and 2005. Population dynamics are difficult to predict in this area due to migration patterns that are influenced by economic and social factors such as drug trafficking, displacements, the supply of public services and others (Tumaco Municipal Development Plan 2002 - 2004). The population in Tumaco is comprised of different ethnic groups: 92% have black origin, 6% have mixed origin and 2% are native. The population density in the area is 38.3 hab/km^2.

In 2005, almost 50% of the population in Tumaco had unsatisfied basic needs (NBI). 24.1% of the people in Tumaco and 17.6% of the households in the area are in conditions of misery. The SISBEN classification indicates that 62% of the total population was living in conditions of extreme poverty in 2004. In that year, 76% of the population living in the urban area was registered in the SISBEN, as well as 50% of the population living in the rural area.

The level of illiteracy in Tumaco is around 24.6%. Generally, the education in Tumaco is highly deficient. The low education quality is reflected in the tests of the Colombian Institute for Higher

8 The impact caused by erosion processes in these areas is mitigated by sediment deposition during the wet season.

Education Promotion (ICFES) carried out in the area showing results below the national average. Among the main problems of the education sector in Tumaco are poor planning, and deficient quality and coverage. With regards to public health, the rural sector in Tumaco has 17 health centers that work with different limitations. Among these limitations are the lack of administration capacity, low coverage, deficient attention capacity and equipment, and difficult access to the service.

Concerning basic household services, both the drinking water distribution network and the sewage system in Tumaco are deficient. The water system is over 30 years old and the maintenance is of bad quality. Moreover, more than 35% of the urban population and over 90% of the rural population lacks this service. As a result, the population mainly consumes water from rivers without proper treatment. The sewage system is highly deficient. It covers only 5% of the houses located in the districts of Pradomar, La Florida, Miramar and La Ciudadela. While some of the population disposes of residual waters into septic wells, 90% deposit it directly into the sea without any type of treatment causing contamination problems in the area.

The main economic activities in Tumaco are agro-industry, fishing and shrimp cultivation. The production supplies both domestic and international demand. The physical characteristics and geographical location of the port in Tumaco makes it a convenient port for oil export. Therefore, Tumaco's main export is palm oil. In 2004, the port registered foreign trade of 39,336,840 tons. Despite not recording imports, the trade displayed a growth of 14% compared to 2003. In the rural area, the main activities for men over 10 years old are agriculture and fishing, while for women the main activity is house labor and mollusk fishing. Generally, agriculture is the main generator of labor in the area, where palm oil plantations provide employment to 4,000 people.

The temperature in Tumaco ranges from an average high of 33°C to an average low of 18°C. Rainfall is constant throughout the year (annual mean 250cm), with heavy rainfall in the months of April, May, June and January and less rainfall in the months of February, October and November. The humidity is relatively high, with measures that lie between 80 and 88%, reaching 100% at night.

Tumaco has rich water resources due to high rainfall and rivers that come from the 5 basins that form Tumaco's inlet. Rio Rosario has influence over 60% of Tumaco's inlet and is formed by four sub-basins: Caunapi, Alto Rosario, Bajo Rosario and Mejicano. Rio Rosario and Mejicano drain directly into the sea and run through 25.2% of Tumaco's territory.

The coastal zone of Tumaco is divided in three zones: a low belt, a flat area and a high area. The 3 to 5km wide low belt is affected by tides. The tide regime in Tumaco is semidiurnal with two high tides and two low tides every 24 hours. The average for high tides is 2.807m and 0.294m for low tides. The mid range is 2.513m and the average SLR is 1.530m. The inter-tidal zone is divided into inter-tidal platforms without vegetation cover and floodable platforms with vegetation cover. The first areas are where sediments cluster and are completely covered with water during high tides. The second areas are periodically flooded by tide action. They are covered mainly with mangroves and ferns, and other vegetation that can stand halophytic conditions. These areas can also receive sediments from fluvial systems. Adjacent to the low belt described above, is a region that varies from 35 to 45km wide. Bordering this region are higher areas that reach over 500m above sea level.

Most of the beaches in Tumaco are relatively well conserved because they have not faced major human pressures. Beaches in Tumaco can be divided into: 1) ample beaches: over 20m wide, with some vegetation, dunes and littoral cords that are less than 70cm in height; 2) moderate beaches, between 5 and 20m wide; and 3) narrow beaches, less than 5m wide. Locations with potential for tourism in the bay of Tumaco are the beaches of Bocagrande, el Morro Island and the Mira River. In geomorphologic terms, the coastline of Tumaco has been constantly changing over the

past 3 decades. According to the surveys held by the Contamination Control Centre of the Pacific (CCCP) in Tumaco (2002), the changes in morphology are mainly attributable to erosion and sedimentary processes induced by ocean dynamics affecting the area such as high tides and the effects of the "El Niño" event in 1982/83 and 1995/96. To a lesser extent, human activities have also impacted Tumaco's coastline. Activities that had a large impact were the artificial refill of Tumaco Island in the 1960s and the joining of La Visiosa Island with Tumaco in the 1970s.

Tumaco's forest cover represents 60% of the total territory. The ecosystems close to the coastline are formed by tropical rainforests. These rainforests characterized by small temperature variations and high precipitation and humidity, are the most complex ecosystems in terms of structure, stratification and species diversity. Tropical rainforests cover 42% of Tumaco's territory. In general, forests resources in Tumaco are exploited for local use and trade. Some of the species in these forests are recognized as highly threatened due to over-exploitation, fragmentation and contamination, among other reasons. Away from the coastal areas, agricultural systems and cattle ranges are expanding.

In littoral areas the most predominant vegetation is mangroves. The Nariño Department has the largest mangrove cover of the country with a total of 149,735ha. Most mangrove species can be found in Tumaco. Mangrove ecosystems cover 29% of Tumaco's total area (97,400ha) and can especially be found in the Guandarajo estuary, in the Mira river estuary, in some areas between cliffs and recent littoral cords on the southern part of Tumaco Island, and on the beaches of Bocagrande, Cabo Manglares, and Ancon's Bay. In general, mangroves have been affected by human settlements, as well as by unsustainable extraction activities, aquaculture (mainly shrimp farming), and tannin production.

4. Vulnerability Assessment and Scenarios

Determining and reducing vulnerability is a critical part of building adaptive capacity to potential climate change effects such as SLR as it considers present situations and possible future conditions. It is important to consider the results of this assessment in local planning to reduce the associated risks of SLR in the study areas and enhance resilience to current climatic variability and extremes, and consequently to future climate change. The vulnerability assessment includes the evaluation of the natural systems' susceptibility and the socio-economic systems' vulnerability.

4.1 Natural Susceptibility Assessment

Using the results of the first regional workshop and available information, the natural susceptibility assessment is estimated based on the indicators described in annex 3. These indicators are computed to obtain the overall natural susceptibility index (annex 1) for each area.

4.1.1 Cartagena de Indias

The natural susceptibility of the study area in Cartagena – formed by Cartagena Bay and the Ciénaga de la Virgen – is determined by the following results.

Ecosystem coverage

The Ciénaga de la Virgen and Cartagena Bay have three main types of marine ecosystems: mangroves, sea grasses and beaches. Over the past 20 years, mangroves in these areas have deteriorated as a consequence of wood exploitation and other human-related pressures, resulting in a total loss of 10 to 24% in the Ciénaga de la Virgen and 90% in Cartagena Bay. The susceptibility of these ecosystems to this indicator is considered to be medium-low. Sea grasses are also highly susceptible to changes in the surrounding environment and a loss of over 92% of sea grasses has been calculated for the entire area. As a result, this indicator defines this ecosystem as highly susceptible. Beaches experience a constant loss and gain of area due to climate variability and

ocean dynamics, resulting in erosion and accretion in some areas. Beaches that experience highly erosive processes and are therefore highly susceptible are located in the areas of Castillo Grande, Bocagrande, El Laguito and Tierrabomba.

Water quality and hydrographic processes integrity
The result is not as negative as expected despite the fact that that water bodies are used as receptors of untreated waste in Cartagena. The values obtained show that water quality is not a hazard for associated flora and fauna, indicating medium-low susceptibility.

Ecosystem quality
Unplanned urban and industrial development in the Ciénaga de la Virgen and Cartagena Bay has resulted in a lack of sewage treatment that has deteriorated the ecosystem quality in these areas. Additionally, waste accumulation and infrastructure have interrupted water exchange between the Ciénaga de la Virgen and the sea, resulting in further degradation. The ecosystems in Cartagena Bay are also affected by the fuel and oil coming from the port. This has resulted in associated macrofauna loss and high contamination levels. In general, sea grasses are threatened by fragmentation and are highly susceptible. Mangroves are also fragmented and suffer from different types of human-induced pressures. As a result, this ecosystem's quality has a medium level of susceptibility.

Recovery areas
Studies carried out to evaluate the system's state in Cartagena have identified the need to protect and recover some areas. CARDIQUE proposes a system of protected areas for mangroves in Cartagena Bay and in the Ciénaga de la Virgen. Considering that protective measures for mangroves are intended, but are not in place yet, this ecosystem has a medium-high level of susceptibility to this indicator. The protection of sea grasses on the other hand, is not supported by any regulation; therefore, this system is highly susceptible.

Land use: habitat conversion
Cartagena Bay is occupied by urban and industrial areas. Industry has a significant impact on the ecosystem due to the constant disposal of wastes and fuels into the bay. Fishing activities and wood exploitation also take place where mangroves are still present. The main factors threatening mangroves are housing construction (urbanization) and agricultural expansion. As a result, this indicator values this ecosystem in a medium-high level of susceptibility. The beaches also have a medium-high level of susceptibility because they are invaded and altered by new building construction.

The land use in the Ciénaga de la Virgen area is characterized by settlements of people living in poverty conditions. In general, people in this area exert significant pressure on the ecosystems. The land in this area is mainly used for urbanization, agriculture, fishing, and aquaculture. Flooded areas where mangroves used to grow have been colonized, deforested and filled out with different materials to make them suitable for building construction. This process has taken place without planning, resulting in a complete lack of basic infrastructure for public services and waste disposal. This area also receives an inflow of untreated wastes from other areas of the city with an estimated volume of 15 tons of organic matter per day. Additionally, urbanization and agroindustrial activities affect the natural water exchange with the sea and produce agrochemical waste that affects the natural system.

Hazards[9]
The climate hazards for this area are: liquation, soil erosion and flooding risks. Based on the information analyzed, these are not considered to be severe for the natural system (medium susceptibility).

9 This evaluation combines the information provided by risk maps for different areas in Cartagena, and expert knowledge that helps to determine the impacts that such hazards may have on the natural system.

The ecosystems in Cartagena face several pressures that make them highly vulnerable, diminishing their capacity to cope with the effects of climate change. The overall susceptibility for sea grasses is high, for mangroves is medium and for beaches it varies from low to high depending on the location. Sea grasses face constant hazards that have resulted in an almost total loss of its coverage area. Given the degradation of this ecosystem and the lack of measures to reduce the pressures affecting it, its recovering capacity is highly susceptible. Among the mangroves in Cartagena, the most threatened are the ones located in the urban areas of Tierra Bombas and the Ciénaga de la Virgen. These mangroves face tremendous pressure as a result of urbanization and human activities. Nevertheless, it is important to consider that efforts to recuperate and regulate the use of mangroves in Cartagena are intended. For beaches, erosion and building expansion are the main pressures affecting their susceptibility making them highly susceptible in some areas of Cartagena.

In general, the ecosystems' qualities are degraded by unsustainable use and land use conversion processes, and to a lesser extent by water quality and hydrographic processes. Fragmented ecosystems are the most susceptible natural systems in Cartagena. In the study area, natural systems' susceptibility is directly related to human presence: high susceptibility is mainly the result of the impacts caused by human activities and settlements.

4.1.2 San Andres de Tumaco

The natural susceptibility of Tumaco is determined by the results presented below. The focus is placed mainly on mangroves since there is no available information to evaluate the susceptibility of beaches for all the indicators.

Ecosystem Coverage[10]

Mangroves in Tumaco present a medium-high to high level of susceptibility for this indicator. These ecosystems are deteriorated mainly as a result of pressure exerted on them by local communities that use them as a source of fuel and wood. In some areas, the impacts are caused by agriculture expansion (mainly coconut plantations) and urbanization, as well as by human activities and settlements.

Water quality and hydrographic processes integrity

Water quality data obtained by INVEMAR's marine quality network (2001 to 2004), does not exhibit threatening values, despite the fact that water bodies in this area are used as receptors of untreated waste, due to a lack of sanitary services and appropriate waste disposal. The values obtained show that water quality has a medium-low level of susceptibility and is not the main hazard for associated flora and fauna in the area.

Ecosystem quality[11]

In general, the ecosystem quality of Tumaco's mangroves is not considered to be in a critical state. However, the mangroves located in the most populated area of Tumaco are highly susceptible. In this area, the main threats to mangroves are extraction and unplanned urban development (without a proper sewage treatment). Moreover, major causes of pollution are the occasional hydrocarbon spills that occur in the area which have a large impact on mangroves and associated fauna.

Recovery areas

In the most populated area of Tumaco, natural recovery processes are very unlikely to occur leading to a permanent loss of mangrove areas. No protective measures have been taken by the government in Tumaco to protect mangroves. Despite this, some areas are naturally recovering from highly destructive processes that took place in the 1960s and 1970s as a result of tannin extraction. These recovering areas, however, are small compared to areas that are currently being

10 Information used to calculate this indicator for Tumaco's mangroves represents just one time period (1997), as this was the only information available.

11 This indicator combines mangrove area loss, associated representative parameters and Holdridge's complexity index.

degraded. As a result, Tumaco's mangroves are considered highly susceptible systems to climate change effects.

Land use: habitat conversion
Tumaco is occupied by agricultural and human settlements. Densely populated areas present greater land conversion processes resulting from urbanization. In these areas mangroves are used as fuel and wood. Other areas are being converted into agricultural areas and to a lesser extent to aquacultural areas mainly to develop shrimp pools. These activities put tremendous pressure on mangroves, particularly because recovery processes are very slow. Regulations to restrict and guide the sustainable use of natural resources do not exist in Tumaco. Therefore, the susceptibility level of mangroves is high for this indicator.

Hazards
Tumaco's mangroves and beaches have a medium level of susceptibility to important climate hazards such as tsunamis, erosion, and flooding.

Mangrove ecosystems in Tumaco face major pressures that make them susceptible, diminishing their capacity to adapt to potential impacts caused by climatic events. The lack of local measures and planned management to conserve these ecosystems make degradation processes that affect their susceptibility more difficult to control. This situation is particularly alarming close to Tumaco's urban area, where mangrove ecosystems face pressures from urbanization, direct exploitation and generally low environmental quality due to waste water disposal in the area. In general terms, it is estimated that mangroves have a medium level of overall susceptibility. For beach ecosystems, the lack of available information complicated their susceptibility assessment in Tumaco. Nonetheless, considering that the daily tide variation contributes towards building the response capacity of these ecosystems, the overall susceptibility of beaches is estimated at medium-low to medium level.

4.2 Socio-economic Vulnerability Assessment

Socio-economic vulnerability is based on the technical, institutional, economic and cultural ability of society to cope with or prevent impacts to the socio-economic system. Socio-economic vulnerability is influenced by the susceptibility of ecosystems and vice versa. It is also influenced by the infrastructure, location, living conditions, governance and social dynamics that define the level of empowerment and access to resources that determine the range of viable options to react to difficult situations. Socio-economic vulnerability is estimated based on the indicators described in annex 4. These indicators are computed to obtain the overall socio-economic vulnerability index (annex 2) for each area.

4.2.1 Cartagena de Indias
The socio-economic vulnerability of Cartagena is determined by the results obtained for each indicator presented in Table 4.

According to stakeholders' perceptions, the sewage system is not able to cope with the city's annual flood due to deficient maintenance. This indicator shows that 23% of the urban area and 50% of the rural area have a medium level of vulnerability.

The overall socio-economic vulnerability of the urban area in Cartagena is estimated at medium to medium-high level. Neighborhoods located on the southern border of the Ciénaga de la Virgen exhibit high socio-economic vulnerability. The north-western urban area and neighborhoods along Santander Avenue exhibit high and very high vulnerability levels. The neighborhoods close to Chambacu and San Lorenzo lagoons exhibit high and medium-high vulnerability. Finally, the southern area of Tierra Bomba presents medium and medium-high level of vulnerability.

Table 4. Vulnerability of Cartagenas's Socio-economic System

Life quality	According to stakeholders' perceptions, the sewage system is not able to cope with the city's annual flood due to deficient maintenance. This indicator shows that 23% of the urban area and 50% of the rural area have a medium level of vulnerability.
Services	Approximately 50% of Cartagena's rural area has high vulnerability and about 40% very high. However, 66.5% of the urban area has medium-low vulnerability.
Housing	While 40% of the rural area in Cartagena has medium-low vulnerability, 72% of the urban area has low vulnerability.
Human capital factor	Both urban (36%) and rural (43%) areas have a medium-high level of vulnerability, denoting the deficient coverage of basic education in Cartagena. Access to education in the rural area is particularly difficult.
Natural disasters	Both urban (84%) and rural (73%) areas exhibit low vulnerability. This means that most of Cartagena's population feels safe in the place where their houses are located.
Public investment	In general terms, Cartagena has low vulnerability regarding public investment.
Population indicators	The total study area (97% of the rural area and 95.5% of the urban area) exhibits very high vulnerability.

The overall socio-economic vulnerability of the rural area of Cartagena is estimated at a medium to medium-high level. According to the assessment, the population located in the rural area of the Ciénaga de la Virgen presents an overall medium-high socio-economic vulnerability. A similar situation occurs with the population close to La Boquilla. In these areas mainly firewood is used to cook and sanitary services are deficient.

4.2.2 San Andres de Tumaco

The socio-economic vulnerability of Tumaco is determined by the results presented in table 5.

Although the results show significant differences in life conditions between the urban and rural areas, the overall socio-economic vulnerability for both is estimated at medium-high to high level. In the Tumaco and Visiosa Islands over half of the secure areas have high vulnerability. Also, Miramar urbanization presents very high vulnerability to SLR. On the Island of El Morro, most of the secure areas show a medium-high level of vulnerability, while the secure areas of the continental area of Tumaco have a high level vulnerability to SLR. Concerning the rural coastal area of Tumaco, 48.4% of the area exhibits a high level of vulnerability and 22.6% a medium-high level of vulnerability.

Table 5. Vulnerability of Tumaco's Socio-economic System

Life quality	The three secure areas* of Tumaco's urban area, present medium-high vulnerability. On the other hand, 80.6% of the rural coastal area has high vulnerability and 19.4% very high vulnerability.
Services	This indicator estimates a medium vulnerability for the 3 secure urban areas of Tumaco. In the rural area, 32.3% of the houses exhibit very high vulnerability and 48.4% high vulnerability.
Housing	The housing in Tumaco's urban area shows a medium level of vulnerability. However there are neighborhoods in each of the 3 secure urban with high vulnerability, such as Luis Avelino Pérez on the Island of Tumaco, Pradomar on the Island El Morro and Ciudadela in the continental area. In the rural area, 93% presents a medium-high level of vulnerability for the housing indicator.
Human capital factor**	In general, Tumaco's urban area exhibits a low vulnerability with respect to the human capital factor, except for el Pindo and Ciudadela which have medium-low vulnerability. In contrast, the entire rural area has a very high vulnerability.
Natural disasters	Although the classification of the urban area corresponds to the secure areas, the public perception of the location of houses in risk areas exhibits medium-high vulnerability for Tumaco's island and La Viciosa. Continental areas present medium-level of vulnerability and el Morro Island a medium-low level. A large part of the coastal rural area (45%) shows very high vulnerability.
Public investment	Given that Tumaco applies the Broke Law (*Ley de Quiebra*), investment resources are low as they are redirected to pay public debt. As a result, no investment is made in disaster prevention and housing, two of the variables with the heaviest weighting in this indicator. Consequently, the urban and rural areas have a very high vulnerability.
Population indicators	Both the rural and urban areas exhibit a very high level of vulnerability, except for Chajal which shows a high level of vulnerability.

* The secure areas of Tumaco are areas that have been identified as safe in case of natural events such as tsunamis. Three of these areas located in the urban area have been selected for the study to demonstrate that a potential SLR may affect even the most secure areas.
** To analyze the human capital factor, the Sisben is used.

4.3 Scenarios under the 2019 Vision

The scenarios described hereafter do not assume to predict what will happen, but are merely descriptions of different possibilities the study areas may face according to their present situation and

the way local governments are planning their future development. Scenarios are placed in the year 2019, when the National Vision is to be fulfilled by the present administration.

From the socio-economic point of view, the national vision expects an annual economic growth rate of 6% and a significant improvement in the quality of life of the population. It envisages a 100% urban coverage of both water supply and sewage treatment (compared to a current 97.4% and 90.2% respectively) and a rural coverage of 82.2% for water supply (compared to 68.6%) and of 75.2% for sewage treatment (compared to a current 57.9%). Moreover, 100% coverage in basic education and 40% in higher education (the current rate is 25.7%) is planned. Furthermore, by 2019, Colombia plans to integrate its marine area (44.8% of the total territory extension) into the country's development strategy, enhancing the growth of potential productive sectors such as tourism (by eight times) and bio-trade.

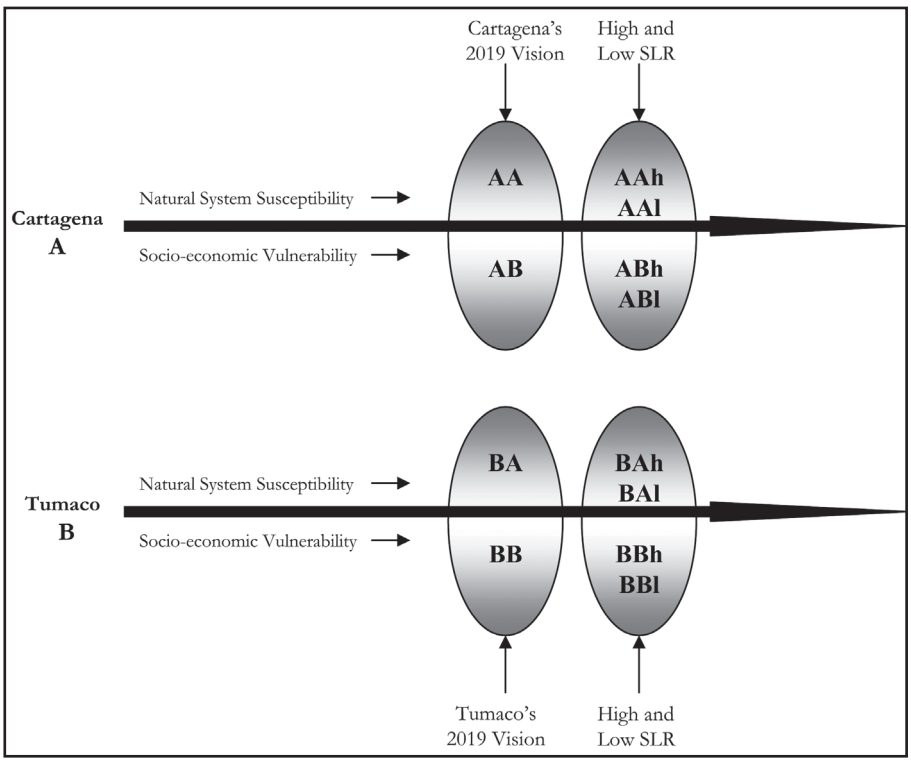
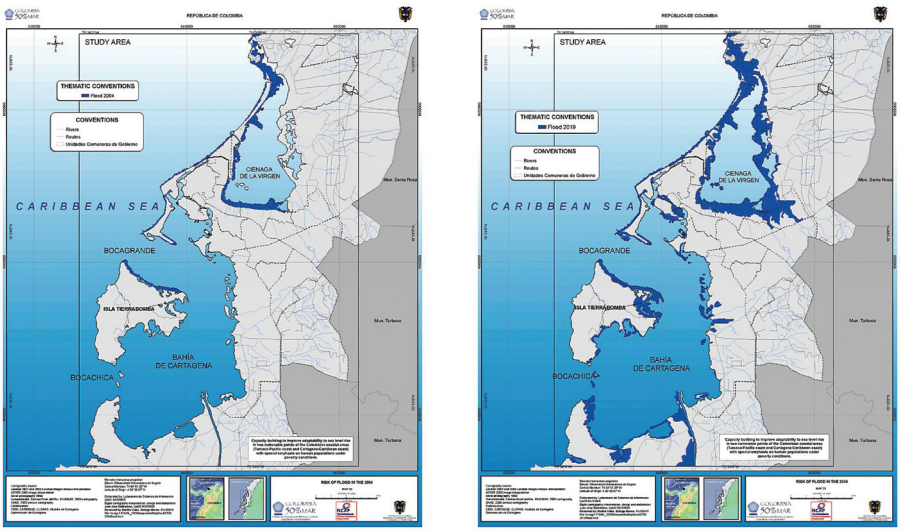


Figure 6. 2019 Scenarios Development Framework

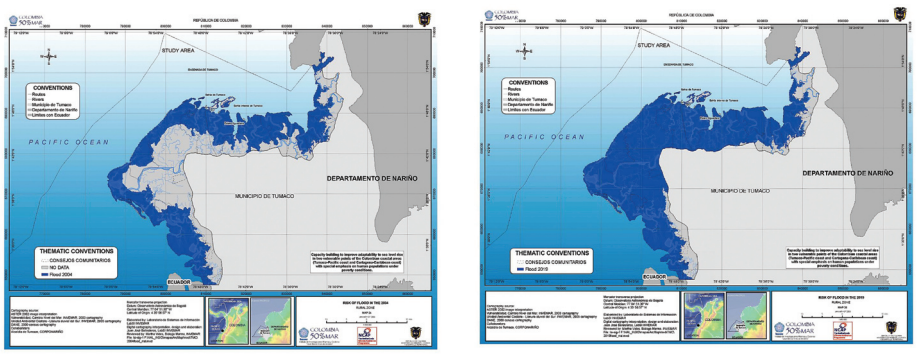
On the subject of the environment, Colombia's vision for 2019 implies a development based on the sustainable use of natural resources involving society in the different decisions to be taken on environmental matters and on the analysis of costs and benefits of development strategies. The need to integrate environmental considerations into all development planning is recognized. As a direct result, the national vision aims for a reduction of environmental impacts and pressures causing biodiversity loss and ecosystem degradation. It also aims for an increase in the adoption of prevention and mitigation measures in the country.

The following scenarios (see figure 6) are developed with the objective to foresee the effects that a change in the socio-economic variables (bought about by the achievement of the Colombian Vision 2019 objectives) may have on the natural systems' susceptibility and socio-economic vulnerability of the study areas.



Low SLR High SLR

Figure 7. Cartagena de Indias SLR Levels for 2019 Scenario Development



Low SLR High SLR

Figure 8. San Andres de Tumaco SLR Levels for 2019 Scenario Development

Box 3. Cartagena's Vision for the Environment

Cartagena's vision for the future is of a developed city, exploiting its potential in a sustainable manner, positioned highly in the tourism sector both nationally and internationally. According to the Territorial Organization Plan (POT), Territorial Environmental Management Plan (PGAT), and the Colombian 2019 Vision, Cartagena will integrate environmental considerations into its territorial policies and planning. This means introducing measures to ensure the protection and sustainable use of its natural systems, as well as improving the quality of life of the populations that depend directly or indirectly on these systems.

Thereafter, different SLR levels are added to the scenarios to assess the possible impacts these may cause on the systems (see figure 6). Two SLR levels are considered: low and high. The high levels used for the 2019 scenario development are based on severe flooding scenarios that the study areas faced in the past (see figures 7 and 8). This was useful, because stakeholders could relate to past events to recognize the impacts of SLR and on this basis propose adaptation measures.

4.3.1 Scenarios for Cartagena's 2019 Vision

AA: Effects on Cartagena's Natural Susceptibility

Despite population and industry growth, the integration of environmental considerations into the development strategies of Cartagena will allow for maintaining and at times reducing the susceptibility of natural systems in this area. Water quality and the integrity of hydrographic processes may improve as proper waste disposal and sewage treatment systems are introduced. This action reduces the pressures placed on mangroves in Cartagena Bay, thus improving the ecosystem's quality. Despite this, mangroves in the northern area of the Ciénaga de la Virgen will disappear as a result of drainage from urban expansion. The combination of the different indicators calculated for the 2019 scenario show that the overall susceptibility in Cartagena will maintain the current levels: mangroves medium level, sea grasses high level and beaches medium to high level of susceptibility.

Scenarios AAl and AAh: SLR Impacts on the Susceptibility of Cartagena's Natural System

Adding to this scenario the effects of a potential low and high SLR, it is possible to see that the areas with higher susceptibility indexes are the more affected ones. In general, a low level of SLR exacerbates erosion processes on beaches impacting natural communities, resources, and services provided by this ecosystem. Mangroves on the other hand, tend to disappear given the absence of available areas for migration mainly due to physical barriers. It is estimated that a low SLR will flood 17.5km^2 of beach and 2.23km^2 of mangrove areas. A high level of SLR will cause the same effects but in a larger magnitude, flooding 18.6km^2 of beach and 13.3km^2 of mangrove areas.

The most affected mangrove areas appear to be the ones closer to human settlements. Although mangroves are crucial in reducing erosion processes and could serve as buffer zones to climatic events protecting the human settlements located nearby, these ecosystems will tend to disappear given the lack of space to migrate in these areas. With this in mind, it is important to find measures to preserve these systems and implement strategies that will help mangroves adapt to SLR.

An SLR will cause the disappearance of almost all the beaches in Cartagena Bay and in Tierra Bomba. Beaches play a very important role for the tourism industry in Cartagena and serve as a protective zone for the infrastructure located nearby. As such, a significant loss of beaches could have serious impacts on the city's socio-economic development. The next section further explores the impacts that SLR could have on the socio-economic system developed under the 2019 Vision.

Scenario AB: Effects on Cartagena's Socio-economic Vulnerability

Box 4. Cartagena's Vision of Socio-economic Development

The national government's goals for 2019 include the improvement of housing in the urban zone, the development of "social" housing in the urban and rural areas, and the relocation of houses in high risk areas. Among other things, Cartagena envisions a constant population growth; 100% water supply coverage in urban areas and 82.2% in rural areas; 100% coverage in waste collection services; and 100% education coverage in rural and urban areas. The risk perception regarding housing location will diminish by 80% and the gap between the rural and urban areas' living conditions will notably reduce.

The achievement of the socio-economic goals established under the Cartagena's 2019 Vision contributes towards reducing the overall socio-economic vulnerability of the area from a medium-high to a medium-low level. Table 6 presents the vulnerability changes for each socio-economic indicator.

Table 6. Socio-economic Vulnerability of Cartagena's 2019 Vision

	Vulnerability		
Indicator	**Present**	**2019 Vision**	**Comment**
Life quality	medium- low	low	Full coverage of basic services in urban areas and over 80% in rural areas will reduce the quality of life gap between urban and rural populations
Services	U: high R: medium- low	low	100% coverage of basic services in urban areas and over 80% in rural areas
Housing	U: low R: medium- low	low	Changes in the materials used for building houses in the rural and urban areas
Human capital	medium- high	medium- low	Although a cover of 100% in basic education is intended, maximum score is not obtained
Natural disaster	low	low	Relocation of the houses that were in risk areas
Public investment	low	low	Financial situation of Cartagena can increase social investment to 90%; 15% in disaster prevention
Population	very high	very high	Constant growth rate

Note: U: Urban; R: Rural

Scenarios ABh and ABl: SLR Impacts on the Vulnerability of Cartagena's Socio-economic System

The effects of a potential SLR could seriously impact Cartagena's economy, cultural heritage and the quality of life for the population. A potential SLR could impact the local economy by 1) flooding the beaches that are an important asset for tourism; 2) flooding the road that connects Cartagena with Barranquilla and the interior of the country, isolating the city from a large portion of Colombia; 3) flooding the Perimetral road around the Ciénaga de la Virgen affecting the population located in this area; and 4) flooding the facilities of the ports and interrupting their operations. Moreover, an SLR could also have negative impacts on the cultural heritage of the city by affecting the historical walls and monuments causing a possible collapse of these structures. Lastly, by impacting Cartagena's natural systems, an SLR could affect the quality of life of the population. For instance, a rise in the sea-level could cause penetration of the salt wedge into the Juan Gomez

marsh considered the city's main source of water for human consumption. This would significantly affect the water supply for Cartagena's population. Finally, flood and erosion processes caused by SLR could also directly affect human settlements causing population displacement and relocation. This is particularly the case with settlements located on Tierra Bomba Island.

To estimate the socio-economic impacts of SLR, value at risk (in pesos) is calculated using two levels of SLR and the 2019 socio-economic scenario (see table 7). In general, the value at risk in high vulnerable areas increases due to an improvement of the socio-economic factors. Affected population was calculated using a constant population growth. In terms of population, the area most affected by SLR under Cartagena's 2019 Vision will be the south of the Ciénaga de la Virgen.

Table 7. Socio-economic Impact of SLR on Cartagena's 2019 Scenarios (value at risk in millions of pesos)[12]

Area	Low SLR	High SLR		
	Value at loss	Affected population	Value at loss	Affected population
Urban	654,127	58,956	872,226	303,891
Rural	NI	1,749	NI	4,667
Total	654,127	60,705	872,226	308,558

Note: NI: No Information

4.3.1 Scenarios for Tumaco's 2019 Vision

Scenario BA: Effects on Tumaco's Natural Susceptibility

Box 5. Tumaco's Vision for the Environment

To reach its 2019 Vision objectives, Tumaco has planned different strategies. One of these strategies emphasizes environmental education with the goal of creating commitment and understanding among the community of their responsibility towards the sustainable development of the area. Aimed at generating environmental awareness among the population, Tumaco foresees a reduction of the pressures exerted by human activities on the natural systems. In this sense, environmental quality will improve not only as a result of institutional action, but also due to a change of behavior in the population. Another strategy that Tumaco is planning includes the promotion, establishment, recovery and implementation of protected areas, either by the state or civil society. Also, Tumaco plans to increase its participation in the green market. To do so, traditional production systems will be promoted, introducing improvements that do not have negative impacts on the environment. In addition, research in science and technology will be enhanced, as well as business development. The combination of these strategies will contribute towards the main objective of Tumaco's 2019 Vision: to guarantee food security for the population without threatening natural systems, promoting sustainable development and strengthening green market programs.

The integration of environmental considerations into the planning process and the adoption of more sustainable production practices under Tumaco's 2019 Vision will reduce the impacts on natural systems generated by population growth and socio-economic development. Ecosystem quality will be enhanced as a result of the establishment of protected areas and the teaching of the

12 Currency conversion for 2002: 1 US$ is equivalent to 2296 Colombian pesos.

Box 6. Tumaco's Vision on the Socio-economic Development

By 2019 Tumaco envisions 70% basic education coverage; 40% reduction in housing deficit; relocation of houses located in risk areas (80% relocated in areas with no associated risks); and improvement of housing (external walls will be made using exclusively wood and bricks). Tumaco also aims to promote electricity and gas for cooking replacing firewood, coal and kerosene. Finally, it also foresees universal coverage of basic services, as well as fiscal sustainability, implying a large investment in health, education, basic services, infrastructure, housing and disaster prevention before 2019.

Table 8. Socio-economic Vulnerability of Tumaco's 2019 Vision

Indicator	Vulnerability		
	Present	2019 Vision	Comment
Life quality	U: medium-high R: high	U: medium- low R: low	Tumaco will achieve a remarkable improvement in quality of life for inhabitants
Services	U: medium R: very high	low	Remarkable improvement in quality of life in the rural area expanding basic services coverage
Housing	U: medium R: medium- high	low	Changes in the materials used for building houses in both the rural and urban areas
Human capital	U: low R: very high	medium- high	Increase to 70% basic education coverage including the rural and urban areas
Natural disaster	U: medium- high / medium R: very high	low	As a result of housing policies and relocation of houses in risk areas, 80% of the population lives in areas with no associated risks, and the remaining 20% in areas with different associated risks
Public investment	very high	medium- low	Investment increase for housing and disaster prevention
Population	very high	very high	This indicator presents no variations. Since the coastal area is the most vulnerable and the most populated, this indicator remains the same.

Note: U: Urban; R: Rural

population about the need to conserve these ecosystems. This means that although total ecosystem coverage might not increase, due mainly to land conversion for urban and agricultural expansion, ecosystem degradation will be reduced due to a more sustainable use of the natural resources and the creation of protected areas.

Moreover, the improvement in waste disposal and sanitary systems and agricultural practices will reduce the pollutants affecting ecosystem quality such as water quality and maintain the integrity of hydrographic processes. Therefore, although population growth may exacerbate domestic and agricultural activities, these activities will not affect the susceptibility of natural ecosystems. The overall susceptibility of Tumaco's natural systems will remain the same, due to the long time that natural systems take to recover and the high influence that human actions have upon them.

Scenarios BAl and BAh: SLR Impacts on the Susceptibility of Tumaco's Natural System
Adding to this scenario the effects of a potential low and high SLR, it is possible to see that given Tumaco's topography and local conditions (tide regime and other oceanic dynamics) both SLR levels will affect the entire area covered by mangroves and beaches. Nevertheless, Tumaco would have enough space to allow for migration of most of these ecosystems if local regulations were implemented to stop the construction of potential barriers. As a result, the overall natural susceptibility of Tumaco is estimated to remain at a medium level for mangroves and beaches.

The threat to mangrove ecosystems remains high given the amount of people present in the area and the unsustainable way they use these ecosystems. However, the loss of beaches will probably be compensated by new accretion processes that will occur, thus complicating the process to determine the effects that SLR can have on these ecosystems.

Scenario BB: Effects on Tumaco's Socio-economic Vulnerability
In general, the socio-economic vulnerability in the rural area of Tumaco decreases from a high to a medium level of vulnerability in 2019. In the urban area all the secure areas exhibit a medium level of vulnerability and also show a decrease compared to the current medium-high level of vulnerability. The overall decrease in socio-economic vulnerability in 2019 indicates an increase in both the rural and urban populations' quality of life compared to the current state. Table 8 portrays the vulnerability changes for each one of the socio-economic indicators in Tumaco.

Scenarios BBh and BBl: SLR Impacts on the Vulnerability of Tumaco's Socio-economic System
If there was only a low SLR, the urban area divides into areas with a medium-level of vulnerability and areas with a medium-low level of vulnerability. The estimations reveal that the islands have lower socio-economic vulnerability to flooding compared to the continental area. This is because the infrastructure of the islands is built considering a potential increase in the sea-level, while in the continental area the infrastructure is built without taking into consideration any preventive measures. In general terms, a medium level of vulnerability is estimated for the urban area in Tumaco. The impacts of a high SLR are similar but larger in magnitude.

Table 9. Population affected by SLR in Tumaco's 2019 Scenarios

Area	Low SLR	High SLR
Urban	33,271	37,172
Rural	8,463	12,988
Total	41,734	50,159

To evaluate the socio-economic impacts of a potential SLR in Tumaco it was not possible to calculate value at risk due to the lack of available information. Table 9 presents the affected population for a high and low SLR scenario assuming a growth rate in line with the development planned under the 2019 Vision. Although the rural area has a larger flooded area, the population most affected by SLR is in the urban area. This is explained by the fact that the urban area in Tumaco is more populated than the rural area.

5. Sea-level Rise Adaptation Measures

Generally, adaptive measures to SLR will fall into one of the following three categories: retreat, accommodate or protect. Retreat typically focuses on planning for relocation and emergency management. It involves preventing development in vulnerable areas or planning development in certain areas under the condition to abandon them if necessary. Accommodation measures are based on the principle of not counteracting the migration process of ecosystems caused by SLR. To do so, functional uses of land are adapted allowing for both migration processes and productive activities to continue. Finally, protection measures involve planning and regulation to protect systems from the effects associated with SLR. It is generally recognized that anticipatory and precautionary measures for adaptation are more effective and less costly than forced, last minute emergency adaptation measures.

Within the categories presented above, adaptation to SLR can be promoted by planning, building physical structures, introducing legislation and/or creating organizational/institutional capacity. Planning is related to the decision-making process and the development of programs that can directly or indirectly integrate adaptation into the management of the study areas. Physical structures refer to engineering work (soft and hard structures, see below) that can be built to protect the areas from the effects of SLR. Legislation refers to the normative framework that can support the implementation of measures to prevent impacts from SLR. Finally, creating organizational/institutional capacity relates to institutional strengthening, education, public information and participation, emergency management capacity and inter-institutional cooperation, among others.

Using a modified checklist and database to evaluate adaptation measures, a list of measures was generated for both Cartagena and Tumaco. An Adaptation Decision Matrix was then used in workshops with local stakeholders to identify suitable measures for both of the study areas. In specific terms, several adaptation measures consisting of the different adaptation categories described above were proposed for each area.

To prevent the impacts of a potential SLR and cope with the effects, the following adaptation measures were locally proposed for Cartagena. Additionally, suggested protection measures for this area are described in box 7.

- Establishment of a new regulation to design and build housing and infrastructure in general that takes into consideration a potential 1m SLR. For instance, hotels have to be designed with consideration that their ground-floor may flood occasionally.
- Development of retreat plans for the population settled on beaches with high erosion level such as La Boquilla.
- Development of an action plan for the protection of shores and roads.
- Viability study for the construction of artificial reefs located parallel to the coast to reduce wave action on the beach.

In San Andres de Tumaco, the adaptation measures identified with local stakeholders considered the following. In addition, proposed protection measures for this area are given in box 7.

- Establishment of a new regulation to design and build housing and infrastructure in general that limits construction below 3.4m above sea level. The area below this height has to be desig

Box 7. Protection Measures for Cartagena and Tumaco

Coastal defense and stabilization structures can be used to protect coastlines from SLR effects such as erosion processes, large waves, and flooding. Engineering work is divided into hard and soft structures usually implemented in combination with each other. Hard structures are usually composed of levees and beach stabilization structures. Soft structures are generally natural systems and elements characteristic of the coastal border that can act as effective protection barriers. These comprise beach nourishment and vegetation coverage.

Protection measures to protect Cartagena's coastline:

- The construction of a longitudinal levee between the sectors of Castillo Grande and El Laguito estimated to cost around 45,000 million pesos depending on what material is used.
- The construction of a 1m high dike on the boulevard of Bocagrande and Castillogrande to protect the beaches of Cartagena Bay.
- The refill of beaches in three tourist sectors of the city – Castillogrande, Bocagrande and La Boquilla – with material extracted near the areas. To guarantee the stability of the fillers, the placed material needs to be confined within two curved lateral groins. The filling is estimated to cost 4,300 million pesos.
- The construction of protection structures such as walls in the northern part of the industrial area of Mamonal and la Manga.
- The elevation of the ports so that activities conducted in these areas are not interrupted.
- The restoration of marshes on the coastal border of Cartagena and mangroves on Tierra Bomba Island. In both areas potentially affected human settlements will be relocated allowing for natural systems to recover.

Two protection measures have been proposed for Tumaco:

- The relocation of people living in the densely populated area of Tumaco Island and the recovery of the natural vegetation in this area. The people on the coastal border of the Island of Tumaco are living in poverty conditions and are highly vulnerable to tsunamis, flooding and other climatic events. After their relocation takes place, vegetation will be planted in this area allowing mangroves to recover and to create a protective barrier. This area is equivalent to almost 30% of the island.
- The second measure is proposed as an alternative in case people cannot be relocated. This alternative improves the existing road infrastructure on the Island of Tumaco and enhances the activities in the port area and tourism development on el Morro Island. This measure consists of a longitudinal dike that surrounds the Tumaco Island, the elevation of roads, the relief of bridges, the relief of the port area, and the refill of the beach el Morro Island.

In San Andres de Tumaco, the adaptation measures identified with local stakeholders considered the following. In addition, proposed protection measures for this area are given in box 7.

- Establishment of a new regulation to design and build housing and infrastructure in general that limits construction below 3.4m above sea level. The area below this height has to be designated for conservation of the natural systems. These natural systems will be buffer zones that will protect the infrastructure from a potential SLR. For instance, sand and silt deposits stabilized by mangroves and other natural systems will form a natural dyke serving as a safety zone. If infrastructure is developed close to this limit line (3.4m), additional small-scale measures will have to be implemented.
- Strengthening of education programs incorporating training on the value of natural deltas and coastal processes.

- Development of an early warning system and "safe-zones" to protect the local population in case of natural events such as tsunamis, earthquakes and storm-surges.
- Action Plan to cope with the "El Niño" event.
- Development of a research program to study natural coastal processes and the development of adaptation/protection strategies.
- Development of a land use planning system that incorporates risk zones.

In general terms, six adaptation measures are identified for Cartagena and Tumaco (see figure 9).

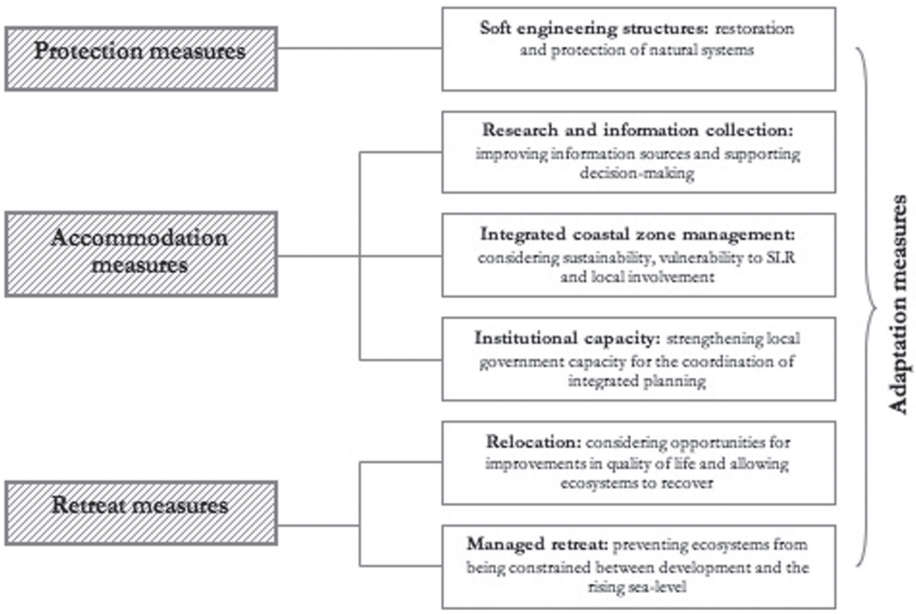


Figure 9. Identified Adaptation Measures to Sea-level Rise for Cartagena and Tumaco

A common theme among all the selected measures is the state of the natural systems. Therefore, it was decided to adopt a strategy that considers the recovering and protection of the coastline's natural systems as an approach that will transverse all measures suggested, regardless of if they are protection, accommodation or retreat measures. To prioritize the identified measures and select the most suitable ones a policy option analysis was conducted for each proposed measure considering the national context. The following section presents a synthesis of the analysis conducted for the three main adaptation strategies selected for Cartagena and Tumaco.

6. Policy Options Analysis

The policy option analysis is carried out within the national context and considers the sustainability guidelines set out under the framework of the Environmental National Policy for the Sustainable Development of Oceanic Spaces and the Coastal and Insular Areas of Colombia (PNAOCI). The analysis is carried out considering the following criteria for each alternative: effectiveness, efficiency, equity, political feasibility and implementation capacity. As a result of the analysis, three strategies are proposed to prevent the impacts caused by the effects of SLR, and contribute to the objectives of the National Disasters Prevention and Attention Plan, the PNAOCI and its Action Plans. This section presents a synthesis of the analysis carried out for each proposed strategy: 1) Integrated SLR-related Risk Management; 2) Coastal Tourism Development; and 3) Research Initiatives and Scientific Development Programs.

6.1 Integrated SLR related Risk Management

The integrated SLR related risk management includes adaptation measures to prevent potential SLR impacts on the coastal area and risk management actions to be incorporated into the territorial organization plans of the departments and municipalities.

6.1.1 Justification

The weak planning and low institutional capacity have affected the incorporation of an integrated SLR related risks management strategy into the development plans at the national and local level. So far, attention has been given to the biophysical, social, and economic aspects of the system's vulnerability to SLR, neglecting the political and institutional vulnerability. These aspects however play fundamental roles and can have large impacts on the overall vulnerability of an area. For instance, institutional weaknesses such as poor coordination among governmental entities and lack of capacity to control coastal productive activities have contributed towards the increase of pressure exerted on coastal ecosystems and the degradation of the environment. This in turn, has increased the overall vulnerability of the area to SLR effects. Moreover, political and institutional vulnerability have negative impacts on the efficiency and effectiveness of policies and measures, the successful adoption of an integrated approach in policies and management plans, the legitimacy of the governmental action, and the participation of the different sectors in policy decision-making and implementation. As a result, weak political and institutional capacity is affecting the incorporation of preventive measures to SLR related risks into development and management plans; delaying necessary action to be taken to increase adaptation capacity to potential impacts in coastal areas.

It is a common view that addressing risks and disasters is the exclusive responsibility of governmental entities in charge of national emergencies, leaving risk prevention and management outside the scope of development planning. The vulnerability assessment conducted in this study reveals that poor socio-economic conditions and the unsustainable use of natural systems contribute to a high vulnerability to climatic hazards such as SLR. In this sense, promoting sustainable development can contribute to decreasing vulnerability and building adaptive capacity. Moreover, land use development has to consider high risk areas and potential impacts caused by SLR to avoid potential losses. To follow up on these issues an integrated SLR related risk management approach has to be incorporated in an organic and systematic way into national and local development strategies.

Although national policies promote the incorporation of risk prevention measures into the territorial development and management plans; this is not always properly done particularly at the local level. The Territorial Organization Plans (POTs) and the Territorial Development Plans (PDTs), as guiding instruments for the long term sustainable development and the short and medium term territorial management, play a strategic role for risk reduction and prevention at the regional and local level. The Local Management Risk Plan constitutes a component of the PDT that focuses on emergencies (Emergency and Contingencies Plan). This plan is supposed to include actions and investments defined in the POT to avoid disasters, reduce existing risks and prevent new risks. Therefore, the POT and the Local Risk Management Plan constitute the best mechanisms to incorporate an integrated SLR related risk management strategy into local sustainable development planning.

In the particular case of Cartagena and Tumaco, an integrated SLR related risk management approach has not been incorporated into their POTs yet[13]. This option analyzes the actions and considerations necessary to follow up on this process and successfully implement an integrated SLR-related risk management in the study areas.

13 Tumaco is currently developing its Territorial Organization Plan.

6.1.2 Option Analysis

To ensure that the integrated SLR-related risk management is effective, it must be in line with the Territorial Organization Plan objectives and the Development Plan strategies. It should be framed as a sub-program of these plans and include different projects that aim at optimizing the use of land and natural resources according to the potentials and the vulnerability of the area.

Moreover, to ensure the effectiveness of the integrated SLR-related risk management it is important to incorporate the identified protection adaptation measures to SLR into the different planning instruments. By doing so, a more preventive approach will be adopted in the decision-making related to risks and investment in coastal areas. The adaptation measures should be in line with climate change policy and the integrated management strategies proposed under the coastal water loggings regulation, the regulation on the uses and activities in areas threatened by flood, and the regulation on the protection of areas considered of vital socio-economic interest.

So far, a certain level of coordination has been reached at the national level for the incorporation of an integrated risk management approach into development policies. However, at the local level the situation is different. POTs have not successfully incorporated an integrated risk management strategy. The success of this process at the local level will highly depend on: 1) available information and scientific research to support decision-making; 2) a degree of compromise between civil society and the private sector; 3) the financial support and investment for risk management; 4) a better coordination between local authorities, planners and decision-makers; and 5) the adoption of a long-term perspective in the decision-making process.

Although there are no known references to estimate costs and benefits to assess efficiency, it is possible to say that the integrated SLR related risk management has several benefits. Among the main benefits are: supporting the project investment decision-making process by incorporating the risk factor related to SLR; providing relevant information and reducing scientific uncertainty and information gaps that hinder adequate decision-making in coastal management; and supporting the integrated management of coastal areas. Costs may include necessary investments in: conducting research to improve the methodologies used to develop scenarios; generating databases with indicators; establishing networks to facilitate efficient access to information; training communities and investors in risk management; and building protection measures against SLR.

In terms of equity, the people that benefit from implementing an integrated SLR related risk management are: the national government by improving the planning and decision-making process; the territorial bodies and their environmental authorities by gaining the capacity to prevent risks; and the communities in general by becoming less vulnerable and improving their quality of life. On the other hand, the entities that will assume the costs of this implementation are: the national and local governmental bodies, the international community that support the initiative and the private companies that perform research for project development.

With regards to political feasibility, the potential allies of this strategy are the Inter-American Development Bank that helps countries to integrate risk reduction into their planning and development investments; the United Nations Development Program; the Ministry of Environment; Housing and Territorial Development; different governmental entities; communities; research institutes; and investors. Opponents to the strategy are entities that see their interests affected by its implementation such as large landowners; industry; illegal occupants; and pressure groups (armed sectors). To manage the opposition, some actions have been considered: 1) ensure the participation of different stakeholders in the planning processes; 2) create awareness among investors and civil society in general, particularly among the communities settled in the most vulnerable coastal areas; 3) develop an integrated information system; 4) consolidate follow-up and monitoring networks; and 5) establish mechanisms to overcome current challenges, such as financial constraints. In general terms, the possibility of implementing this strategy is high, because there is already a

political framework and normative framework that would facilitate the adoption of an integrated SLR-related risk management

The political feasibility is directly related to management capacity, in that the existence of a policy and normative framework regarding risk prevention and attention matters, coastal and insular development, water loggings management and territorial organization and planning set the necessary basis to implement an integrated SLR related risk management strategy. In addition to these already established policies and regulations, Colombia has the vision to pursue an integrated management of its coastal areas (MIZC), setting a favorable condition for the adoption of this strategy. Moreover, the incorporation of an integrated SLR related risk management strategy could be assisted by the current institutional framework that has the potential to provide support at the national and local level for its implementation.

Nevertheless, to ensure an appropriate management capacity, some improvements are necessary at the institutional level. Among the most important required changes is the reinforcement of the inter-institutional coordination mechanisms to make the existing system operational and enhance the effectiveness of risk-related policies and regulations. Moreover, it is important to consider that the current institutional and local structure is rigid and any transformation that implies the adoption of political decisions, political will, budget allowances and modifications makes institutional changes slow and difficult.

In summary, the possibility of implementing the proposed strategy is supported by an existing policy, normative and institutional framework, as well as several allies who benefit from its implementation. These conditions could make this strategy politically feasible. However, the identified obstacles, weaknesses and actions necessary to improve the management capacity and ensure the strategy's effectiveness represent difficulties that challenge the success of its implementation. As a result, the probability of this strategy being successful has been estimated to be moderate (less than 75%).

6.2 Coastal Tourism Development

Coastal tourism development refers to a tourism development model that incorporates environmental sustainability of coastal ecosystems and services as an essential asset for the development of the sector. This sector will be integrated into the regional economic, social and environmental dynamics.

6.2.1 Justification

Currently, the tourism industry has the highest growth rate within the global economy. This industry is constantly innovating to face market competitiveness and meet growing demand. Tourism companies are specializing their services and increasing the diversity of products targeting different market segments. As a result, different options are available to the tourists including: cultural tourism, sports tourism, nautical tourism, ecotourism, agro-ecotourism, among others.

Colombia has significant comparative advantage for the development of costal tourism. The country's geographical location gives access to important areas of the Caribbean Sea and Pacific Ocean, as well as to different islands. The coasts are accessible all year round and offer different tourism alternatives such as nautical tourism and ecotourism. Cartagena is the largest tourist destination in Colombia. Tourists primarily visit Cartagena for leisure and recreation. Baru Island has a particularly great potential for coastal ecotourism due to its excellent beaches. Tumaco also has diverse ecosystems and a rich biodiversity that make this area highly attractive for developing ecotourism. However, the tourism industry in Tumaco is still incipient and lacks proper infrastructure. The development of ecotourism in Tumaco would bring significant socio-economic and environmental benefits by diversifying the local economy, inducing the establishment of micro-enterprises, generating local employment, improving transport and communication infrastructures, and reducing the impacts on ecosystems and cultural heritage.

Although environmental quality and ecosystems integrity are a fundamental part of the product and services offered by the coastal tourism industry, the uncontrolled growth of this activity and the unsustainable use of the natural resources are negatively affecting it. In Colombia, the coastal tourism potential is challenged by infrastructure deficiencies and the degradation of beach ecosystems and environmental quality in general. This has a negative impact on the above mentioned comparative advantage of the country not allowing it to compete successfully in the international tourism market.

In addition to the threats mentioned above, the tourism industry could be seriously affected by SLR. Flooding and erosion caused by SLR could damage the tourism infrastructure and affect the beach ecosystems that are one of the main assets in this industry. In doing so, SLR could put public and private investment at risk. So far, there is great uncertainty among investors regarding how climate change effects, such as SLR, could impact the tourism industry. Nevertheless, if environmental quality and natural systems are recognized to be essential resources for tourism, it is necessary to focus on their management and risk prevention strategies to avoid enormous losses for tourism activity and investment.

To enhance the competitiveness of coastal tourism in Colombia, and in this case in Cartagena and Tumaco, it is necessary to develop appropriate planning that considers the different elements that play an important role in this activity. In this sense, the tourism development plan has to integrate adequate management of resources into the destination areas, infrastructure, marketing activities, legislation, land use planning, vulnerability and risks. An integrated approach to developing coastal tourism could determine the difference between developing a competitive tourism market that contributes to the long term sustainable development of coastal areas or an uncompetitive market that will not be sustained over the longer term. A coastal tourism development strategy proposed for Cartagena and Tumaco which adopts this approach and considers several factors for its successful implementation is analyzed below.

6.2.2 Option Analysis

Tourism could effectively contribute towards the sustainable development of Cartagena and Tumaco if carried out with respect to the natural and cultural environment, rationally using natural resources and considering the vulnerability of destination areas. To be effective the conceptualization of the tourism development plan must combine knowledge of nature, the understanding of traditional local cultures and the objectives of sustainable development.

Moreover, to ensure effectiveness a work plan for tourism development must be established to guide its development in such a way that it contributes towards local socio-economic development and the conservation of natural systems, whilst enhancing the protection and adaptation of vulnerable areas to climatic events such as SLR. In doing so, it is fundamental to include in the work plan strategies for the revitalization, restoration, accommodation and protection of natural systems such as beaches, mangroves and water loggings within the areas of tourism interest.

To adopt a more integrated approach to the tourism development plan that considers the elements and strategies mentioned above, it is critical to have access to useful information that will assist in decision-making. For instance, the vulnerability assessment and the adaptation measures identified in this study could contribute towards preventing impacts related to SLR and reduce risks in coastal tourism areas. Providing information to the tourism industry on how climate change effects such as SLR could impact the coastal area provides relevant information needed to develop and integrate suitable adaptation measures into tourism development plans. Also, training the sector's human resources on the subject of risk management would contribute towards adopting a more integrated approach in tourism development plans. Finally, efficient tourism planning has to be a continuous and dynamic process, therefore policies and plans have to be flexible and allow for adjustment to changing circumstances. Currently, the conditions exist for tourism development

plans to be designed and coordinated by different interested entities and incorporated into Regional Development Plans, Territorial Organization Plans and Disasters Prevention and Attention Plans. However, the success of this process will depend highly on institutional cooperation, the quality of tourism services, environmental quality, and vulnerability of destination areas, as well as available information on potential tourism in the coastal areas (in the case of Cartagena and Tumaco).

Although there are no known references to estimate costs and benefits and assess the efficiency, it is possible to mention that among the main benefits of this strategy are: 1) the development of an integrated long-term sectoral plan for tourism development; 2) the conservation and promotion of natural and cultural "assets"; 3) the diversification of the regional economy and generation of local employment; 4) the reduction of pressures exerted on the natural systems and the cultural patrimony; 5) the contribution to sustainable development; and 6) research on natural attractions, cultural traditions and values. Among the costs are investments in: the design and establishment of a monitoring system for tourism activities in coastal areas; the establishment of networks to facilitate information; the development of measures to reduce vulnerability; the development of research; and capacity building.

In assessing equity, the beneficiaries of implementing a tourism development plan are: communities with an opportunity to diversify their economic activities; the country and the municipalities that will generate more income; the international community that has the opportunity to visit and value the natural and cultural heritage; the tourism sector that can improve the decision-making for investment and development; and the territorial entities and their environmental authorities that will improve their decision-making capacity. On the other hand, the entities that will assume the costs of implementing this strategy are the national government; the Ministry of Commerce; Industry and Tourism; the Development Projects Financial Fund (FONADE, an industrial and commercial enterprise of the government); local governments; private companies performing research to develop the tourism sector; and the international community that supports ecotourism development initiatives and projects.

In terms of political feasibility, the potential allies of this strategy are: the Inter-American Development Bank by financing studies and investment projects that contribute towards tourism development in the member countries; the United Nations Development Program; the Ministry of Environment; Housing and Territorial Development; the National Planning Department; the environmental authorities of Cartagena and Tumaco; the communities; investors; and research institutes. The potential opponents are interest groups affected by the implementation of this strategy including: industry; the armed groups; the large landowners; and the illegal occupants. To manage the opposition it is necessary to: 1) guarantee the participation of different stakeholders in the different planning processes; 2) create awareness about tourism activities and conservation practices for ecotourism development among investors, society in general, and local communities in particular; 3) design and implement an information system for the Colombian Caribbean and Pacific littoral; 4) consolidate the tracking and monitoring networks; and 5) set out mechanisms to overcome the limitations, especially financial limitations, and to facilitate the implementation of an integrated tourism development plan.

The feasibility of this strategy is supported by the management capacity that currently exists in the country. The already established policy framework in Colombia regarding coastal and insular development, water loggings management, climate change, and risk prevention and emergencies facilitates the integrated tourism development in coastal areas. Moreover, Colombia has specific policies and plans for tourism development at the national, regional and local level. In the case of Cartagena, these are: 1) the Colombian Caribbean Littoral Master Plan that identifies Cartagena's tourist products for potential businesses; 2) The Cartagena de Indias Sectoral Tourism Plan (04 to 07) incorporated into the General District Development Plan; 3) the Tourism Policy guidelines; and 4) the POT. Tumaco has 1) strategies to support the Development of the Nariño Department

that foresees an enormous potential for the agro-ecotourism in the area and identifies natural, cultural and theological attractions; and 2) the Tourism Sectoral Plan (03 to 06) framework that identifies the region as a cluster with potential for tourism. In addition to the policy framework, existent laws and decrees in the country form an adequate normative framework for the development of tourism in coastal areas.

Although established policies and regulations contribute to the management capacity necessary for the implementation of this strategy, this process could be jeopardized if the institutional capacity, which in this case involves different entities at the national and local level, is not strengthened by: 1) reinforcing the inter-institutional coordination mechanisms at the local and national level; 2) strengthening the decision-making capacity in institutions; 3) setting up mechanisms to obtain financial resources; 4) implementing monitoring and evaluation mechanisms for tourism-related policies and activities; 5) increasing the institutional capacity to ensure compliance; and 6) increasing flexibility in the institutional structure to allow for modifications along the way.

To conclude, the possibility of implementing the proposed strategy is supported by an existing policy and normative framework and several beneficiaries of this strategy. The combination of these conditions contributes towards the political feasibility of this strategy. However, if the identified difficulties and necessary actions to successfully implement the strategy are considered, the success probability of this strategy is estimated to be moderate (less than 75%).

6.3 Research Initiatives and Scientific Development Programs

Research and scientific development programs refers to the establishment of an inter-institutional and interdisciplinary research collaboration group in the country to facilitate and generate research and information of high quality on the subject of climate change and its associated effects on the Colombian coastal areas.

6.3.1 Justification

Scientific and technological research fulfill an important function by providing the necessary information and understanding to solve problems, maintain or change systems, make use of resources and plan for future developments. The achievement of the Colombian 2019 Vision will require an important input of scientific and technological information, not to mention the high level of institutional cooperation and investment this will demand. Considering the current deficiencies in national research capacity and available information, this could indeed become an obstacle for the achievement of the 2019 Vision.

Among the main difficulties that currently affect research development in Colombia are the problems related to gathering information aggravated by the deficient inter-institutional cooperation between research entities. Moreover, different methodologies and time periods used for research cause discrepancies and complicate data interpretation and analysis. In addition, information is deficient due to data gaps and scientific uncertainty. This is mainly because research entities in Colombia are going through serious difficulties to finance their operations and projects, resulting in research underdevelopment and insufficient information to properly contribute to the national and local decision-making, planning and evaluation processes.

With climate change, there is a general lack of knowledge and information about its effects and possible impacts on the country. Moreover, there is only weak cooperation between the research community and the entities in charge of the policy decision-making process regarding the reduction of climate change related risks. To date, the best national-level results obtained on the potential impacts from climate change effects, as well as on adaptation capacity, are found in the First National Communication of Colombia to the United Nations Convention Framework on Climate Changes coordinated in 2001. Although Columbia has some information on this subject, this

mainly corresponds to individual institutional efforts with differing objectives without any long-term planning focused on establishing a coordinated research and policy path.

These deficiencies and difficulties to developing research in the country hinder proper planning based on high-quality information and coordinated work to achieve common goals. To improve this situation, it is necessary to strengthen national scientific and technological research, and institutional capacities. Among the important steps to be taken is the establishment of a research policy course that is relevant and coherent to the needs of the country. The strengthening of the inter-institutional cooperation to develop and carry out joint-research programs is also fundamental. For instance, the complexity of conducting research on vulnerability to climate change effects calls for combining efforts and coordinating inter-institutional work complementing expertise, disciplines and resources. While this could facilitate obtaining financing resources, it could also improve the research quality. This information could then be used as relevant input to support the development of policies and strategies. This important step could be complemented by the improvement of access to quality information and the enhancement of public participation in the decision-making.

The proposed strategy focuses on the improvement and strengthening of research capacity in the field of marine and coastal sciences and climate change. A new approach is proposed and a set of considerations are outlined for the implementation of a research program that promotes inter-institutional cooperation and multidisciplinary research. This approach is based on the adoption of a long-term vision for research development in marine and coastal sciences so that it incorporates the challenges and effects that climate change generates over time. The strategy includes the development of competitive scientific and technological research capacities; the sustainable financing of research programs and projects; the construction of a national culture centered on science and technology; and the engagement of the business sector with regional science and development.

Finally, it is important to mention that the proposed option is in line with the National Pact for Technological Innovation, where the academics, the researchers and technological development players agree to focus their efforts on strengthening national work and their association with international research networks creating Investigation Centers of Excellence. The strategy also contributes to the new Law Project for Science and Technology that will soon be presented to the Congress of the Republic, the objectives of the Science and Technology Plan 2020, the science and technology component of the 2019 Vision, and the Investigation Agenda for the Free Trade Treaty.

6.3.2 Option Analysis

To ensure the effectiveness of this strategy and improve the research capacity in the country in coastal and marine sciences and climate change, it is important to enhance inter-institutional cooperation by supporting the development of joint-research in strategic areas of the Colombian coastline. In this way, research will not be conducted individually and the efforts to produce scientific information of national importance will be combined. It is also important to enhance scientific cooperation at the international level by promoting an open exchange of quality information in marine and coastal sciences and global climate change.

Moreover, for this strategy to be effective it is essential to create the mechanisms to increase the participation of science and technology researchers in the decision-making process, in particular in the planning of adaptation and mitigation to climatic events in coastal areas. If this strategy is effective and research capacity is enhanced in the country, the generated information could become a strategic input for the development of a knowledge-based economy. In such a scenario, Colombia could plan its development and increase its productivity and competitiveness within the international context based on the generation, diffusion and use of knowledge. This focus requires the construction of a long-term vision with clear plans to align research and policy development paths with consideration for the challenges created by climate change.

Currently, there is an interest in the country for the coordination of inter-institutional and multidisciplinary research, as well as for information generation for the decision-making and planning

processes. For example, Colombia has developed a structure that seeks to optimize the interaction between different governmental entities called the national sciences and technology system (SNCyT)[14]. This already established inter-institutional network could set the conditions for the implementation of this strategy. However, the success of this process will depend highly on overcoming challenges related to: the lack of coordination between the different entities that form the current national science and technology system; the limited budget allocation for scientific and technological research; the low number of researchers in the field of coastal and marine sciences; and difficult access to quality information.

Although no references could be found to estimate *efficiency* based on costs and benefits, it is possible to mention that among the main benefits of this strategy are: 1) the improvement of the scientific and technical research capacity and the structure of the involved institutions; 2) the improvement of public knowledge and the quality of information for decision-making particularly regarding global climate change and the effects on coastal areas; 3) the development of quality information to respond in a more scientific and strategic way to the engagements agreed under the Climate Change Convention and the Kyoto Protocol framework; 4) the consolidation of a new scientific research system for the marine and coastal areas; 5) the improvement of cooperation among different research entities at the national and international level; and 6) easier access to quality and relevant information. Among the costs are investments needed to cover the design of methodology and data standards that can be incorporated into different research processes, the design of indicators and methodologies, the improvement of research facilities and infrastructure, capacity building of human resources, and the development of an information system on climate change.

In terms of *equity*, the beneficiaries are: 1) the national government and local authorities by improving the planning and decision making process, particularly regarding climate change effects and integrated management of coastal areas in the country; 2) the SNCyT by strengthening its capacity; and 3) the general public, investors, companies and local communities, by having greater access to quality information. On the other hand, the entities that assume the costs are the Inter-American Development Bank that supports capacity building for risk reduction management; the World Bank; the organizations and/or countries that signed scientific research cooperation agreements with Colombia; and finally, the national government, the Ministry of Environment, Housing and Territorial Development and the National Royalties Fund.

In terms of the *political feasibility*, the allies are considered to be the Inter-American Development Bank that contributes towards the countries' capacity to integrate risk reduction into their planning; the working group proposing the Science and Technology Law Project to the Congress of the Republic; and the governmental entities related to planning, environment and research. This strategy has no opponents since no entities find their interests affected by its implementation.

The political feasibility of this strategy goes hand in hand with the *capacity management* that the country has built to date. Colombia has a vision that aims at improving its research capacity so that the country's science and technology become competitive at the international level improving access to strategic knowledge and information. This vision sets favorable conditions for the development of the proposed strategy. The strategy is supported by an existing policy framework in the country that promotes: the exchange and cooperation between national and international research centers; the generation of information as the basis for integrated management planning; the establishment of guidelines for science and technology policy (coordinated by Colciencias[15] during the 2002 to 2006 period); the development of the national science and

14 The SNCyT consists of the Ministries of Education, Foreign Commerce, Economic Development, Agriculture, Health, Mines and Energy, Communications and Environment, among others.

15 Colombian Institute for Technological and Scientific Development

technology policy (included in the National Council of Economic and Social Policy – CONPES document 3080 coordinated in 2000) and the development of national environmental research (Environmental Research National Policy).

The *capacity management* to implement this strategy is not only supported by a policy framework, but also by a normative and institutional framework. Among the entities that could directly be involved with the implementation of this strategy are Colciencias, the SNCyT, research institutes, universities, NGOs and the private sector. However, to create the right conditions and capacity management for the implementation of this strategy, it is necessary to strengthen the cooperation between the different entities involved and to reinforce their research capacity. To do so, financial resources and training will be essential.

In summary, the *possibility of implementing* the proposed strategy is supported by an existing policy, normative and institutional framework. This framework combined with several interest groups that benefited from this strategy contributed towards the political feasibility of this strategy. Taking into account the current weaknesses and obstacles, and all the necessary considerations to ensure this strategy's efficiency and effectiveness and the actions needed to improve the management capacity for its successful implementation, the *success probability* for this strategy is estimated to be high (above 80%).

7. Lessons and Strategic Recommendations

7.1 Lessons Learned

Long-term planning is essential

To adapt effectively to SLR and other climate change effects planning needs to start at least 10 to 30 years ahead of time. At times it will be necessary to plan for the relocation of people, habitats and buildings. To do so cost-effectively early action is required. Moreover, to cope with the uncertainty related to climate change and coastal dynamics, flexibility in management and planning is necessary.

Think and act in a wider context

The boundaries used for territorial planning do not consider the boundaries of Environmental Coastal Units.[16] To adopt a flexible and responsive approach to deal with coastal change, planning and action needs to consider a much wider spatial context which includes managing freshwater catchments and coastal units.

Work in favor of nature not against it

Experience has demonstrated that working while respecting natural processes is the most sustainable approach. In some cases, this will mean undoing past mistakes by destroying physical structures and allowing the coast to recover naturally. In other cases, it will be necessary to divide action into phases, implementing temporary solutions in the short-term whilst allowing natural defenses to develop in the medium and long-term.

Solutions need alliances

Given the impact that decisions taken today may have on the site and the surroundings, it is not possible to operate in isolation. Facing the problems and challenges affecting the study areas

16 Colombia has 3 coastal planning regions: Caribbean Insular, Caribbean Continental and Pacific. Each of these regions has different socio-economic characteristics. Moreover, each of these regions is divided into Coastal Environmental Units (CEUs). There is a total of 12 CEUs in the coastal area of Colombia. Each CEU is different and has particular biotic and physical characteristics that define its specific management. For each unit an administrative structure has been proposed to empower institutions and local communities to implement measures that would reduce natural and human induced hazards.

requires collaborative action between the local population and neighboring coastal owners and managers. Mutually beneficial solutions like large-scale realignment projects can only be achieved by adopting a strong partnership approach.

Involvement is critical

Raising awareness of the potential impacts of climate change effects in coastal areas is vital to gain public trust. Any strategy that implies realignment of the coast could create uncertainty and even hostility among the local population. Therefore, building consensus and providing information is fundamental and crucial to find sustainable solutions. This process takes time and effort, but INVEMAR is not alone in building capacity. All coastal institutions face the challenges generated by climate change and SLR. To cope with these challenges and plan the development of the coastal areas, these institutions need a common approach that manages the risks these changes may bring.

7.2 Recommendations

- The study has determined that SLR will have mainly negative impacts since it will cause sea intrusion, erosion and flooding, among other effects that will affect both study areas. Therefore, a deeper study of the consequences of SLR is crucial, to define how impacts can be reduced.

- However, it is important to note that SLR can also result in some positive effects. It is therefore important to carry out more research into the potentially positive impacts so that adaptation measures can be developed to diminish the negative effects but seize the positive benefits generating new opportunities for sustainable development.

- Risks related to SLR and other climate change effects have not been included in any management plan or development policy at the national, regional or local level. The country must implement adaptation measures as soon as possible so that these act as preventive measures (planned adaptation) and not as reactive measures, which are more expensive and more difficult to implement. The planning process should be continuous, participative and flexible allowing for changes along the way.

- To implement the most suitable adaptation measures and strategies it is important to first build capacity. In this sense, this study has been critical as it generates relevant information and discussion among stakeholders to support the decision-making process into the reduction of SLR related risks. This study has also identified considerations and actions that have to be taken into account to achieve successful implementation of the proposed adaptation strategies.

- Indicators have to now be designed at the local level to define the effectiveness of adaptation measures over time; local institutional capacity has to be strengthened; more research and quality information has to be produced to support decision-making and planning; and involvement and cooperation between stakeholders has to be enhanced.

- Given the constant threat of tsunamis in Tumaco and large daily tide variation, it could be considered that this area has a high response capacity to sea level changes. However, the state of their natural systems which have been greatly affected by human activity has converted Tumaco into a highly vulnerable area. In the future, this situation will worsen. Therefore, more studies and actions have to be developed in Tumaco (as well as in Cartagena) that focus on increasing adaptive capacity by decreasing the susceptibility of natural systems.

- During the last workshop in Cartagena, stakeholders suggested that the study area for Cartagena should be expanded to the south, where better preserved mangroves are currently facing pressures from industrial and urban expansion. Coral reefs are also presented in this area that together with the mangroves could serve as potential natural barriers to reduce wave impact.

- The ability of humans and natural systems to adjust and adapt to SLR lies in the interdependence between socio-economic systems and natural systems. This interdependence is evident in the study areas where the sustainability of livelihoods depends on the quality of ecosystems and the environment, as well as on access to and the use of natural resources. Therefore, given future uncertainties and the development objectives in both areas, enhancing natural systems' resilience in Cartagena and Tumaco should be prioritized as an adaptive strategy.

- In the process of implementing adaptation strategies, it is important to consider the culture in both study areas. Previous efforts to introduce risk prevention measures into these areas have failed due to a lack of understanding about the culture. Therefore, it is necessary to engage different stakeholders in the process, in particular it is crucial to inform the local communities about the risks and involve them in the process. Likewise, the involvement of the private sector is indispensable.

- Another important challenge for the successful implementation of adaptation strategies is financial support. This issue has created conflict in the past because it is not clear who should be the responsible entity to cover the expenses to introduce these measures.

- Finally, to improve the quality and availability of information it is necessary to develop a network of information exchange and strengthen the inter-institutional cooperation between research and governmental entities.

ANNEXES

Annex 1. Natural Susceptibility Index

The Natural Susceptibility Index has the following components:

$$BSI = ßEQ + €EC(THL) + θWQHPI + θRA + θLU(HC) + θTH$$

where,

BSI = Natural Susceptibility Index

and,

EQ= Ecosystem Quality Indicator
EC (THL)= Ecosystem Cover Indicator
WQHPI= Water Quality and Hydrographic Processes Integrity Indicator
RA= Recovery Areas Indicator
LU(HC) = Land Use Indicator
TH= Hazards Indicator

and the weights given to the indicators are ß, €, θ

Values	Susceptibility Level
> 81	High
61 – 80.99	Medium-high
41 – 60.99	Medium
21 – 40.99	Medium-low
0 – 20.99	Low

The highest value for the Natural Susceptibility Index is 100. An increase in value denotes an increase in the susceptibility level. To simplify the analysis of the BSI the following classification is used.

Annex 2. Socio-economic Vulnerability Index

The Socio-economic Vulnerability Index has four components:

$SVI = LQI + NCRI + PII + P$

where,

LQI = Life Quality Indicator
NCRI = Natural Catastrophe Risk Indicator
PII = Public Investment Indicator
PI = Population Indicator

The Life Quality Index is based on the methodology[17] used to calculate Colombia's Life Quality Index.

$$ICV_i = \sum_{f=1}^{F} \sum_{j=1}^{C_f} W_f W_{fj} V_{fj}^i$$

where,

W_f is factor associated weight, factors are sets of variables incorporated to the indicator.
W_{fj} is variable j weight, belonging to factor *f*
V_{fj} is the valuation received by *i* commune in the response category that belongs to *j* variable of *f* factor
F is the number of factors
C_f variable number in each factor
i is the commune

The Natural Catastrophe Risk Indicator is the potential risk of partial or total household destruction as a result of natural events given an inadequate household location.

$$IRCN_i = \sum Y_j Z_j^i$$

where,

Y_j is variable *j* weight, belonging to the factor
Z_j^i commune *i* value in *j* variable

The Public Investment Indicator represents the expenses designated to health, education, infrastructure, aqueduct and sewer construction, household and disaster prevention. Besides assessing vulnerability, this indicator allows evaluation of adaptive capacity in case of natural disasters such as flooding as a result of sea-level rise.

$$IIP = \sum X_j K_i^j$$

where,
X_j is variable *j* weight, belonging to the factor
K_i^j commune *i* weight in *j* variable

17 For more details on this methodology see Gamboa, González, Cortes, 2000

Finally, the Population Indicator indicates the participation of population in a given geographic area (Government Commune Unit for Cartagena) from the municipality's total population.

$$IP = \sum J_j R_i^j$$

where,

J_j is variable j weight, belonging to the factor
R_i^j is the value received by i commune in j variable

Finally, the Socioeconomic Vulnerability Index values are located in the range [0,100]. An increase in the value indicates that the vulnerability diminishes. To simplify the analysis of the SVI the following classification is used:

Values	Vulnerability Level
Under 15	Very high
15 - 28.9	High
29 - 42.9	Medium-high
43 - 56.9	Medium
57 - 69.9	Medium-low
Above 70	Low

Annex 3. Indicators for Natural Susceptibility Assessment

Ecosystem coverage	Estimates the total area covered by an ecosystem in a given area. It focuses on the changes of natural vegetation cover that can impact biodiversity and an ecosystem's integrity. This contributes towards defining how ecosystems behave under different pressures and if protection measures are necessary to preserve them.
Water quality and hydrographic processes integrity	Is used for aquatic and associated terrestrial ecosystems. Water quality is measured based on a set of physical, chemical and biological parameters. If the parameters do not fall within the standards, water quality might be affected. Possible causes can be identified based on the measurements.
Ecosystem quality	Provides an idea of the state of the ecosystems found in the area and the different pressures affecting them, giving an idea of their resilience capacity.
Recovery areas	Areas where measures and policies have been adopted to improve ecosystems' quality and reduce the pressures on them. It also includes areas where natural recovery processes are taking place.

Land use: habitat conversion	Identifies changes in land use and pressures put on different ecosystems. It is obtained from analyzing land use maps and available historical data.
Hazards	Climate hazards are referred to as climate change effects such as droughts, floods, storms and heavy rainfall, among others. The identification of the hazards in a system contributes to understanding the factors that make a system more or less vulnerable, foreseeing possible strategies to increase the system's capacity to adapt.

Annex 4. Indicators for Socio-economic Vulnerability Assessment

Life quality	Composed of variables that evaluate water supply, sewage disposal, garbage disposal and cooking fuel.
Services	Groups variables concerning cooking fuel, water supply source and sanitary service.
Housing	Includes external wall materials and type of floor used for housing construction.
Human capital factor	Measures a population's education. It is composed of the proportion of the population that receives education and is analyzed by age ranges.
Natural disasters	Measures the population's perception with respect to the vulnerability of their house location to natural disasters such as flood, avalanche, landslides and others.
Public investment indicator	Includes investment in health, basic education, infrastructure, housing and disaster prevention. Disaster prevention is the variable with the highest weight in this indicator so that municipalities' vulnerability to SLR can be evaluated.
Population indicators	This indicator is composed of the number of inhabitants and the number of houses inside the Government Commune Units.

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