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República de Colombia

Netherlands Climate Change Studies Assistant Program, Colombia: Defining vulnerability of Bio-geophysical and Socio-economic systems due to sea level change in the Colombian coastal zone (Caribbean and Pacific) and adaptation measures.

Executive Summary

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Executive summary

Global sea level rose 10 to 25 cm during the 20th Century and this rate of rise is expected to accelerate during the 21st Century due to human-induced global warming. The Intergovernmental Panel on Climate Change (IPCC) estimated that the global rise from 1990 to 2100 would be between 23 and 96 cm, with a mid estimate of 55 cm. More recent scenarios also express a high uncertainty. The local change in sea level at any coastal location depends on the sum of global, regional and local factors and its termed relative sea-level change. These include sea level changes due to regional atmospheric and oceanic changes and regional and local uplift and subsidence of the land.

Such evidence and the great concern involving the impacts of SLR on low land coastal areas have allowed several countries, Colombia among them, to start with their own vulnerability assessments. The project "Defining vulnerability of bio-geophysical and social-economic systems due to sea level change in Colombian coastal zone (Pacific and Caribbean) and adaptation measures"[1] aims to evaluate a general preliminary adaptation measures . All the out comings of the project are based on the actually available secondary information and expert knowledge.

This project has been conducted according to the Common Methodology recommended by the IPCC. It has involved a team of Colombian experts who worked closely together with the counterparts of INVEMAR on the seven steps the methodology recommends. During the process, extensive opinions were collected based on the particular knowledge that the involved experts had from the Colombian coasts.

Step 1. Definition of boundaries

This step defines the limits chosen by the NCCSAP, Colombia project, to be the study area to assess the vulnerability of the coastal zone of Colombia to the impact of accelerated sea level rise (ASLR) due to global warming. To define the study area, physical, biological, social, economic and political criteria were taken into account.

The coastal dynamic processes, among the physical criteria, were considered the most important to define the limits of the study area. Emphasis on the sharp differences between the Colombian Caribbean and Pacific coasts was made, in order to select the appropriate boundaries. The one-meter contour line couldn't be used because the existent cartography of Colombian coastal zones lacks detailed contour lines, being the minimal in some areas of the Caribbean; the one located at 25 m high, and for some areas of the Pacific coast the 60 m or even the 100 m contour line. Some detailed cartography is available for urban areas, for mineral exploitation localities and for engineering works localities. Unfortunately, this

[1] The study do not take into account other climatic variability or changes different to the sea level rise, although the relevance of evaluating some other factors such as temperature or weather phenomena in this kind of assessment.

detailed information has restricted access, is scarce and would have not served to the first general view of the problem, because of the 1:300.000 scale chosen.

Due to this lack of detailed information and being unable to locate the one-meter and following contour lines for the whole coast, the decision of finding and unifying a unique limit, had to be made. Based on the experts' opinion and knowledge, it was decided that the upper limit of the study area should be the contour line defining the +60 m of altitude and the lower limit should be the –200 m contour line. This area involves all the process and criteria that could be taken into account for the present study.

The chosen area was proved for each of the components needed to evaluate the vulnerability assessment (VA) due to ASLR (bio-geophysical, social-economic and governance component). The effects of the main dynamic process involved on the coastal area related to ASLR such as erosion, salinity intrusion and inundation were in fact included into this fringe. All the marine and coastal ecosystems (estuaries, coastal lagoons, beaches, mangroves, sea grasses, coral reefs and sedimentary bottoms) were included in the fringe up to the –200 m. The social and economic indicators such as demography, quality life and economic development activities, could be established for the selected area; on this regard, several discussions were made based on the availability of the information given on departmental or municipality level. Very strong assumptions would have to be made in order to extrapolate the available information to a different scale (physical units). The national, regional and local governance could also be evaluated on the designated area.

Case study areas

The selection of case study areas is based upon the will of having a closer look on the vulnerability assessment of the Colombian coastal zone due to ASLR. The characterization of the coasts of Colombia, regarding life quality indexes, population concentration and migratory processes, is a relevant factor taken into account for making this selection. The cultural diversity in the Caribbean and Pacific Region embraces different indigenous groups and Afro Colombian groups to whom different resources exploitation methods are attributed. It is also a fact, that there is not similitude between the productive systems of the two coasts; there is a greater development in cattle raising, mining and industry in the Caribbean compared with the Pacific region. Because of the above, one representative area on each of the coasts was used. It was also important to have a representation of an urban area that will show a more direct impact of the phenomena.

The first case of study area chosen to appreciate a more detailed VA of the Colombian coastal zone is framed inside the Environmental Coastal Unit "Estuarina del rio Sinú y el golfo de Morrosquillo". This Unit is shaped by a mosaic of continental, coastal, insular and marine ecosystems that spreads approximately 260 km, southwest - northeast direction from Arboletes point, in boundaries between the departments of Córdoba and Antioquia, up to San Bernardo in San Onofre's municipality (Sucre). This zone of the Colombian Caribbean includes the littoral of Sucre and Córdoba departments, Tortuguilla Island, Fuerte Island and the San Bernardo Islands Archipelago. In this unit, two sub-units differing by its physiographic characteristics are named; the first one, located southwest from Tinajones' delta (river mouth of the Sinú River), up to Arboletes point in the limits with the department of Antioquia (includes the municipalities of San Bernardo del Viento, Moñitos, Broqueles, Rio Cedro, Cristo Rey, Puerto Escondido and Los Córdobas); and the Northeast sub-unit that includes the whole system of Morrosquillo's Gulf (Municipalities: San Antero, Tolú and San Onofre) chosen to be the first case study area for the present VA study.

Morrosquillo's Gulf is located in the southern sector of the Caribbean Colombian coast, between the departments of Córdoba and Sucre, with an approximate area of 1000 km2 and depths between 15 and 55 m. Morphologically it is constituted towards the central zone by an extensive coastal plain that limits on the north and south with two coral terraces. In the southwest sector is located the Sinú River mouth, its evolution and dynamics depend on the fluvial and marine processes especially by rate of waves and tides. The case study area covers the south part of Morrosquillo's Gulf from the Tolú's municipal head-board up to the Rada Point, between the geographical coordinates of 9 ° 18 ' 00 " and 9 º 36 ' 50 " N and 75 º 34 ' 50 " and 76 º 08 ' 30 " W.

An important characteristic of this area in relation with the vulnerability assessment is the presence of the Sinú River delta. The basin of the Sinú River is the most important of the department of Córdoba, with an area of 13.700 km2, of which 1.100 km2 corresponds to the department of Antioquia and the remaining 12.600 km2 to the department of Cordoba. This condition influences the marine water salinity in the Gulf, especially in the south sector. During the humid season of the year, the salinity distribution makes possible to identify the influence of the river discharge with values between 26.5 and 31.8 PSU.

From the geomorphologic point of view, the study area is divided in five regions, inside them different geomorphologic units could be identified according with their origin and /or evolution: alluvial, marine, denude, structural and lacustrine. These units are in constant change influenced by marine processes as waves, tides, coastal currents and terrestrial processes like the exhaust of rivers, the river influence or processes of action in mass. Human influence has demonstrated to be decisive at the moment of altering the units, primarily with structures that try to protect the beaches against the coastal erosion.

Inside the marine and coastal environments outlined in the southern area of Morrosquillo's Gulf, it is necessary to mention the mangroves ecosystems, coral reefs, meadows of sea grass, soft bottoms communities of the continental shelf and estuaries, deltas and coastal lagoons. These environments are part of the whole geomorphologic environment of the coastal zone, being the habitat of different biological resources used as sustenance for great part of the population inhabitants of the coastal zone of the area. This mosaic of ecosystems found at this area will permit to assess the vulnerability of these systems to sea level rise with the purpose of extrapolate the impacts and changes to similar environments of the Caribbean coastal zone.

The Morrosquillo’s Gulf is not only important for its physical characteristics and biological diversity, but also for its social economic aspects and development problems. The inhabitants of the Caribbean Colombian coast have big expectations of development in the selected region, since they can find sites and natural systems of recognized importance there, such as: Coveñas’ maritime petroleum terminal, Tolcemento’s industrial Port, La Caimanera wetland, systems of marshes and swamps of Cispatá’s Bay, Delta of the Sinú River and Fuerte Island.

Because of the strategic location of the Morrosquillo’s Gulf on the Caribbean Sea, it has given origin to a process of consolidation in economic terms and services in the territorial area through time. These characteristics have determined the importance of the region related with development activities (port, tourist and fishing activities among others).

The second study area chosen to assess the vulnerability of the coastal Pacific Colombian zone corresponds to the Integrated Management Unit (UMI) Guapi - Iscuandé. The problems and conflicts of this area are similar to those of the whole Pacific coast, where is common the

untidy utilization of the resources of the coastal zone, stimulated by the processes of intensive exploitation done in an intensive way and without planning, this causes the erosion of the natural productive base, and economic, social and environmental problems. The major pressures in this sector obey to forest, fishing and mining utilizations that have given the relevancy of taking this site as the study area.

The Pacific study area is located at the department of Cauca in the municipalities of Guapi and Santa Bárbara de Iscuandé. The area boundaries at east and west correspond to Iscuandé and Guapi Rivers path, respectively; at the south the area is delimited by the secondary rivers of Temuey and Baltazar, and at the north, the boundary corresponds to the external edge of the continental shelf, approximately 55 km off the coast line, just behind Gorgona Island.

Several natural threats impact the area of Guapi, including the ones associated with higher seismicity, (in relation with the convergence of the Nazca and South America Plates), such as tsunamis, earthquakes, tectonic subsidence and liquefaction of the soil. Other threats related with geological process are inundations and coastline erosion.

The biotic component of the study area is important because of the higher grade of human intervention. The existing ecosystems are: Coral reefs at Gorgona Island, currently protected by the law because the island was declared Natural Park in 1993, even though, artisan fishermen use extensively the area. These coral reefs are the biggest ones on the Pacific coast.

With a zoning pattern dominated by *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa* and *Conocarpus erecta*, mangroves are restricted to places characterized by higher sandy substrate with few tide inundations. Behind the mangroves margin, a transition zone between mangroves and guandal forest is observed including species like nato (*Mora megistosperma*), piñuelo (Pelliciera rhizophorae), mangle (*Rhizophora spp*.), suela (*Ptterocarpus officinalis*), sapotolongo (*Pachira acuatica*), calabacillo (*Meliosma spp*), among others.

The aim of the social-economic description of the study area is to understand the dynamics of the population of Guapi and Iscuandé as for growth, structure and composition of the population in relation with some aspects associated with the employment demand and offer, in order to have basic information for assessing their vulnerability due to sea level rise, and extrapolate it to others sites in the Pacific coast. In relation with the economy of the area, Guapi has been identified as a growing regional economic center.

The third area of study corresponds to the urban area of San Andrés de Tumaco. The city is head of municipality and is located in the Colombian southeast region. San Andrés de Tumaco extends along 3.760 km2 representing 12.11% of the department. Tumaco's cove starts at Punta del Cocal and extends to Punta de Cascajal where a group of islands (Tumaco, La Viciosa and El Morro) are united to the continent through a new bridge called El Pindo. The study area corresponds to the urban perimeter of those islands and the continental urban perimeter that develops along the Tumaco-Pasto road.

The study area shoreline is under continuous change due to its geographical localization and to coastal processes that occur nearby. The Mira River sediments surplus, the northwest persistent wave movement, the consequent northeast littoral drift, the semidiurnal tides regimen with a 3.5 m amplitude, the seismic movements action and tsunamis generation and

the abnormal sea level rise due to El Niño phenomenon conform a group of natural hazards that, associated with urban and socio-economic developments in the region produce an interesting study area for the vulnerability assessment at the sea level change scenario in the country.

A seal level rise projection of 30 and 100 cm over the next 30 years and next century was used to provide a worst-case situation. It is important to note at this point that due to the lack of information, some of the information required by the IPCC methodology had to be presumed or derived from other information. Even so, there are cases, such as the detailed topography or periodicity and impacts of natural phenomena that cannot be assumed or derived, and dynamic flooding models had to be developed for the 1/10, 1/100 and 1/1000 lines construction among other issues.

Step 2. Characterization and inventory of the study area

Overview

Colombia is located in the North-western corner of South America, bordering the Caribbean Sea, between Panama and Venezuela, and the Pacific Ocean between Ecuador and Panama. Both the Colombian Caribbean and Pacific coastal zones are located in the intertropical zone, being one of the most diverse countries in the world.

The study area on the Colombian Caribbean zone extends along 1642 km and includes the Departments of Guajira, Magdalena, Atlántico, Bolivar, Sucre, Cordoba, Antioquia and Chocó. The Pacific coast embraces the Pacific Ocean coastal zones between Ecuador and Panama boundaries. The landward boundary is the 60 m line of the Cordillera Occidental to the Mataje River Basin and Atrato River mouth, along 2188 km. Parts of the Chocó, Valle del Cauca, Cauca and Nariño Departments are included in this region. The landscapes in the regions include alluvial soil low lands, great river bounds, hills and mountains.

For this summary a brief description of the information gathered for each component is presented. The bio-geophysical chapter describes climate and some of the coast attributes on matters relating to climate, oceanography, meteorology, geology, hydrology and ecosystems. The socio-economic component describes the coastal regions demographic and productive characteristics. The governance component summarizes the institutions, law instruments, plans and policies with jurisdiction on coastal zones. The last section reviews the natural coastal hazards, reported by the media.

Bio-geophysical system

Oceanography, Meteorology and Geology Components

The compilation of the oceanographic and meteorological information consisted on the assembling of the data obtained by the Oceanographic and Hydrographic Research Center of Colombia – CIOH - and the Pacific Contamination Control Center – CCCP - during the development of different projects and investigations. Meteorological conditions, currents, seasonal variability, salinity and temperature profiles and the occurrence of oceanic events are evaluated in the main document.

For the present study, the Caribbean and Pacific areas are characterized from a larger scale point of view: The information on oceanographic issues is not restricted to the fringe between the 0 m and –200 m offshore. A more detailed study on the area of interest has not been performed in Colombia, although oceanographic behavior information from Cartagena on the Caribbean, and Tumaco on the Pacific is available. Since the latest is one of the case study areas, this detailed information on Tumaco's oceanography has been included.

Caribbean coast

The Caribbean current directly influences the Caribbean coast. This current, which is the primary source of the Gulf Steam, begins where the Guayana Current meets the Lesser Antilles. Here it changes name to the Caribbean Gulf. It continues along the northern coast of Venezuela, Colombia and Central America.

The seawater at the Caribbean coast is warm and relatively not very deep, with complex environmental characteristics determining the big amount of species and endemisms. This semi-enclosed sea has a stable thermocline almost through the entire year, perturbed only by winds and currents.

The Caribbean Sea is influenced by a considerable amount of fluvial contribution from the Sierra Nevada de Santa Marta, Magdalena, Atrato and Sinú rivers, all of them influencing silt distribution, material exchange and the dynamics of certain physical processes.

An important characteristic of this coast is the up-welling occurring at the Guajira Peninsula and at the Tayrona Natural Park. As a result of it, the environmental conditions are good enough for high productivity and sufficient biological material to support important fisheries.

More westbound the area enclosed by the landmass of central and South America inside the Colombian Basin form the South-western Caribbean. Two main features dominate the circulation of this area, the Panama–Colombia Counter current and the Panama–Colombia Gyre. Tides regime in the Caribbean is either mixed semi-diurnal or mixed diurnal being the greater amplitude 0.5 m. The Common methodology refers as an important issue the description of the tidal range to define the risk areas I, II and III.

These areas, in absence of any existing sea defence, will be subjected to inundation or flooding at least once per 10, 100 and 1000 years. The following figure (Figure 1), illustrates these areas and the values obtained for the Caribbean and the Pacific coasts. For the Caribbean, an estimative of 4845 km2 of total area at risk was calculated.

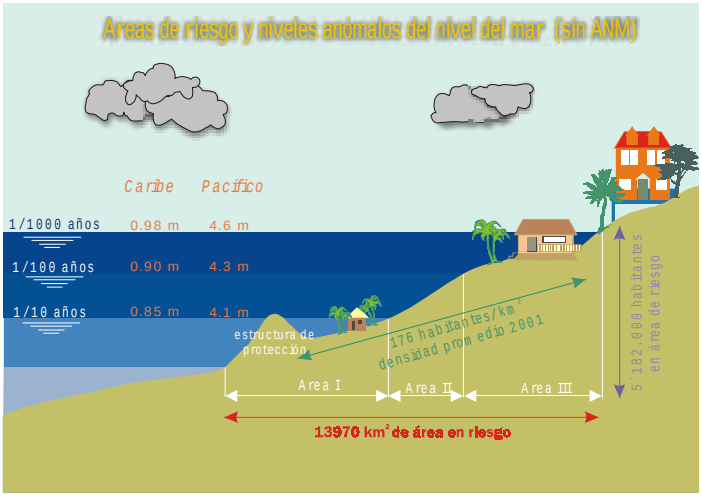


Figure 1. Risk areas without Sea-level rise

Pacific coast

The current pattern on the Pacific coast is much harder to explain. The Southeast Trade winds strongly influence on the Pacific Coast currents distribution. Bearing also in mind the amount of superficial water under such influence, the stronger currents in the southern sector can be explained. Climate in the region is mostly tropical humid with rainfalls along the coastal zone varying between 3m/year (Tumaco area) to 7m/year (Buenaventura area).

The Pacific coast of Colombia has a meso-macro tidal regime and is subject to a medium to low wave energy regime associated to the trade winds influence. Pacific tidal amplitude is greater than the Caribbean one; the former reaches up to 5 m in some areas, being the lowest amplitude 2 m, whereas in the Caribbean it does not reach more than 0.5 m. The Pacific tidal regime condition allowed the formation of great intertidal areas that can extend for kilometers. This situation does not occur in the Caribbean coast where intertidal areas are not extensive.

The total area at risk for the Pacific is as much as twice the Caribbean coast, around 9126 km2. This condition is due in part, to the differences between the tidal range and the mayor occurrence of great impact phenomena, such as tsunami on the Pacific.

Potential influence of the biotic component on currents

Although there is not a full detailed description on the extension of the intertidal areas, there are information on historic or seasonal variation, dynamics or their role in the Colombian coastal processes so, the biotic component influence cannot be denied. As a general rule, Colombian coasts are conformed by beaches, mangroves and cliffs, mangroves being the most researched of those three systems.

Anthropogenic uses of intertidal areas

Anthropogenic uses of intertidal areas comprehend residence, ports development and recreation among others. In some cases even, mostly in the South Pacific, intertidal areas hold complete towns living on palafitte constructions.

Hydrological resources

Colombia is one of the richest countries on hydrological resources in the world; there is a description of the Caribbean and Pacific basins and their hydrologic resources. Water resources have been divided in six categories according to their origins: rain, superficial waters, subsoil waters, thermomineral waters, marine and oceanic and glacier waters. Most of them can be found in the Colombian coastal regions and have been described in the main document in accordance with the detail of the information available. The coastal regions are under great influence of the river basins, but information regarding such influence has not been produced in detailed yet.

Colombia's water drainage has been divided in six river basins. The Caribbean basin receives water (15.430 m3/s) from very important rivers that drain Colombia from south to north, the most important being the Magdalena, Sinú, San Jorge and Rancheria rivers. The Caribbean Sea currents are influenced by the Magdalena river basin one of the largest rivers in South America, Its plume can reach the southern banks of Jamaica, but it has been observed to a lesser extent in the eastern basin because of the western dominance of the Caribbean current. The most important rivers that flow into the Pacific basin are the Patía, San Juan and Micay Rivers (6903 m3/s in total). The sediment discharge from rivers influences the soil composition and may help the coastline maintenance.

Subsoil waters are an important but understudied resource. In the Caribbean important coastal cities, such as Riohacha and Santa Marta, among others, extract water for human consumption from underground reservoirs. The information collected at the moment does not mention aquifers size, quantity or water quality but authorities have reported worries regarding saline intrusion.

The regions that have reported more aquifers are Guajira, Magdalena, Bolivar and Antioquia in the Caribbean region. There is subsoil water extraction in the Tumaco area (Pacific region) but water quality is not adequate for human consumption.

There is not much information on thermomineral waters. Some sources are reported in the Atlantico, Magdalena and Antioquia departments for the Caribbean region. There is not current information on this topic on the Pacific region.

Biotic elements

Terrestrial ecosystems

In an ideal vegetation profile, from the seashore to the hills of the Caribbean region, the vegetation should consist of mangroves, beach formations, cardons, tropical dry forest and hills forest. However, due to human intervention, this profile is rare or non-existent. The

following zone biomes have been possible to identify, in the Caribbean region, in a scale of 1:300.000:

Tropical dessert zonebiome: Xerophytic formations located in the Guajira region. This kind of vegetation is basic for soil protection during the rainy season.

Tropical dry forest zonebiome: Continuous forest coverage located in an extended portion of the Caribbean plain, between 0-1000 m of altitude, temperatures higher than 24°C and precipitations between 700-2000mm/year. This biome is habitat for a big number of fauna and flora species.

According to Holdridge classification applied by the von Humboldt Institute, the Pacific region forests have been classified as: Tropical Rain forest, Tropical pluvial forests, Pre-mountain Pluvial forests, Low Mountain pluvial forests and Very wet low mountain Forest. There are different forests associations regulated by soil variation, precipitation levels, altitude, salt-water influence, humidity and degree of human intervention. In an ideal forest profile it is possible to identify a great diversity of vegetation types such as: mangroves, coastal jungle, land vegetation and hills vegetation.

Marine ecosystems

Starting with a definition, platform seabed is defined as everything between the subtidal zone (5 m depth) to the platform brakes, excluding the intertidal zones and plant-colonized beds. Those two are considered to be different ecological units. In general, platform beds have a high coverage with hard substrate, which is mixed with gravel, sand and calcareous remnants. As depth increases, the substrate becomes softer and finer to that point where it becomes mud. There are broad platform extensions where sand, sand-mud and mud seabeds are found and where living organisms have developed extensive structural and physiologic adaptations.

There are few studies regarding benthos ecosystems in the Caribbean and the Pacific coasts, most of them referring to invertebrate inventories. It has been found that discharges do affect marine ecosystems, as is the case of Cartagena Bay. Mud seabeds dominate the Caribbean continental shell. From the Cispatá Bay to the Guajira limits, there is a mixing zone with mud predominant beds and sand dominant beds.

Regarding the Pacific coast, the continental shell has been reported to be very narrow: approximately 15 km. Only in the south, it extends 55 km. The occurrence of a wider platform in the south has been attributed to rivers sediments discharges. Sedimentary beds of the Pacific Colombian coast are divided in two types at Corrientes Cape, terrestrial mud towards the north and sandy terrestrial mud towards the south.

Coral reefs

Colombian coral reef knowledge is incipient at the moment. In the Caribbean, coral areas are distributed in discrete groups along the coast, on the continental shelf and as atolls, banks and reef oceanic complexes forming the San Andres and Providencia Archipelago. Fresh water discharges with sediments fluxes (a consequence of natural terrestrial erosion and human activities), determine the exclusion of coral reefs in areas nearby the Atrato, Sinú and

Magdalena rivers mouths. Sectors having coral reef formations are the Caribbean part of Chocó, Urabá, Santa Marta and the Tayrona Natural Park. More remotely at the extreme Guajira, there are some small not well-developed coraline formations. Those reefs exhibit a particular structure and species composition attributes.

In the Pacific Ocean, where are several estuaries, high river discharges, high sediment load of the water, surges waters, low temperature and rich in nutrients, coral reefs are non-existent or are present as small coraline communities. If present, the Pacific coral reef areas are smaller and less developed that those found in the Caribbean Sea. They are concentrated in four sectors: Malpelo and Gorgona islands, Utria Inlet and Tebada Bay and two other places in the Pacific part of the southern Chocó region. The corals distribution and formation in the Colombian Pacific is directly related to the accessibility-presence of hard substrates and clear waters, distant from rivers discharges, estuaries and mangrove forests.

Sea grass distribution

Sea grass distribution in Colombia is limited only to the Caribbean Sea due to the environmental conditions they need: Sandy bottoms, 20-30 m water depth, and absence of freshwaters discharges. The species found in the Caribbean are: *Thalassia testudinum*, *Halodule wrightii*, *Syringodium filiforme*, *Halophila decipiens* and *H. baillonis*, but only *T. testudinum* and *S. filiforme* form large meadows.

In the Colombian Caribbean, sea grasses occupy 43e3 hectares, distributed discontinuously along the continental coast and the San Andres and Providencia Archipelago. The largest meadows are located on the Guajira coast, followed by the ones on the coasts of Cartagena to Morrosquillo Gulf, including San Bernardo and El Rosario Archipelagos.

Transition systems (from saltwater to fresh, from aquatic to terrestrial)

Even though these types of ecosystems are well-studied world wide, in Colombia there is not much documentation regarding their distribution and location. However, for some areas such as Santa Marta, communities have been studied in detail. Here, seven community types and, thirteen marine vegetation types were reported. In Malaga Bay (Pacific region), a number of different biologic associations have been identified.

Rocky littoral

Rocky littoral is relatively scarce in the Caribbean coast but there are some small systems along the coast. This type of system is more common in the Pacific coast especially close to the Baudó Mountains lowlands. The northern part of this coast is dominated by rock littoral. Towards the south of Corrientes Cape, cliffs form non-continuous formations.

Beach ecosystems

Colombia has the longest littoral segment with the most beaches potential that exist along the American continent. The sand is dark and exposed to the wind and open sea and there are no ports or infrastructure for massive tourism conditions.

According to wave intensity, beach ecosystems have been categorized in low or high-energy beaches. In the tropical zones in general and in Colombian especially, the second type with strong wave action dominates. Low energy beaches tend to be colonized by mangroves and sea grasses evolving into other systems. The Colombian pacific beaches are much more zoned and differentiated due to tidal range than the Caribbean coasts.

Mangroves

A recent diagnostic recognizes the existence of approximately 4x106 hectares of mangrove divided over the two coasts. Colombian mangrove systems have been studied widely since the middle of the twentieth century. Their ecological importance as well as their role in the socio-economic aspects off the regions and the need for conservation and preservation has been recognized in an early stage. Despite of that, severe environmental problems have been reported, such as intervention and degradation to almost the destruction point, due to a lack of knowledge regarding these ecosystems importance, and due to exploitation attractiveness. Development of infrastructure for urban and shrimp industry purposes is the main cause for degradation.

Coastal lagoons, estuaries and deltas

In general, mangrove belts surround coastal lagoons and estuaries. Organic matter contribution is the basis for the productivity of these systems. Water physic-chemical characteristics vary and are subject to tidal range, periodicity and moon phases. Tides, currents, temperature, salinity, turbidity and nutrients are the physicochemical factors involved in their function.

There are four estuaries in the Caribbean (Magdalena, Canal del Dique, Sinú, Atrato rivers mouth) and 59 coastal lagoons that have an approximated extension of 1.6x106 hectares.

The Atrato-San Juan River Basin develops on the Pacific alluvial and deltaic coastal plain. The great deltas of the Pacific coast evidence the significant amount of sediment coming from the central and south parts of the Andes. It is possible to identify three big deltas along this coast: San Juan River Delta, Patía River Delta and Mira River Delta.

San Juan River Delta is considered the most important delta on the South American Pacific; it receives sediments by the order of 16 million tons/year. The presence of mangrove swamps, barrier islands and estuarine lagoons is evident on this delta because of loads of river contributions. Patía Delta is the longest one on the Pacific coast; its tectonic development has produced the progressive southwest migration of the Patía River. Mira Delta is characterized for lengthened barrier islands and internal littoral cordons penetrating more than 5 km through the deltaic plain, it is dominated by wave energy.

Concluding on the bio-physical system

The Caribbean coast is a region occupying 2.3% of national territory that lodges a great number of marine and terrestrial ecosystems, water resources and wide geomorphologic units. A number of certain oceanographic phenomena occur in this sector such the up-welling, oceanic filaments, thermal fronts and the Magdalena River influence on coastal circulation.

The Pacific coast characterizes a humid tropical zone with abundant precipitation and high humidity. It occupies 2% of the Colombian territory and due its tectonic context it is classified as a high-risk seismic area. It also has a big representation of marine and terrestrial ecosystems, as well as geomorphologic units: Rocky Coast Relief, Littoral Cordons and Barrier Islands, Mangrove Swamps and Fresh-water Swamps.

Socio-economic sector

Department: Territorial entity with autonomy to administer sectional matters, planning and promotion of the socioeconomic development into its territory, according to terms established by law. Departments execute administrative and coordinating functions, mediate between Nation and municipalities and offer services determined by the Constitution.

Municipality: Fundamental territorial entity of the political-administrative division of the Country, with political, fiscal and administrative autonomy according to the limits established by Constitution and by Republic laws. The objectives of the municipalities are offering adequate public services, the construction of infrastructure demanding local progress, territorial planning, promoting communitarian participation and improvement of social and cultural aspects.

The socio-economic component aims for the identification of social and economic factors inherent to the Colombian coastal zones development. Issues such as population growth rates, population economic characteristics, land use and productive activities among others, have been revised bearing in mind the need to present an actualized and consistent description of the socio-economic component for the formulation of development factors and scenarios in the following steps.

Each region (Caribbean and Pacific) is divided into four segments: 1) population distribution descriptions (including indigenous groups); 2) population growth issues; 3) land use and stakeholders categories and, 4) productive activities occurring in the coastal zones.

Caribbean region

Population distribution

The Caribbean coastal region embraces 27x103 km2 distributed over eight departments. This coastal region represents 53% of the national coastal municipality area. The municipality population is 5,8 million people. Its growth rate is higher than the national growth rate. The urban centers concentrate more than 70% of the regions population (Table 1).

Table 1. Summary of administrative and demographic information in the Colombian coastal zones.

	Units	Caribbean	Pacific
Study area	Km^2	26,900	23,500
Administrative division	No.	8 departments; 59 municipalities	4 departments; 25 municipalities
Municipality area	Km^2	63,200	50,800
Municipality population	No.	5,800000	795,000
Population density	No./km^2	94	16

In addition, it has been estimated that the main capital cities, Barranquilla, Cartagena and Santa Marta, together enclose 44% of the total Caribbean region's population and most of the regional economic activities associated to industry, trade and services happen within these cities.

The population distribution, in the Caribbean region, is under the influence of three determinant aspects: 1) socio-economic conditions and land property schemes, 2) capital cities as development centers and, 4) politic and public order conditions.

According to the information collected regarding population occupation, trade (28%) is the most common activity, followed by agriculture (14%) and industry (12%).

Barranquilla is the main industrial city of the region, followed by Cartagena and Santa Marta; trade and tourism activities are concentrated in those cities as well. Even though agriculture is distributed along the entire region, Ciénaga, Turbo and Pivijay are the greatest agriculture areas, banana crops being the most common activity.

Demographic aspects

All the demographic aspects considered in this study have taken the level of municipalities as reference level for the maximum level of detail for which official data are available in the country. However, according to the common methodology used by the IPCC, the general socio-economic information in the present step must consider the distribution of the population of the study area according to the areas of flood risk. This is a requirement for more details than available, through the political administrative division of the municipalities. The difficulty of estimating the population trend of the area of study and the population in the respective areas in flood risk has led to the assumption of uniform distribution of the population on the municipality level (Table 2).

These results show a more significant impact to flooding risk on the population on the Caribbean coast as compared to the Pacific coast.

Life conditions

Indicators that have been used as criteria for the quality of life description, are those considered by the Colombian government statistics institute and include: water supply,

domestic discharge characteristics, home ownership, health and security subscriptions and education outreach.

Table 2. Summary of administrative and demographic information in the Colombian coastal zones.

	Units	Caribbean	Pacific
Study area	Km^2	26,900	23,500
Administrative division	No.	8 departments; 59 municipalities	4 departments; 25 municipalities
Municipality area	Km^2	63,200	50,800
Municipality population	No.	5,800000	795,000
Population density	No./km^2	94	16

Source: Invemar, 2002

Aqueduct supply, in the Caribbean region, is bellow the national average thus other water sources such as aquifers, rainwater and water-trucks are used as well. Sewage system distribution and connection to domestic discharges are low too. Hence other means for domestic discharge are used like septic tanks, latrines, and the sea. In addition, there are a high proportion of homes without sanitary implements.

The data regarding house property, suggest that there is no relation between home ownership and poverty conditions in the Caribbean. Most of the population owns their home. A factor more related to poverty is the percentage of population subscribed to the national security and health systems. In the Caribbean this is lower than the national mean. Less than a 50% of the population receives this type of benefits.

School assistance is greater than the national mean, but university and postgraduate degrees assistance is lower. A greater average education level than that of other regions of the country can be explained by the population distribution on economic activities, industry and trade sectors enclose 40% of the occupied population.

Those criteria indicate life quality conditions and social and cultural benefits that should promote social progress. However, despite these beneficiary circumstances, development and normal social progress dynamics can be strongly interfered by violence conditions. The actual crisis especially affects rich areas. In the Caribbean region, the higher violence indexes are especially found in banana plantation territories. Conflict intensity, kidnapping, murders and other ways that somehow influence administrative, industrial and agrarian centers express violence indexes.

Fiscal income

The Caribbean municipalities present a great heterogeneity in their fiscal income (current pesos of 1995), indicating different resources for the people. Nevertheless, in general terms, in the Caribbean continental area, municipalities enjoy a mean level of income. The cities of Barranquilla (Atlantic), Cartagena (Bolívar) and Manaure (Guajira) present an income per capita superior to the other municipalities.

Land use and land tenancy

Based on the information provided by SIG, the four predominant types of land use in the Caribbean Continental are agricultural use (30%), followed by a mixed use category (livestock and extractive forest use (18%), extractive forest use only (12%) and finally, livestock only (8%)). Notice that 24% of the area is considered to be a category without apparent use (Table 3).

Table 3. Land use and inundation risk areas in the Continental Caribbean.

	Caribbean Coast								
Use type	**Total Area of use**	**Total Area of use (%)**	**Zone I area**	**% Zone I**	**Zone II area**	**% Zone II**	**Zone III area**	**% Zone III**	**Summage of the inundation of the three risk areas according to land use (%)**
Non apparent use	6,302	24.4	342.0	5.4	392.2	6.2	482.0	7.6	**2.5**
Agriculture	7,716	29.9	261.9	3.4	309.7	4.0	411.5	5.3	**4.2**
Cattle raising	2,087	8.1	218.6	10.5	239.3	11.5	259.6	12.4	**11.5**
Forestry	3,186	12.3	465.3	14.6	491.5	15.4	615.9	19.3	**16.4**
Mangrove extraction	615	2.4	572.1	93.1	582.7	94.8	602.5	98.0	**95.3**
Aquaculture	14	0.1	4.7	34.3	5.1	37.6	5.8	42.2	**38**
Recreation	845	3.3	578.8	68.5	592.2	70.1	638.6	75.6	**71.4**
Mining	40	0.2	1.9	4.7	2.1	5.2	2.1	5.2	**5**
Urban	310	1.2	65.9	21.2	73.5	23.7	91.8	29.6	**24.8**
Industrial	10	0.05	5.4	52.4	5.9	57.8	7.9	77.5	**62.6**
Mixed (Cattle raising and forestry)	4,684	18.2	1342.6	28.7	1458.0	31.1	1732	37.0	**32.3**

Note that some uses with little representation in terms of area still are particularly susceptible in terms of flood risk. This is the case of the extraction of mangroves, industry, recreation, aquaculture use and urban use.

Pacific coast

Population distribution

Four departments have jurisdiction on the Pacific coast, covering 23.5x103 km2 of the area of study and 47% of the national coastal municipality areas. Almost 800x103 people occupy the municipality area. Twenty percent of who are indigenous living in 28 indigenous reservations, 77% of the people has an African origin and only 3% has white origins. Despite this distribution, participation on economic activities is not proportional. This has unbalanced the social and politic conditions, although during the last decade indigenous and African origin communities achieved recognition of their rights as ethnic and cultural groups.

Regarding this matter, it can be said that the Pacific communities are much more organized than the Caribbean ones and that there are national laws that allow natural resources exploitation according to their traditional knowledge.

Population density is lower than the national mean (Tables 1, 2) and migration to greater cities has increased for the past 10 years, people leave their home towns searching for a better quality of life and escaping violence.

However, population distribution over urban and rural areas is not as uneven as it is in the Caribbean region, but still it is more concentrated in urban centers. Buenaventura and Tumaco receive population from the region and concentrate 34% of the region's inhabitants and the services sector is localized in these cities. Some rural areas report negative growth rate due to migrations towards the inner country or inside the region due to violence or natural disasters effects.

Regarding population distribution on economic activities, which differs to that from the Caribbean, almost 50% of occupied population belongs to the primary economic sector: agriculture, fisheries and mining. Agriculture shows to be the mayor proportion. It has also been highlighted, that most of occupied population inhabits the municipalities of Tumaco, Buenaventura and Timbiquí.

Life conditions

Even though quantitatively freshwater availability in the Pacific region is similar to that of the national mean, qualitatively rivers are the main source and public aqueduct outreach is lower than the national mean and similar to the Caribbean one. Domestic discharges connected to the sewage system are similar to the national conditions and better than those showed for the Caribbean, there are other ways of domestic discharge as well. Up to 20% of domestic outputs are discharged inadequately, mainly in rural areas.

House ownership is also greater than the national mean but contrary to the Caribbean circumstances, in the Pacific region, there seems to be a relationship between poverty and house property.

Social benefits affiliation is closer to the national rate than the Caribbean region, but still is not satisfactory, 43% of the population lack of social and health benefits systems.

School assistance is below the national mean: almost 20% of the population has never attended any education institution of any kind. In addition, 79% of the population has only been educated to primary education.

The Pacific region used to be isolated to the violence conflict but for the past two years violence has increased in several ways along the entire region, but mostly towards the southern sectors.

The improvement of the quality of life of the inhabitants as it is defined through the classic indicators, depends to a large extent, on the local financial investment undertaken by the municipalities. Investments are the results of the municipalities institutional capacity to respond to social and economic needs such as infrastructure, public services and so on.

Therefore, the indicator of income per capita at the municipality level may contribute to explain social inequalities observed between different municipalities.

Fiscal income

In the case of Pacific coast, the municipalities have a low fiscal capacity and present a relative homogeneity in terms of their fiscal revenue per capita. The municipality of Buenaventura, in the department of Valle del Cauca, and Tumaco, Charcol and Roberto Payán in the department of Nariño represent a better fiscal condition.

Table 4. Land use and inundation risk areas in the Pacific region.

	Pacific Coast								
Use Type	**Total Area of Use**	**Total Area % of Use**	**Zone I area**	**% Zone I**	**Zone II area**	**% Zone II**	**Zone III area**	**% Zone III**	**Summage of the inundation of the three risk areas according to land use (%)**
Forestry inadequate exploitation	632.8	2.7	391.1	62	488.0	77.1	632.8	100.0	**79.7**
Forestry - wood	4,969.6	21.2	879.8	17.7	909.6	18.3	4,871.3	98.0	**44.7**
Selective forestry	1,139.8	4.9	31.2	2.7	32.4	2.8	1,139.6	100.0	**35.2**
Hunting and/or fishing	4,996.0	21.3	2,556.8	51.2	2,574.1	51.5	4,944.4	99.0	**67.2**
Permanent crops	411.4	1.8	93.0	22.6	93.2	22.7	411.4	100.0	**48.4**
Seasonal crops	2,011.3	8.6	450.5	22.4	462.2	23.0	1,981.3	98.5	**48**
Vegetation extraction	868.9	3.7	452.6	52.1	453.6	52.2	865.1	99.6	**68**
Extensive cattle raising	9.3	0.0	0.0	0.0	0.0	0.0	9.3	100.0	**33.3**
Intensive cattle raising	5.4	0.0	0.0	0.0	0.0	0.0	5.4	100.0	**33.3**
Miscellaneous crops	1,542.2	6.6	862.8	55.9	876.0	56.8	1,505.2	97.6	**70.1**
Recuperation	552.1	2.4	338.9	61.4	349.9	63.4	535.1	96.9	**74**
Rural	2.3	0.0	2.2	95.2	2.2	95.2	2.2	95.9	**95.4**
Non apparent use	14.5	0.1	0.0	0.0	0.0	0.0	14.5	100.0	**33.3**
Agroforestal systems	441.2	1.9	123.7	28.0	124.3	28.2	441.1	100.0	**52**
Wild life	5,808.6	24.8	1,113.0	19.2	1,126.5	19.4	5,749.8	99.0	**46**
Urban	58.9	0.3	47.4	80.4	47.4	80.4	58.9	100.0	**87**

Pacific coastal area is characterized by its dominating use by wildlife habitat (25%), the hunting and/or fisheries (21%), the logging use (21%) and the periodic crops (9%). The identification of 12 types of additional uses shows the importance of the diversification of human activities in the use of the land. One relevant fact to be noticed in this table is the identification of those areas under high-risk conditions for its inhabitants. The urban and rural areas have participation higher than 80% in the area of risk I (1:10).

Regarding land ownership, the Pacific and the Caribbean coasts have different regional particularities linked with economic, institutional and political effects in case of legal and economic changes related to the land property regimen. Whereas on the Pacific coast

predominates a collective territorial public rights system (nation areas) with effect on the production levels, productivity and forms of land use; the Caribbean coast has a predominance of a private scheme of land property with comparatively higher economic yields. For this criterion an analysis is done with three situations: the ownership of lands, the use and the possession in property.

Productive Sectors (Caribbean and Pacific)

This variable not only allows to identify the current productive uses and in consequence the cost of opportunity if land use change. Land use would be affected in the future by different hypothetical sea level rise scenarios. Productive Sectors will also give information about the economic and social costs related with the generation of income and employment in each of the coastal regions. The basic data in the country are organized on department level. For this reason, municipality level data were estimated from that using the assumption of equal distribution.

The economic sector with the higher GDP representatives in coastal departments is industry (44%). However, this value should be considered with precaution because includes two metropolitan areas outside of the study area (Cali and Medellín). Within the area of study, Atlántico and Bolivar departments depend highly upon industrial GDP, basically due to Barranquilla and Cartagena production. To give an impression, if one compares the Cartagena and Barranquilla-Soledad gross industrial production (17%), is with that of the Bogotá-Soacha metropolitan area (largest gross production participation, gross industrial product 24%), it is possible to realize the importance of these three Caribbean municipalities in the national industrial production.

Trade is the second sector on relevance (24%), distinguishing Bolivar and Atlantico's participation, at the study area. Agriculture is in the next level of importance (15%), particularly in Magdalena; the mining sector is mostly representative in La Guajira department (7.8%). Cattle raising is important in the Magdalena and Atlantico's areas; hotels and restaurants (6.6%) are represented mainly by Bolivar and Atlantico; fisheries (1.7%) with Valle, Nariño and Bolivar and finally forestry (0.7%), with Bolivar and Chocó as main producers.

The relative importance of different economic sectors and of socio-demographic aspects described above, constitute the basis for further analysis and for the search of greater level of detail as demands the identification of development factors. This task starts with the analysis of the information presented in the current report and constitutes the central axis for next VA step development.

Concluding the socio-economic component

The population on the Colombian coastal zone is about 5x106 inhabitants for year 2001, this is 12% of total population in the country. The population growth dynamics is up to national average. The distribution is basically urban and the life conditions measured through the Unsatisfied Basic Needs Indicator (NBI) show a disadvantage relation in relation with national average, excluding the Insular Caribbean.

Land use is very different for the three coastal areas: Cattle and crop raising are first on the continental Caribbean; in the insular Caribbean the use is for tourism, and in the Pacific coast, the areas are occupied for wild life and forest exploitation.

Governance

The governance component has been summarized in four tables representing each one of them different aspects that are associated to administrative and managing aspects of the Colombian Coastal zones. It has been attempted to include all the possible institutions and entities that are involved with marine and coastal resources management as well as any law instruments that might affects coastal populations. The document contains a detail description of each of the institutions, plans, policies and legislative framework involved or with jurisdiction on coastal issues and areas. This summary is a brief list of national, regional and local entities with administrative, assessing, implementing and scientific functions, among others in the marine and coastal zones.

Table 5. Stakeholders involved in the Colombian Coastal Zones Management

Function	Institution
National Environmental Information System SINA	Group of norms, orientations, activities, resources, programs and institutions that have allowed the 99 Law implementation
Administrators with politic functions	Ministry of Interior
	Ministry of Economic Development
	Ministry of transport
	Ministry of Environment
	Ministry of Agriculture and Rural Development
	Ministry of Energy and Mines materials
Administrators with Co-ordination, Consultancy and Assessing Functions	Ocean Colombian Commission (CCO)
Administrators with Planning Functions	National council for Economic and Social Policy (CONPES)
	National Planning Department
Administrators with Implementation and policy functions	Ministry of Defense – Maritime General Direction DIMAR
	Regional Autonomic Corporations (CARs). There is a CAR on each department
	National Roads Institute
	Colombian Agrarian Reform Institute (INCORA)
	National Fisheries and Aquaculture Institute (INPA)
	Special Administrative Unit – National Natural Parks System
Administrators with Scientific and Technologic Research functions	Institute of Hydrology, Meteorology and Environmental Studies IDEAM
	Institute of Marine and Coastal Research INVEMAR
	Geographic Institute Agustin Codazzi (IGAC)
	Pacific Environmental Research Institute (IIAP)
	Biological Resources Research Institute Alexander von Humboldt
	INGEOMINAS
Administrators with control and security functions	Superintendence of Ports and Transports
Territorial Entities	Caribbean, Pacific and Insular Coastal National territories Departments, districts, municipal and indigenous territories.

It has been included as well as a list of the international treaties that have been signed by the Colombian government together with the national legislation. Table 8 refers to the goal of coastal departments development plans; table 9 appoints to property and finally a diagram summarizes the national, regional and local institutions involvement on coastal issues.

Table 6. Framework legislation for the Colombian coasts management.

Type of legislation	**Law Instruments**	
International legislation	Convention on wetlands of international importance (Ramsar, 1971)	
	Declaration of the UN Conference on the Human Environment (Stockholm, 1972)	
	Convention for the prevention of Pollution from ships MARPOL (London, 1973)	
	Agreement for regional cooperation on combat against contamination in the Southeast Pacific due to hydrocarbons and other deleterious substances (Lima, 1981).	
	Treaty for the Southeast Pacific marine environment and coastal zone protection (Cali, 1981)	
	United Nations Convention on law of the Sea- UNCLOS (Montego Bay, 1982)	
	Treaty for the protection and development of the Great Caribbean region marine environment and Protocol relative to activities for avoiding oil spills emergencies in the Great Caribbean Region (Cartagena, 1983)	
	Protocol for Southeast Pacific Conservation against contamination from land sources (Quito, 1985)	
	Protocol for Southeast Pacific marine and coastal protected areas conservation and administration (Paipa, 1989)	
	Protocol relative to wild flora and fauna special protected areas in relation to the Great Caribbean region marine environment protection and development (Kingston, 1990)	
	Declaration of the UN Conference on Environment and Development (Río de Janeiro, 1992)	
	Convention on Biological Diversity (Nairobi, 1992)	
	United Nations Framework Convention on Climate Change (New York, 1992)	
	Constitutive treaty for the Caribbean States Association (Cartagena, 1994)	
	World action program for the Marine Environment protection concerning land based activities (Washington, 1995)	
Normative Legislative Planning It reefers to those environmental and land planning legislation process that exist as a general framework.	National Constitution	Arts. 7 y 8 particulars obligation on cultural and natural national richness protection
		Art. 63 Public domain uses
		Art. 72 Nation heritage
		Art. 79 conservation, biologic diversity, environmental education
		Art. 80 Natural resources exploitation, planning and management
		Art. 95.8 Environment protection
		Art. 313 Grants allowance to municipality councils
		Art. 334 natural resources exploitation
		Art. 339 National Development Plan and land planning entities proper development
		Art. 337 Expedition of regulation on economic and social matters
		Art. 366 Quality of life

Table 7. Regulation framework and Ordinary Jurisdictional Planning. It includes regulations dictated by the Congress as well as those compulsory laws for authorities and particulars, included in Decrees, Resolutions and Agreements, etc.

Issues	Law Instrument	Objective – Aims
Planning	Law 136 –1994	Municipalities function and municipality land planning process
	Law 152 - 1994	National Planning System Conformation
Coasts and Seas	Law 10 – 1978	Territorial seas, exclusive economic zone and continental platform regulations
	Law 2324-1984	Maritime General Direction reorganization
Ports	Law 1 –1991	Ports expansion plans
Maritime and riverine transport	Law 105 - 1993	Transport General Statute
Environmental legislation	Decree 2811-1974	Natural resources and environment code
	Law 99 - 1993	Colombian nation and state organizations and entities environmental policy fundaments, objectives and principles definition.
	Decree 1541 -78	Water resource principal regulation rule
	Law 2 - 1959	Natural Reserves
Urban Development Planning	Decree 1333 - 1986	Urban planning, delimitation and development
	Law 9 - 1989	Urban areas activities allocation, priorities, treatments and uses.
	Law 388 - 1997	Territorial Development Law
Natural reserves	Law 2 - 1959	Reserved areas system creation
Environmental Policies, Programs and Plans	National biodiversity policies	
	National Water Policy	
	Forests Policy	
	Cleaner Production National Policy	
	Wild Fauna Policy	
	Fisheries and Aquaculture Development Policy	
	Environment Collective Project	
	Agenda 21 for the Pacific	
	National Development Plan (PND)	
	Caribbean Plan (ESCARIBE)	
	Colombian Caribbean Prospective and Strategy development plan. Caribbean XXI Century	
	Transport Master Plan	
	Great River of Magdalena Recuperation and Managing Plan	
	Coastal Territorial Entities Plans	

Table 8. Coastal regions development plans.

Department	1998-2000 Development Plan
San Andrés, Providencia and Santa Catalina Archipelago	Economic conversion, socio-cultural integration and sustainable human development Faced to XXI century
Guajira	The community is first
Magdalena.	For the good times
Atlántico	A bridge to XXI century
Bolívar	Development Plan for a Great Bolivar
Córdoba	Cordoba united for Competitiveness
Sucre	Management and Development for Sucre
Antioquia.	Antioquia bring us together
Cauca	To work for Cauca

Table 9. Property in the Colombian Coastlands.

Types of Goods	Concepts & Definitions
Goods of the Nation	It is reefer to those public domain goods that have been defined by law. It is impulsive that they are of public use and foment national richness.
Maritime and riverine Public Domain goods	All goods that due to their nature, use or affectation are designated to satisfy collective needs and interests, thus those that transcend individual rights
Marine public domain goods	Interior waters, territorial seas, Exclusive economic zone, coastal lagoons, estuaries, marine beaches, intertidal lands and an extension of 50 meters added to the maritime and riverine fringes
Rivers Public domain	It comprehends all rivers and waters along their natural course Waters that runs true artificial channels that have been created from natural channels including estuaries, lagoons, lakes, marshes, wetlands, currents, sub-soil water deposits, river beaches, riverine alluvium terrain and a 30 meters fringe from the rivers and lagoons permanent channel.
Untitled lands	None owns lands that locate within the national territory boundaries. These lands are not fiscal goods
Islands	Constitute the Country national territorial reserve and are not alienable
Ethnic territories	Lands that are appointed under the Land entitlement law. The 70 Law from 1993, constitutes the norm under which it was given jurisdictional development to the mandate established in the National Constitution transitorily article No. 55l, regarding property rights and cultural, social and economic rights of identity.

Coastal hazards and historical response strategies

As it has been appointed in previous reports, although there is evidence on the occurrence of sea level historical changes, there are no historical data referring to them in Colombia; the country also lacks information on detailed topography of most of the coastal regions. Both issues are very important to assess the impacts of sea level rise in coastal areas. In addition it was necessary to search for other mechanisms that could give an idea of the impact of sea level rise in the coastal areas. Coastal zones in general are continuously under pressure from coastal hazards and natural phenomena. Colombia is not an exception to them and most of the events that have had effects on urban areas, have been reported by newspapers. In general the information supplied by such means is not as accurate as it is required. Still it is good enough to point out damages caused by local or regional events such as hurricanes and tides maximum peaks and the reactions of public and private parties to repair and prevent the occurred damages. The information supplied in the document tables has been extracted from both national and regional newspapers and from the project DesInventar[2] , which is being developed by some Latin American institutions including the OSSO in Colombia.

Natural hazards reported since 1931, were classified according to their origins, consequences and intensity and were summarized in nine categories: sea level rise events, tropical storms, hurricanes, rainy season events, flooding, earthquakes, volcano eruptions and tsunamis. A complete explanation of them can be found in the body of the document. From the reported data it can be outlined that floods from rivers and estuaries have been the most common events reported in the Colombian coastal zones for the past 70 years. Followed by tropical

[2] http://www.desinventar.org/desinventar.html

storms, sudden and temporary sea level rise, rainy season, hurricanes, seismic, volcanic eruptions, habitat destruction and tsunamis. There has occurred only one tsunami in the past 70 years (1979) that affected Tumaco, in the Pacific region, one of the project's cases study sites.

Information collected includes: industrial and accommodation infrastructure damage, tourism industry losses, people affected, death and injured people, crops losses, public services damages, communication pathways, ports and airport damages, cattle raising and fisheries losses, epidemics increase, landslides, beach erosion and coastal defences damage or lost. Not much analysis can be done with such data since the information gathered is not complete for all fields and, being extracted from newspapers it is possible that the media have only focused on human casualties more than in any other event.

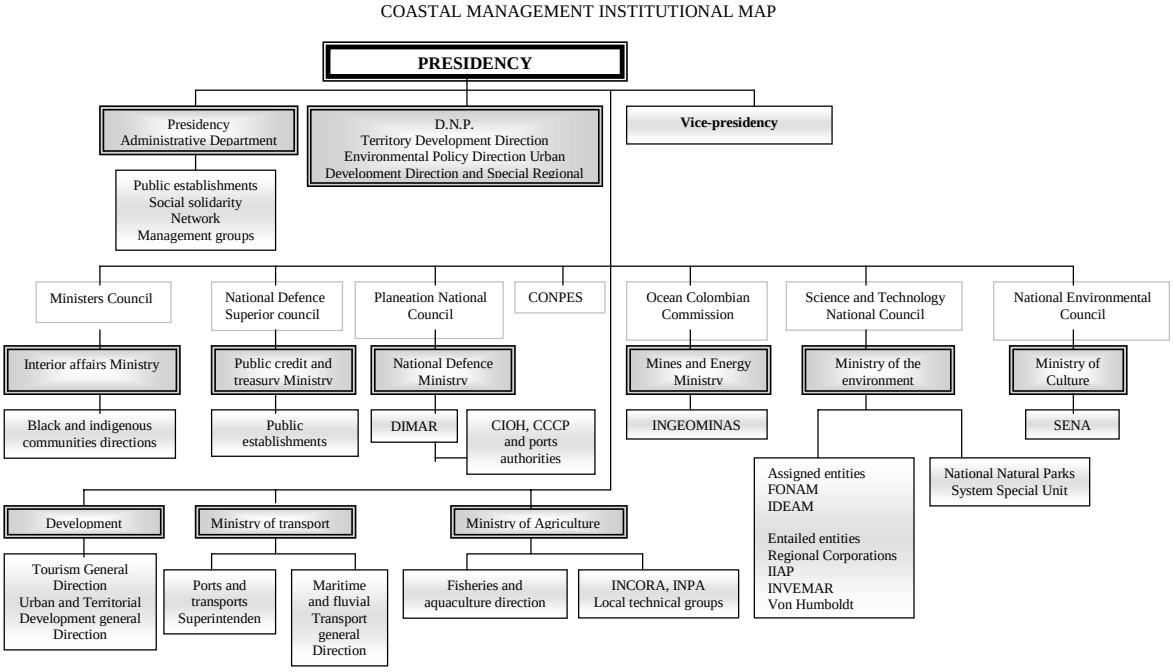


Figure 1. Coastal Management Institutional Map

Bearing in mind data quality, most reported effects from the selected categories are presented. Affected people and damaged homes are the most common consequences but depending on the event other effects were greater. The effects on each coast and each case study areas have been summarized as well, independent of the event, people affected and accommodation damages are the most reported consequences. In the Caribbean region homes damaged occupy the first place whereas in the Pacific people affected present greater values; lost crops are the second most important effects in both regions, similar consequences are observed in the case study areas. Main capital cities seem to be the most affected by coastal hazards, it is possible that even though coastal hazards occur along the entire coastal zones, cities are under greater pressure as population concentration centers and with more infrastructures that can be damaged in a coastal hazard event. Thus, Barranquilla, Cartagena and Santa Marta, in the Caribbean, are the most affected places and Buenaventura and Tumaco in the Pacific.

Step 3. Development factors

In order to establish strategies to approach sea level change in Colombia, there are other issues that have to be considered. It is important to recognize the significance of the environment and human activities extension in the vulnerability assessment process, as has been appointed by the IPCC methodology. This implies that socio-economic development, population growth and other forces, such as the armed conflict in Colombia, can not be constant or can change throughout time and thus lead to a change in those natural, physical and socio-economic assets, as well as natural changes affect human distribution and activities. It is important to generate ideas on how population and economic activities will change at short medium and long terms and about the capacity of addressing sea level rise impact through the generation of prevention and responses strategies.

There are many aspects of sea level rise and its consequences that we are not able to predict. However, in the present project several scenarios for the Colombian coasts were studied, which involved socio-economic and environmental variables and that are described in the document. Scenarios for this project were considered as a way of structurally thinking about uncertainty and possible developments. The definition of scenarios adopted was the one given by Rotmans:

> *Scenarios are hypothetical descriptions of alternative images of the future and of causally related processes, events and actions which lead to these images of the future, where a final situation is sketched from a starting situation, usually the present situation.*

According to this definition scenarios are not the same as a vision of the future or as predictions. But they are hypothetical descriptions of possible future developments, processes and succession of events in a period of time defined. In general terms, they answer to a conditional analysis “what if”.

To assess the impact of sea level rise on the natural environment, qualitative and quantitative variables have been chosen; the impacts on the physic environment will affect any economic activity that is being developed in the area, hence natural scenarios proposed in here will affect other scenarios development. The environmental variables chosen are mangrove extension, special areas for conservation, number of species and coastal ecosystems environmental services.

The climate scenarios presented were extracted from a WWF series that describes climate change scenarios for several countries and regions around the world, using data from the IPCC. Information regarding CO2 concentration has been mentioned. The discussion has been focused on temperature changes, sea level rise, runoffs and future precipitation. It has been assumed that temperature will rise but at a slower rate than in temperate regions. Warming will be constant but will be greater in the Andean and inner regions than in coastal areas, even though rivers run off at the low areas will be a great problem reason why river basing planning measurements must be consider in integrated coastal zone management.

The socio-economic characterization of the coastal areas threw substantial differences between the Pacific Coast and the Caribbean Coast, as regards population tendency, indicators of life quality and the development of the characteristic economic sectors for each one of them. These differences explain mostly by the historical context of occupation of the

territory, the land tenure system, the type of economic activity, and by the institutional context in which the social actors undertake economic, social, cultural and political exchange.

From this characterization, heterogeneity is also denoted to the interior of oneself coastal region. The technical report 3 shows these differences between the two coastal regions and at the interior of each of them when it comes to different degrees of vulnerability of increment of sea level. The socio-economic variables selected represent the development factors defined as those key elements in the current and future development of the municipalities and coastal regions.

These development factors are quantitative and qualitative and they were chosen as a result of the analysis of the socio-economic characterization of the Colombian coasts carried out in the technical report 2. Each development factor has a measurement indicator that allows a quantification of the social and economic incidence of different outlined scenarios of sea level increment. As far as qualitative variables are concerned, as we see it later, do not enter in the projections undertaken in the scenarios. Nevertheless, it was important to consider them as inputs aiming at facilitating the interpretation of the results of the projections and the analysis of the institutional and political capacity to implement strategies of response due to increase of sea level.

Scenarios for both Colombian coastal zone, Caribbean and Pacific, were built up based on information raised by different sources, in particular from government institutions. These institutions have carried out their projections based on a series of assumptions related to economic and social variables. Implicitly or explicitly, these projections are reflected in the scenarios in which the armed conflict may have an impact on the demographic and economic variables.

Based on the recommendations made by the Intergovernmental Group of Experts on Climatic Change, to determine possible scenarios, there were chosen two scenarios: a pessimist one and an optimist one. These two scenarios seem to be more appropriate given the current level of information and uncertainty and because they correspond closely to the projections made for the Colombian future evolution. Economic growth, population growth and the level of the armed conflict were used to build up these scenarios in order to estimate the grade of realization of future recommendations in case of sea level rise.

Assumptions regarding relations between economic growths, the state of armed conflict and population growth are included in the analysis. A high level of armed conflict implies low GDP and low population growth, whereas a low level of conflict, bearing other variables constant, would imply a greater GDP and a constant or positive population growth.

The following chart summarizes the social and economic variables for the chosen scenarios:

	Scenario 1	Scenario 8
Level of Armed Conflict	HIGH	LOW
GDP growth	LOW	HIGH
Population growth	LOW	CONSTANT

Methodological framework is explained in detailed in the main document. Projections for population growth were built up with the same criteria and information produced by the DANE. Fedesarrollo undertook GDP projections.

As general results, a social conflict reduction to a low level (scenario 8) could mean that the GDP average annual growth rate would be 3.7% for year 2030 and 4.5% for year 2100. An expansion in the population growth will also occur along with the economic growth during these years. Due to the population growth dynamics it is expected that risk areas population in 2100 will not rise as accelerated, as it will during the period 2001-2030.

In relation with land use, constraint by the level of available information, the estimation has shown that the industrial and commercial sectors will represent the most important ones in terms of GDP for both 2030 and 2100 in the Caribbean region as well as in the Pacific region.

For scenario 8 (optimistic) cattle-raising sector will be the most affected by the probability of flooding in the Caribbean region, while agricultural and industrial sectors will represent the highest production value/km2 for years 2030 and 2100. In the Pacific, the highest risk sector for flooding will be forestry and the highest production value will be represented by crop raising.

Scenario 1 shows a pessimistic view in which the level of the armed conflict is high and GDP and population growth are low. Under this scenario the GDP average annual growth rate will be about 3.5% for both 2030 and 2100. During this period of time, a reduction in the national population size and a moderate rise on the coastal zone will be evident; at the same time, the number of inhabitants affected by anomalies on the sea level will rise moderately.

Finally, it is clear that under this scenario the highest participate sectors will be industry and commerce for both regions. It is expected that the sectors with the highest production value/km2 will be agriculture and industry in the Caribbean region, and cattle and crop raising in the Pacific region.

Step 4. Evaluation of physical and natural systems responses

In this step, the possible effects and responses from natural systems to accelerated sea level rise (ASLR), as well as the implication in the social and economic issues developing in the Colombian coastal regions are analyzed. It is aimed also, to address the impacts of the sea level change by year 2030, taking into consideration a projection of 30 cm and a worst case scenario of 1 m ASLR projected by year 2100.

Natural system responses

Although a high uncertainty is still prevailing on what are the truthful consequences of sea level rise on the natural system, some assumptions have been made taking into account geological and physical evidence as well as expert knowledge to describe some of the possible responses. These responses had been characterized from the point of view of the known mayor impacts caused by SLR, which are erosion, flooding and saline intrusion. These impacts have been localized on maps and explained wherever occurring.

Erosion

On the worst-case scenario, erosion is expected on most low coastlands in the Caribbean coast due to the low topographic gradient, high sediments and sand movement. Although the degree on which this impact will reveal along the coast is a major uncertainty where natural process are going to be playing a mayor role on the results. Beach erosion could increase in the southern Caribbean as a consequence of land sinking associated to mud diapirism.

Erosion on Pacific low coastland areas is also expected; high precipitation and rivers input have lead to the conformation of a extend submarine sand barriers; deltas and sand barriers are expected to be the most affected systems on this coast. On the other hand, the sustainable management of the major deltas of the Pacific could reversed the erosion effects under a carefully controlled environment, allowing the natural functioning of deltas by utilizing, rather than diminishing, beneficial natural pulsing energies.

More so ever, despite the high rates of natural SLR over the past several thousand years, Pacific deltas have greatly increased in area because of riverine sediment delivery. Sediment deposition leads directly to accretion. Dissolved and particulate nutrients stimulate vegetation growth that increases organic soil formation, thus further increasing the rate of accretion. Deltas have grown through over bank flooding and also by changing channels every several hundred years. The input of river water not only adds sediments, but also brings fresh water that lowers salinity stress and provides nutrients which increases the productivity of deltas. In this sense, it is also expected in some degree the self-response of this system to SLR impacts.

Continuing on the assumption of erosion, high coastal land erosion is expected to be a function of the resistance of cliffs materials. In this sense the southern Caribbean would be more affected whereas towards the northern cliffs, like Sierra Nevada de Santa Marta, significant effects are not expected. The same principle has been applied to the Pacific high coastlands where erosion is expected towards the southern area and in some small local spots towards the north.

Flooding

Again assuming the worst-case scenario, flooding processes in Colombia will occur parallel to the erosion process due to the characteristics of the coast morphology. Sea level rise would occur over all beaches along the Caribbean coastline and lead to the conformation of new sand deposits; flooding would affect the most the southern Pacific coast because of low coastlands extension, the presence of several rivers mouths and numerous internal drainage connections. Flooding will affect coastal lagoons and estuaries also by saline intrusion and the spread of their inundation area, fresh water input is expected to increase as well.

Saline intrusion

Saline intrusion will be more representative in coastal lagoons and estuaries, although the extend and effects of salt intrusion has not been deeply studied for the Colombian estuaries; for this report some qualitative aspects have been described, including ecosystems migration, cultivation land effects and fresh water sources salinization.

Erosion, flooding and saline intrusion effects and ecosystems characteristics were used to address natural systems responses to sea level rise. Even though, the main attention has not been placed in seismic movements which could alter continental /platform levels and hence natural systems responses, it is important to develop further research and remain them present along any diagnosis or management process. For each ecosystem, uses and environmental services that could be potentially affected by a change in sea level were summarized in table 10.

Table 10. Marine, coastal and terrestrial ecosystems goods, and environmental services that could be affected by sea level rise

Ecosystem	Services	Goods
Agro ecosystems	■Maintain limited watershed functions (infiltration, flow control, partial soil protection) ■ Provide habitat for birds, pollinators, soil organisms important to agriculture ■ Build soil organic matter ■ Sequester atmospheric carbon ■ Provide employment	■ Food crops ■ Fiber crops ■ Crop genetic resources
Forest Ecosystems ✦Humid Tropical Forest ✦Dry Tropical Forest ✦Mangroves	□ Remove air pollutants, emit oxygen □ Cycle nutrients □ Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) □ Maintain biodiversity □ Sequester atmospheric carbon □ Moderate weather extremes and impacts □ Generate soil □ Provide employment □ Provide human and wildlife habitat □ Contribute aesthetic beauty and provide recreation	□ Timber □ Fuel wood □ Drinking and irrigation water □ Fodder □ Non-timber products (vines, bamboos, leaves, etc.) □ Food (honey, mushrooms, fruit and other edible plants; game) □ Genetic resources
Aquatic Systems ✦Estuaries ✦Coastal lagoons ✦Marshes	■ Buffer water flow (control timing and volume) ■ Dilute and carry away wastes ■ Cycle nutrients ■ Maintain biodiversity ■ Provide aquatic habitat ■ Provide transportation corridor ■ Provide employment ■Contribute aesthetic beauty	■ Drinking and irrigation water ■ Fish ■ Hydroelectricity ■ Genetic resources
Grassland Ecosystems	□ Maintain array of watershed functions (infiltration, purification, f low control, soil stabilization) □ Cycle nutrients □ Remove air pollutants, emit oxygen □ Maintain biodiversity □ Generate soil □ Sequester atmospheric carbon □ Provide human and wildlife habitat □ Provide employment □Contribute aesthetic beauty and provide recreation	□ Livestock (food, game, hides, fiber) □ Drinking and irrigation water □ Genetic resources
Coastal Ecosystems ✦Mangroves ✦Sea grasses ✦Coral reefs ✦Soft bottom ✦Beaches	■ Moderate storm impacts (mangroves; barrier islands) ■Provide wildlife (marine and terrestrial) habitat ■ Maintain biodiversity ■ Dilute and treat wastes ■Provide harbors and transportation routes ■ Provide human and wildlife habitat ■ Provide employment ■Contribute aesthetic beauty and provide recreation	■ Fish and shellfish ■ Fish meal (animal feed) ■ Seaweeds (for food and industrial use) ■ Salt ■ Genetic resources

It is important to mention that in addition to the potential effects that inundation, erosion and saline intrusion have on natural systems, current pressures on the environment are also high.

Habitat fragmentation, climate change (temperature and precipitation) and resources over exploitation could have equal or even higher effects than sea level rise as such. This is the case of the Colombian coastal ecosystems as well; the extent of sea level change effects over desert zonobiomes and dry tropical forest is expected to be primary as a consequence of saline intrusion and inundation, but tourism, industry and cities expansion have leaded to a considerable reduction of these systems.

Humid tropical forest will be affected by inundation and saline intrusion processes, it is expected a backwards migration, when possible, to more solid land and where the conditions allow colonization. Due to the large extension of the ecosystems, it is expected not to occur a definitive lost of the system, neither on uses or environmental services, as a general rule, once more the anthropogenic pressure over the system plays an important role in the near future.

Coral reefs responses to sea level rise will depend upon their distribution as well as the hydrographic, geomorphologic and biologic aspects occurring at short, middle and long term, also their inherent adaptation capabilities. Sea grasses remain sub-researched in Colombia; the effects of sea level change may be related to sediments and turbidity increment.

Mangrove forests are expected to be the systems under the highest pressure from the effects of sea level rise, flooding rate, tides range and sedimentation rate are the factors that could influence the most in these systems adaptation to new conditions. The expected response would be migration, in places where it can be possible, other wise these systems would be under massive stress. Most of their environmental services would be affected by sea level rise, in particularly the service of shoreline protection.

Social-economic responses

Expected sea level rise effects, natural systems responses and their impacts on socio-economic aspects have been summarized in Table 11. Basically, the main socioeconomic implications are the alteration or loss of social and economic valuable areas, meaning the alteration changes in land use, land value, investment and management costs rise, among others.

The socio-economic analysis for the present report concentrates in the qualitative description of the direct impacts caused by effects associated with sea level rise (30 and 1 m), and the establishment of methodological criteria for the estimation of such impacts. These results contribute to an approach for the formulation of strategies for the step 5.

It is important to understand that the estimation of impacts might be affected by the availability of information, not only for the projected variables but also for the actual scenario. For this reason, the risk of generating underestimations or overestimations is present. It is very important to outline that estimations done involve exclusively quantitative descriptions of inundation direct cost, which is far of a deep analysis on social good wealth that integrates direct and indirect costs. It does not mean a loss in analysis relevance because it is the first approach based on the premise that “to a relative modest increase in sea level there could be a substantial effect on society, unless that costly protective measures are taken”.

It is important to consider that the definition of sea level rise impacts and coastal zone systems responses only could be established with the integration between natural and social economic components. The social economic responses are based on the analysis of different estimated tendencies for a limited number of variables once the sea level rise impacts on development factors have been identified. So, the social economic responses analyses depend upon the qualitative and quantitative description of social and economic impacts, and for this reason are based on the natural system responses.

Table 11. Implications of sea level change effects on the Colombian development factors

DEVELOPMENT FACTORS	INUNDATION	EROSION	SALINE INTRUSSION
Population	To define sea level rise socioeconomic vulnerability, there is a need to identify vulnerable population firstly. Vulnerability is defined in this case as accommodation loss, as a consequence of structures deterioration caused by land erosion and inundation.		Saline intrusion is expected to have an impact on the population, in terms of fresh water availability.
Agriculture	Two impacts can be expected: cultivated area loss and/or potentially cultivated and/or and increment in phreatic level that could alter actual crops distribution.	Gradual erosion of agricultural lands as a consequence of sea level rise added to progressive erosion caused by non-adequate management practices could be one of the principal impacts on agriculture production.	Saline intrusion has two effects; soil's chemical properties alteration and fresh water irrigation sources salinization.
Cattle raising	Cattle areas loss	Erosive processes caused by sea level rise added to soils overexploitation by semi-intensive cattle raising, could accelerate soils degradation that would lead to non productive lands.	Soils salinization could lead to a gradual productivity reduction in soils productivity in terms of plants covertures that are part of cattle raising feeding habits.
Fisheries	As it has been described in natural systems responses, mangrove ecosystems flooding could generate a forest migration depending on the geomorphologic and infrastructure limits. Fish behavior in estuarine areas partially depends on these ecosystems alterations and responses. In general terms, it is expected that a redistribution of sediments could occur with consequences for artisan fisheries. There is still an information gap regarding the effects of sea level rise on large-scale commercial fisheries.		
Forestry	The loss of forests area by inundation could result, at least temporally, in a reduction in goods and services supplies associated to forestry ecosystems.	The intensification and acceleration of erosion rates would increase ecosystems alteration that could affect goods and services supplies associated to this systems	Saline intrusion could temporally generate forestry resources decrease. Even though, it would also generate alterations in population dynamics favoring other species exploitation.
Industry	Industrial infrastructure area loss as a consequence of constructions and equipment deterioration		Saline intrusion would affect the water quality used for services and productive processes.
Commerce	Commercial infrastructure loss caused by constructions deterioration		
Tourism	Tourist infrastructure loss as a consequence of constructions deterioration. An important issue is to address the tourist places where recreation is a very important service.		
Infrastructure	Transport infrastructure as a consequence of roads and ports deterioration.		

In this framework, a description and quantification of the principal social economic impacts due to sea level rise have been done follow by a description of the methodological criteria used to estimate the impacts. This methodology aims to solve relevant questions, under the comparison analysis of the present time, a projection for years 2030-2100 and the possible impact of this future scenario with 0.30 and 1 m SLR (Figure 2). In accordance, the following questions were worked out:

1.What will be the impact of 30 and 100 cm ASLR on the costal zone natural and socio-economic system in terms of loss and risk of people and value?

2. What will be the impact of two different scenarios of development (optimistic and pessimistic, till the year 2030) on the costal zone natural and socio-economic system in terms of loss and risk of people and value?

3. What will be the impact of both of the different scenarios of development (optimistic and pesimistic, till the year 2100) with 100 cm ALSR on the costal zone natural and socio-economic system in terms of loss and risk of people and value?

4. Which of those situations presents the biggest impacts?

5. Does Colombia need to develop ICZM because ASLR will have such a large potential effect or because the expected autonomous development will lead to such an increase in risk for people and value, that ICZM is needed?

Questions 1 to 4 are answered along this step. Question No. 5 will be answered in steps No. 6 and 7.

ASLR\scenario	T_0	T_{2030}	T_{100}
0 meter	Present situation without SLR	Future development without SLR	Future development without SLR
0.30 meter	Present situation with SLR	Future development with SLR	
1 meter	Present situation with SLR		Future development with SLR

Figure 2. Comparison matrix used on the follow up vulnerability assessment.

Methodological framework

A relative change of the biophysical conditions, as the one described on the natural systems responses chapter, have a large impact over the population and the use of environmental goods and services (in terms of magnitude). Each one of sea level rise effects – flooding, erosion and saline intrusion- determines a natural system response that modifies resources uses, as urban and productive activities.

In general terms, among de principal social economic implications can be count the lost and/or modification of areas with social and economic value represented by land use changes, vary on land value and cost inversion increment and /or the maintenance of the cost.

Although, three possible effects have been taken into account (erosion, inundation and saline intrusion), its important to underline that for the social economic analysis, only an approach for the impacts estimation in relation to the flooding effect was made. Notice that the natural system responses determine in a bigger or minor grade the resources usage and its inherent costs and represent a social welfare lost.

In accordance with the results obtained in step 3, the methodological structure of this report was approached through the estimation of direct impacts due to sea level rise among the social economic scenarios outline. Its important to highlight that the accuracy the impacts

identify for each of the scenario could be affected by availability of information, not only for the projected variables but also for the base line variables. In methodological terms, the differences between politic-administrative and technical boundaries used in this project for information collection are a limitation that leads to under- or over estimation of the variables. In general, one can state that the variables are not evenly distributed in the space.

However the assumptions were necessary to be able to operate with the data available, like population and GDP. In order to solve methodological difficulties incapability between study area boundaries, flooding risk areas and potential flooding areas and the administrative boundaries as this is the reference for population and productive sector value information. In the specific case of the study area population, the base of information is represented by the municipalities' projections corresponding to each scenario. Not always the coastal zone municipalities' extension is included in the study area, moreover in a specific view; frequently a portion of the rural area of the municipality is contain in it. Taking into account these aspects, the population was consider for urban areas as the precise value of inhabitants and estimation was calculated for the rural areas based on the assumption of uniform distribution. According to this assumption, the estimation of population affected by inundation due to sea level rise and the population in risk was obtained (see also the chapters on data availability and assumptions in the other reports).

For the estimation of economic values at lost and at risk the following considerations were taken into account:

1. The information used correspond to the departmental GDP economic sector projections in relation with the development scenario optimisms and pessimistic.

2. Due to the difficulties explain above in relation with the boundaries, assumptions were done based on currently information about land uses.

3. In the case of agriculture and cattle sectors information in terms of crops area and grass areas for the departmental cattle were considered for the indicator identification suggested by the IPCC methodology in terms of production value per area.

4. For the industrial sector the information was obtained in terms of aggregate value for Cartagena and Barranquilla-Soledad zones. Projections for the industrial aggregate value for 2030 were calculated based on the national GDP growth rate for 2000 and the rates used on the projections for the development scenarios analysis.

Finally, for the case study areas of Guapi and Tumaco, all the calculations were done in the same way as in the national analysis. The only modification done was that the economic sectors GDP was replaced with the annual gross of the productive system associated to the land uses. For the case study area of Morrosquillo, a estimation of the change on land use between 2000 and 2030 according to the observed dynamic on different vegetal covers as crops area, grass, urban areas, wetlands, among others.

Direct impacts estimations according to the social economic development scenarios

Optimistic scenario

Beyond a social political favorable context, in terms of a reduction on the level of social conflict in Colombia, the population dynamic will be determinated by a constant growth rate and the by a high rate growth GDP. This application of the flooding model to the present scenario is a theory exercise in which adverse impacts caused by a sudden 0.3 m sea level rise. The impacts were quantified through the affected population and economic sectors GDP according the land use categories.

Population impacts

This scenario shows that by the year 2030 approximately 3.7% of the Colombian coastal zone (Continental Caribbean and Pacific) could be affected by flooding due to sea level rise. That is 9.011.712 inhabitants approximately, representing 0.5% of the total country population for the same year.

In the regional context, the estimations show that the affected population has the tendency of aggregation on the Caribbean coast with a 61% of the total affected population, besides the Pacific coast with 39%. In a closer look, the municipalities with the most total affected population will be Tumaco (69,127), Turbo (69,127), Cartagena (43,763), Tolú (43,090) and Pueblo Viejo (20, 782). This population represents the 82% of the total affected population for the year 2030.

This same analysis made under a 1 m SLR scenario for the year 2100, the estimations shown a variation on the above results, not only by the expected flooding but because of the autonomous development between 2030 and 2100. It is observed that from the 12.7 million people that could inhabit the coastal areas, SLR could affect approximately 1.7 million. That is 2% of the national population, being 77% correspondent to the Caribbean and 23% to the Pacific. In this scenario it is also observed a mayor participation of the urban population corresponding to the 85%. By the year, 2100 the mayor number of inhabitants would be located on the municipalities of Cartagena and Barranquilla as well as in the Tumaco, Turbo and Buenaventura areas.

In accordance with the methodology estimations for the new risk areas after the SLR has taken place are necessary to determine. The results show that from the year 2030 to 2100 the percentage of population on the study area that will be localized on the risk area I will pass from 15% to 33%. A different proportion within coasts is observed for risk areas II and III whereas on the Caribbean goes higher while on the Pacific it diminished.

Social economic impacts

On general terms and considering within the analysis the agricultural, catcalling, industrial, forestall and mining sectors, the result shows that 0.4 percentage of the departmental GDP would be affected by the year 2030. The most affected departments under this scenario would be Chocó and Cauca with a 29% and 19% of their total afected GDP.

By year 2100 under the same analysis made above, a total of 0.4% of the total departments GDP would be affected. Agriculture (81%), followed by catcalling (18%) and industry (1%) would be the most affected sectors.

It is observed that by year 2100, the Caribbean GDP would be greater affected in relation of the total obtained for the year 2030 under the current scenario. The participation of the Caribbean GDP would be 53% and for the Pacific would be 47%.

In relation with risk areas, the analysis shows that the agriculture GDP sector will be mostly included on flooding risk area I and II, followed by cattle raising under both SLR projections. Identification of particular risk conditions for industrial sector of Barranquilla and Cartagena is identified for year 2100.

Pessimistic scenario

The assumption that leads this scenario was that a higher level of conflict will imply low rates of consumption and inversion, reflected in a national GDP growth. The same assumption was established for population growth.

Population Impacts

Approximately 4 % of the coastal zone Colombian population could be affected by a 30 cm sea level flooding under this scenario, more or less 8,631.082 inhabitants that represent 0.5% of the total country population for the same year.

In regional context, the estimations show that the affected population must be concentrated on the Caribbean coast with 62% of the total affected population, besides the Pacific coast with 38%. In a closer look, the municipalities with the most total affected population will be Tumaco, Turbo, Cartagena, Tolú and Pueblo Viejo.

Under a 1 m SLR, the total affected population would be closer to 1.4 million people. That is 3% of the total national population of Colombia on that same year. An 86% of this population would inhabit the urban areas.

In reference to the people inhabiting the risk areas by the year 2030 a 14% and 30% of the Caribbean and Pacific coasts would be settled on risk area I. By the year 2100 this percentages are expected to grow until 31% and 38 % respectively.

Socio-economic impact

Under the present scenario a 0.1% of the total departmental GDP would be affected by the year 2030. By the year 2100 this percentage grows to 0.4%. The most affected economical sector would by agriculture (74%) followed by cattle (24%) and forestry (1%).

Case study areas

Morrosquillo Gulf

Optimistic scenario

Population impacts

The estimations shows that for 2030 the population of the case study area would be around 90,249 inhabitants belonging to the San Antero, San Bernardo del Viento and Tolú municipalities. Based on the flooding model, around 27% of the inhabitants would be affected by a 30 cm sea level rise. This proportion could increase to a 40% by a 1 m SLR by the year 2100 (111,992 total projected population for the same municipalities).

Socio-economic impact

Due to flooding, the most affected economic activity by 2030 would be agriculture (94% of the total gross GDP) in contrast to 2100, when the aquaculture sector would be then more affected (46%), followed by agriculture and cattle with 32% and 22% respectively. The total grocery affected will be mostly concentrated on San Bernardo del Viento municipality.

Pessimistic scenario

Population impact

For 2030 pessimistic scenario, the population of the municipalities of San Antero, San Bernardo del Viento and Tolú would be around 87,069 inhabitants, distributed as follows, Tolú 50.4%, San Antero 19.7% and San Bernardo del Viento 29.2%. Based on this data, the population affected has been estimated on 23,940 inhabitants (27% of the population). In terms of distribution the total population affected correspond to Tolú 31%, San Bernardo del Viento 41% and San Antero 28%. From this total, the 75.2% of the population will be located at the urban area. The population on flooding risk area will be more or less 29%, concentrated on Tolú and San Bernardo del Viento. By the year 2100 this proportion could grow to a 40% of the total population (53,270), being Tolú the municipality with the highest participation within the total affected population (44%).

Economic impact

Under this scenario, the most affected activity will still be agriculture followed by cattle, and aquaculture. In spite of this, results the affected gross income is reduced 20% for the optimistic scenario in comparison to the pessimistic scenario for the year 2030. This same analysis shows a 59% of affectation in comparison from the optimistic and pessimistic scenario for year 2100.

Integrated Management Unit Guapi – Iscuandé

Optimistic scenario

Population Impact

The results for this case study area are different from the ones obtained in the Morrosquillo area. It is expected that by year 2030 and 2100 the population will grow from 2,411 to 27,3228 inhabitants respectively. These accelerated populations grow leads to presume an affectation of 5% of the population by year 2030 and a 40% by year 2100.

Economic impact

The most impacted activity will be agriculture with a 72% of the total gross income followed by extractive agriculture- forestry (28%) by year 2030. On 2100, the participation of these same-affected sectors will be 87% and 13% respectively. In terms of municipalities, the total gross income affected will be similar to both, Guapi and Santa Barbara de Iscuandé. The same activities will be affected at the flooding risk areas.

Pessimistic scenario

Population Impact

The total affected population for year 2030 in a pessimistic scenario will be 2,3060 inhabitants (5% of the population). This same indicator for year 2100 will lead to an estimative of 30, 790 inhabitants representing a 39% of the total municipalities population for that year. According to this, Guapi will have 56% of the population affected and Santa Barbará de Iscuandé 46%. In this case, the urban population will also be the most affected. By year 2100, this participation would be of 83% and 17% respectively.

Economic Impact

As in the optimistic scenario, the most affected activities will be agriculture (72% by 2030 and 87% by 2100), followed by forestry use and extractive forestry use. In relation with the flooding risk areas the same order of activities will be affected.

Tumaco urban area

Optimistic scenario

Before doing the description of the results obtained, it's important to remember that this case study area differs from the others due to its characteristic of urban area, where the population is the most relevant element.

Population impacts

Based on the estimations done, it is possible to identify that the population of the urban area of Tumaco will be more or less 19% of the total population of the municipality (22,838 inhabitants). The urban population affected by a flooding due to sea level rise is estimated on 19% for year 2030. In terms of population at risk 22.3% will be located on risk area I and 81.1% at risk area III.

Pessimistic scenarios

Under a pessimistic scenario, the population of the urban area of Tumaco will be more or less 59.5%, which means 109,633 inhabitants. The urban population affected by a flooding is estimated on 88%. The population at risk will be located on risk area I, and 81.1% at risk area III.

Step 5. Formulation of response strategies, costs and benefits

Human responses to the possible changes on the natural system due to sea level rise could be defined based on a hypothetical point of view or based on occurred phenomena. Several attempts have been made trying to predict the human responses to SLR, especially on those countries that are going to be strongly affected. Although several studies have been made around the world to model the responses of the systems such as beaches, mangroves, dunes, rocky coasts and other systems, such studies are just beginning in Colombia.

The ways in which people have responded to changes on subsiding coasts have varied with social, political and economic factors. A global sea level rise is likely to produce three kinds of response:

Evacuation, abandoning the land as it is submerged and eroded, and possible adapting to the effects of the rising sea

Attempts to maintain the existing coastline and coastal margin by means of engineering works

Counter-attack, notably by building walls to enclose and reclaim intertidal and near shore areas.

The response strategies that Colombia would have to assume to reduce the impacts of SLR are fully analyzed thru this step. However, not all the coastal area was analyzed. Only the most critical areas identified by a matrix of importance done at the municipality level were evaluated. This analysis should be considered as an academic and first impression exercise of the IPCC methodology, to identify the strengths and weakness of the present and future of Colombian Coastal Zones Management. The necessary measures to undertake the impacts of the future climate change should be taken under conscious and specific studies, based on former experiences and previous socialization measures. It is also important to address the importance of future studies to consider as well all other climate change impacts.

Human responses

Planned adaptation options to sea-level rise are usually presented as one of three generic approaches:

- Retreat – all natural system effects are allowed to occur and, pulling back from the coast will minimize human impacts.

- Accommodation – all natural system effects are allowed to occur and, adjusting human use of the coastal zone will minimize human impacts.

- Protection – natural system effects are controlled by soft or hard engineering, human impacts are to be reduced in the zone that would be impacted without protection.

In practice, many responses may be hybrid and combine elements of more than one approach. Losses of coastal land have occurred as a result of cliff recession, beach erosion and the retreat of sectors of shoreline on deltas and coastal plains. Apart from urban and industrial areas and ports, where sea walls and other structures have been built to halt coastline recession, usually the human response has been to abandon the threatened structures. Erosion and submergence of beaches, as sea level rises, will be the mayor problem in areas that have been already developed. Where an important infrastructure has developed the retreat option will mean moving or abandoning structures that have been build for recreational use and tourists accommodation.

Where the coastal development consists only of small and relative inexpensive buildings, it is easier to abandon them. In the same way, the actual terrains on the alluvial plains that are dedicated to agriculture would force their owners to retreat to more favorable areas. On parts of deltas already showing erosion because of the reduction of sediment yield by dams; local inhabitants have already abandoned farms and villages, and structures such as fishpond and saltpans.

The most recent reported retreat response on the Pacific Colombian coast is the El Choncho Village, located before its complete retreat, on one of the six barriers islands from the San Juan River Delta. From 1998 until 1999 the island suffered from severe changes on its structure that leaded to the total separation from the continent accompanied with an outrageous erosion rate (15 m/y). In spite of this condition, the population refused to leave their terrains. In 1997 a severe over wash of the whole island alerted the government to negotiate their retreat to the continent, as they did on 1998. The government helped with some construction material, but the new housing construction was totally assumed by the residents.

While important autonomous adaptations will occur in coastal zones, the possible responses to climate change will require planned adaptation. This planned adaptation may include policies to allow autonomous adaptations to occur to the maximum possible extent. Evaluating adaptation requires a full understanding of the impact potential and the adaptation potential. The latter factor embraces autonomous adaptation, and (anticipatory and reactive) planned adaptations. This allows a realistic assessment of the likely initial and residual impacts, and hence the real vulnerability.

The most likely human response to sea level rise, especially in long-settled urbanized areas, will be to try to maintain the present coast line by constructing sea walls, and to introduce drainage systems to prevent submergence of low lying coastal land.

Protection Strategies for the Colombian Coastal Zone

There are three fundamental and interrelated questions about adaptation: Where to adapt? How to adapt? And, When to Adapt? If we knew the future climate with some precision, an analysis of costs and benefits would help us provide the answer to these questions. However, the uncertainty about future climate and many other factors is large and we need to think in a risk- and uncertainty-based manner rather than looking for deterministic solutions.

Sea level rise has potential impacts. Anticipatory planned adaptation can reduce these potential impacts to the initial impacts. Reactive adaptation (including autonomous adaptation) in response to the initial impacts further reduces the impacts to the residual impacts. The realistic magnitude of the initial and residual impacts is a key measure of vulnerability.

Within this concept and conscious that the serious impacts that SLR could have on the Colombian coastal zones, the use of anticipatory measures is fully justified. The analysis of the possible response options for Colombia is here in listed. This analysis is made under the two SLR projections chosen by the project (30 cm by the year 2030 an 1 m SLR by 2100).

Critical areas identification

With the purpose of identifying critical areas due to sea level rise on the Colombian coastal zones, Caribbean and Pacific, a matrix for the identification of importance of each municipality was constructed. The first step of this task was the elaboration of a checklist of main characteristics that can be affected in a relevant way by the effect of flooding. The results of the checklist were organized in 5 components: physical, biotic, social economic, governance and hazards. The last aspect was considered due to the importance of the natural events consequences on the formulation of responses strategies and planning issues.

The following step was to identify a few criteria that could resume the most important and relevant elements that characterized by its important the municipalities. The chosen criteria were the following:

- Percentage of flooding of the municipality within the study area

- Urban population affected by SLR (according to each projection)

- Percentage of affected urban population (according to each projection)

- Presence infrastructure (in danger of being flooded)

- Special management areas (national or international designed areas of conservation)

Afterwards the value of the elements selected for each one of the coastal zone municipalities by the generation of data ranges was assigned with a value of 1, 2 or 3 depending on the qualification of the data ranges in low, medium or high. After this, a calculation of the importance value for each municipality was done in terms of low (green), medium (yellow) and high (red) importance.

The results of the 30 cm-2030 matrix show as hot spots the municipalities of Cartagena and Santa Marta as well as Turbo on the Caribbean, while Tumaco on the Pacific coast was exposed as a hot spot. *Cartagena* is considered as a high-risk area due to the high population density (1452 Hb/km^2), the diversity on the ecosystems close to the city, the cataloguing of special historic and cultural place according to the National scale and the infrastructure that rests on the city.

Santa Marta is one of the most populated municipalities of the Caribbean coast (398,368 inhabitants). It has a great ecosystems and ethnos diversity protected by the National Parks System. Due to port and tourism activities, the infrastructure of the city is significant. Rains and tropical storms cause impacts on the city and its inhabitants.

The municipality of *Turbo* is an area with a big economic, social, demographic and political dynamism. It is located on an alluvial valley and is very vulnerable to erosion. Human intervention and degradation of forests to open spaces for the banana industry have caused several problems on this coast.

Tumaco is the second most important city on the Pacific coast of Colombia. According to the flooding model (Annex 2. Technical Report No. 2) the area loss in Tumaco as well as the population that would have to be relocated will be considerable. This municipality has been affected 3 times by Tsunamis through the last century and it is also affected by fluvial flooding.

Within the 2100 analysis, besides the already mentioned ones, Barranquilla and Buenaventura are considered highly important and thus as a critical areas to be protected against SLR. The municipalities over lower lands as Ciénaga Grande de Santa Marta had in conjunction, a relative importance.

Barranquilla is an industrial district and the third most populated city of Colombia. Its location has favored development in the area, but flooding caused by rivers and swamps affect the region frequently during the rainy season. *Buenaventura* has the most important port on the Pacific coast; the big number of people located on low lands is other reason why this municipality is considered as at high risk. Seismic and other natural phenomena are common in this area.

The importance of the urban areas are reflected by the high population they encounter, the accommodation and industrial infrastructure, the recognition of special categories related with historical and cultural places, landscape and biodiversity values near them and vulnerability to natural events hazards as flooding, tropical storms, strong rains and occasional sea level rise.

Strategies Identification

A multicriteria analysis was implemented with the aim to establish which of the chosen protection strategies would be more suitable to be accomplished in each hot spot area. Despite of all the possible strategies, only those that were considered in the discussion with the expert were subjected to analysis. Even though there are differences between the options to be implemented in each hot spot area, it is very important to note that the implementation of the areas' development plans, some of which are already being implemented, and the investment on research and knowledge creation are the most recommended strategies, despite that are not strategies to address directly the flooding fact. Coastal defences would be feasible in Cartagena and Santa Marta, whereas in Barranquilla the main strategies focuses on the delta management and avoiding the location of population in the southern bound of the river.

Population relocation is another important tool, mostly in the Pacific coast where thousands of people inhabit in the intertidal areas at present time. Buenaventura and Tumaco plans are already in process of implementing the allocation of the people, the main task for local governments will be then, to avoid new colonization of those areas.

Alarm systems are another strategy that even though will not address sea level change would decrease the number of victims caused by natural disasters. It is probably the cheapest option and the one that would save more lives.

Other strategies considered were artificial reefs and islands, beach nourishment, strengthen of existing coastal defences, accretion, adaptation and no intervention. All of them have been described and fully analyzed in the selection process.

Finally, and apart of the cost and benefit analysis, it can be concluded that the strategies for the Pacific coast should be more orientated to management issues because there is not as much infrastructure and there is still plenty of mangrove, so strategies should aim for its development. On the other hand, strategies for Santa Marta, Cartagena and Barranquilla aim to protect the infrastructure and historical monuments considered invaluable for the region, country and humanity.

The most likely human response to sea level rise, especially in long-settled urbanized areas, will be trying to maintain the present coast line by constructing sea walls, and to introduce drainage systems to prevent submergence of low lying coastal land.

Parallel to this analysis a comprehensive research on each hot spot development plan was done in order to establish a total protection strategy that involves the development objectives of the areas as well as the additional measures needed to address sea level rise.

Strategies specification and costs analyses

The IPCC methodology establishes three main response options to sea level rise: accommodate, retreat and protect. The viability of execution of these strategies and the effects caused on the natural system are the main frame to evaluate the vulnerability of the area. In this context, a costs analysis of the possible strategies follows in the present report. However, this first attempt only considers a number of options that were thought to be best in

an optimistic scenario and considering at minimum two situations: a no measure situation and a full protection situation.

The no measure situation aims to settle a reference level, assuming the maximum impact due to ASLR, without additional measures and at 0 costs investment. The full protection strategy shows the maximum economical costs, assuming that the impacts and effects of ASLR would be minimal.

The protection option not only includes the defence of coastal line, but also protection strategies against flooding areas caused by rivers over wash and rain storms. The full protection situation includes two main strategies:

Development plans

This strategy involves the implementation of current development plans as well as current land planning strategies on each of the municipalities identified as a hot spot. According to law (Law 152, 1994) a Municipality Development Plan aims to enable a sustainable economic development that considers programs and projects in which environmental goods and values are estimated, in order to guarantee the environmental surplus for present and future generations. Adding to that, each municipality POT (land planning strategy) aims to gather together, harmonize and actualise other planning strategies such as the development plans, the organic law on urban areas, environmental laws and other strategies described in the national constitution related to development, planning and territory that are implemented in a certain area. According to Colombian legislation the POT is an instrument for each municipality and should establish mechanisms to promote sustainable development, conservation, protection and preservation of cultural and environmental assets, adequate urban planning and the prevention of natural disasters.

Although POT embrace land planning strategies and present projections up to 10 years, both instruments have been included, cited and analyzed along this report for each of the areas that were protection strategies should be adopted.

Additional Measures

Actual development plans do not include the implementation of measures or actions to approach sea level rise and its effects. Thus, these strategies include all those measures that involve the construction of structures or adaptation of systems to sea level rise

Once the critical areas where identified and parallel to the analysis of the possible protection strategies, a comprehensive study on each area development plan was done. Both analyses were gathered together and a final strategy for each area was proposed, based on the development plans and the protection strategies feasibility.

The measures included in a total protection strategy would be developed at short, medium and long term. According to the law Development plans should be accomplished before 10 years time. The completion of additional measures would depend on the investment required and the urgency of it requirement. Measures such as population reallocation, beach nourishment, alert systems and investigation investment should be developed at short term. All the other strategies that rely on structures such as sea walls, river embankment and the

artificial island would be accomplished at medium to long term. Values and costs of such strategies are included as well in the main document.

The results of the multicriteria analysis is presented for the major critical areas:

San Andrés de Tumaco, urban area

A brief reference to the main characteristics of the urban area was done over a map, with the purpose of getting a common view of the area. The city is an important point of economic development situated in a delta. Natural phenomena like earthquakes and tsunamis have affected the city. For this reason, municipality development plans have been established with strategies of adaptation and retreat. The strategies identified in this VA analysis are complementary to those municipality plans.

List of strategies measures identified:

1. Establish a new regulatory measure for designing and construction of houses, infrastructure, roads, etc. The measure is "do not develop anything below the 3.40 meter altitude line". The area below the 3.40-meter line has to serve as an area where natural processes have the space to develop themselves without hindrance. The natural processes will create a natural buffer zone, which will "grow" with the sea. Sand and silt deposits stabilized by mangroves and other plant will form a natural dyke, which can serve as safety zone. If some infrastructure is develop close to this line additional small scale measures must be implemented too, like small dikes or elevated grounds especially when it is concerning industrial activities.

2. Strengthened education programs, in order to train people about the value of natural delta and coastal processes and how to deal with them.

3. Develop and implementation of an early warning system and 'safe-areas' for disasters (Tsunamis, earthquakes and storm-surges)

4. Action plan in relation with "El Niño" phenomena

5. Develop of a research program for the study of natural process, looking forward the generation of protection strategies.

6. Give advice for the adaptation of the local port

7. Develop a regulatory system for land planning, including risk zoning.

Integrated Management Unit Guapi - Iscuandé

This case study area was characterized as a site where people and natural processes have learned to live together. For this reason most strategies are formulated in order to safeguard natural process:

1. Strengthen education programs, in order to train people about the value of natural delta and coastal processes and how to deal with them. Develop a method to extract the local knowledge available on sustainable development of mangroves.

2. Elaboration of a general education program, which includes new productive ways of using natural resources, and other types of economical activity in order to improve general quality of life.

3. Regulation for the management and use of mangroves forest (natural protection structures)

4. Elaboration of a research program based on natural process study, in order to identify protection strategies for mangroves.

5. Mobilization and retreat of affected people.

Buenaventura

Two important aspects taken into account for this critical area were: i) the fact that the city was settled on a small hill, but it has grown towards the coastal zone and, ii) it has become the main Colombian port at the Pacific coast.

Considering those aspects, the main strategies identified were:

1. Create a research program for the study of natural process

2. Educational program to increase the awareness of people to the importance of protection

3. Establish the new regulatory measures for design and construction of houses, infrastructure, roads, etc. Not to develop anything below the 3.40-meter altitude line (see also Tumaco)

4. Elaboration of an education and awareness program in order to demonstrate the importance of mangroves

5. Share sea level rise knowledge with industry managers in order to incorporate this knowledge in construction, design criteria and identify small scale solutions for protection measures on a local scale.

6. Elaborate specific studies on the planning of houses settlement in the area

7. Establish an early warning system for natural hazards

8. Recommend not invest in infrastructure for a large time scale, search for new alternatives and make a cost/benefit evaluation.

Santa Marta

The analysis was done for the municipality of Santa Marta taking four sectors into account: the city of Santa Marta, Tayrona's Park, Taganga fishermen settlement and the tourist village of El Rodadero.

Santa Marta city

1. Formulation of education plans looking forward a tourist development

2. Manzanares' river management plan: retreat of people from the floodplain area, restore natural dynamics in the mouth of the river and protect it from interferences like occupation by houses and early warning systems for flooding associated with rain.

3. Research on the coastal dynamics of sediment transport

4. Study the viability of constructing artificial reefs parallel to the coast for potential reduction of wave action on the beach.

5. Beach nourishment using sediments from the sea

6. Early warning system implementation for the prevention of sea floods during hurricanes or river flooding in the raining season

7. Propose a security insurance strategy to the government for flooding damages from sea or river

8. Construction of a marine dike (of about one meter high) at the Santa Marta Boulevard that can be combined with the actual landscape.

Taganga

1. Construction of a fishermen dock to guarantee productivity of the fishery industry.

2. Implementation of a retreat measure for commerce and people located near the beach.

Rodadero

1. Gaira's river management plan: retreat of people, restore natural dynamics in the mouth of the river and protect it from interferences like occupation by houses, warming system for flooding associated with rain.

2. Beach nourishment

3. Education and awareness plans with an emphasis on tourism

4. Construction of a dike as part of the landscape (like Santa Marta city)

5. Establish a maximum value for investment, elaboration of a cost/benefit analysis

6. Establish criteria for construction of hotels incorporating the variable of 1m SLR.

Tayrona Park

1. Elaboration of a management plan that underlines aspects like the influence of sewage contamination from Santa Marta city and the influence of some rivers in the protected zone.

2. Tourism action plan to prevent highly infrastructure settlement

Barranquilla and Ciénaga Grande de Santa Marta

This critical area corresponds to the delta area of the Magdalena's River. In the left side of the river the port of Barranquilla city is located, at the right side, a coastal lagoon complex is identified including the Ciénaga Grande de Santa Marta. This wetland area has been recognized as Biosphere Reserve and RAMSAR site.

For the site of the port the main measure would be protection and, restoration of natural process for the wetland side.

The strategies considered were:

1. Regulation measures on constructions on the left side of the Magdalena River: do not build in the river floodplain.

2. Develop of natural system integrated research studies with the goal of understanding natural processes between river, delta, wetland and sea.

3. Total water management plan for the Magdalena River, farm areas and Ciénaga Grande.

4. Increase the exchange of river water with the wetlands (Ciénaga Grande) by dredging existing canals.

5. Restore the natural hydrological balance of Ciénaga by reopening all former exchange channels between Ciénaga and the sea (e.g. by constructing a bridge or elevation of the highway between Ciénaga city and Barranquilla).

6. Elaboration of a harbour master plan in which moving the Barranquilla harbour outside the river might be a possibility. Constructing an artificial harbour island in the sea for big boats and limiting the entrance to the actual harbour only to small ones.

Cartagena

This city was identified as the most critical area in the Caribbean coastal zone due to its low altitude. The main measure identify were of small scale:

1. Retreat plan for the population settled on sites with high erosion, as in the zone named Boquilla.

2. Implementation of action of the development project that stated the protection of shores and roads.

3. Research on the coastal dynamics of sediment transport

4. Study the viability of constructing artificial reefs parallel to the coast for potential reduction of wave action on the beach.

5. Beach nourishment using sediments from the sea.

6. Remove the groins when suggested by calculations.

7. Construction of protection structures as walls at the north part of the industrial area of Mamonal and the Manga neighborhood.

8. Construction of a dike (approximately 1 m high) over the boulevard of Boca Grande and Castillo Grande.

9. Establish a new regulatory measure for designing and construction of houses, infrastructure, roads, etc. taking into account the potential 1 m SLR: e.g. designing ground-floors of hotels in such a way that they can be flooded occasionally.

10. Adaptation of industrial harbour.

Morrosquillo Gulf

This area corresponds to the delta of the Sinú River. It is characterized by the presence of beautiful landscapes, wetland areas with high biodiversity, potential resources in the sea, enormous coastal erosion problems, large scale development plans for harbour construction (stretching for 20 km), tourism development.

The main responses strategies identified are:

1. A road protection against erosion between Tolú and Coveñas by the construction of a marine reef.

2. Local research studies on sediment dynamics.

3. Implementation of a drainage system for rainwater at the urban area of Tolú.

4. Management plan for protection and restoration of river basins

5. Population retreat plan (especially for Tolú).

6. Restoration of the sediment dynamics of the Sinú River

7. Formulation of mangroves conservation plans.

8. Elaboration of a strategy for aquifers protection against salt intrusion.

9. Maintenance and construction of dikes

10. Formulation and implementation of a spatial planning and an ICZM proposal

11. Combine ecological and industrial development.

12. Establish a new regulatory measure for designing and construction of factories, houses, infrastructure, roads, etc. taking into account the potential 1 m SLR.

Protection strategies associated costs

Once the strategies have been established there is a need to consider the cost of their accomplishment. A scenario without sea level rise is considered a situation without additional strategies; just the implementation of development plans would be over $1.680.3 millions US dollars, equivalent to 2.2% of the Colombian GDP in 2001. The methodologies for estimating such values as well as those for additional measures are presented and described in the document.

The estimation of the development plans implementation values was done from information extracted from the POT and the areas' development plans. Costs are shown at year 2001 prices. Secondary information was used as well to determine the value of the additional measures; such values were extracted from information from national institutions and from international average values of construction. For year 2001, the implementation of additional measures would add 440.6 millions US dollars. The methodology for accomplishing such figures is fully explained in the document. Reallocation figures were calculated from the value of houses from social benefit. Adaptation figures only consider the adaptation of roads to sea level rise impacts. Beach nourishment figures were extracted from projects of beach creation in Cartagena during 1998. Other sources of information were obtained from personal communications with civil engineers and values of similar projects developed in other countries. The figure for research investment was calculated from the National Environmental Coastal Zones Management Policy.

As a conclusion, the total protection strategy, adding management plans and additional measures to address a 1 m sea level rise, would require a 3% of the national GDP for year

2001. These results, gathered together in previous steps were very relevant to address the vulnerability of Colombian coastal zones to sea level rise in the following step.

Step 6. Evaluation of the vulnerability profile and interpretation of results

Even though, there is uncertainty regarding the impact of sea level change in Colombia, it is for sure that there will be a significant and possible severe change on the natural and socio-economic systems. Throughout this step, following the IPCC methodology, based on the process comprehension, as well as using the information analyzed in previews steps (regarding SLR effects on natural and socio-economic systems); it attempted to establish the vulnerability of Colombian coastal zones to sea level rise.

The concept of vulnerability has been interpreted in several different ways; the analysis established inhere has utilized the concept provided by the IPCC in 1997. According to IPCC's vulnerability concept, a vulnerable system will be a system very sensible to moderate climate changes; such sensibility involves the potential detrimental effects and a low adaptation capacity. It is an integral concept that involves physical, socio-economic, financial and political aspects of the coastal area that is being assessed.

Colombia's internal production, as well as many others South American countries, depends greatly on its natural resources. Considering the potential impacts of climate change, it is precise to incorporate significant changes on development planning strategies at national and regional levels. Latin American countries' vulnerability to sea level rise can be summarized by loss of areas and biodiversity, damage of historical heritage, damages as consequence of marine intrusion, potential increment of river flooding at low lands and transitional and lowland forests loss. Environmental damage (i.e. fresh water availability, flooding, and agriculture lands loss, among others) is a consequence of climate change, climate variability and land use practices. Such damages will probably lead to the strengthen of health, well-being and socio-economic problems and the encouragement of rural migration to urban centres aggravating internal conflicts enhancement.

The analysis herein presented has been divided in two phases: natural systems susceptibility to sea level change and specific impacts in the socio-economic and natural systems; the second phase, involves the respond options implementation feasibility.

Socio-economic impacts have been represented by the capital values at loss and at risk as well as the population affected and at risk. A comparative analysis of the socio-economic impacts at present time and for year 2030 and 2100 was produced, taking into account autonomous development as well as the "total protection" and "non protection" strategies.

Natural values have been only produced for mangrove areas due to the current difficulties to predict changes in other ecosystems. Such values have been presented in terms of areas at loss, as well as on their capability to respond to sea level change.

The second part in this step assesses the feasibility of implementing protection strategies proposed applied to present conditions. Conditions analyzed included: legislation and regulations, institutions and organizations, economy and finance, technical feasibility and cultural and social conflicts resolution.

Quantitative analysis for vulnerability assessment

Natural Systems Impacts

Value at change of the mangroves areas

As stated on the Step 4, the natural response of the mangrove ecosystem is limited by its capacity of adaptation and migration toward changing conditions (SLR rates, tide amplitude and sedimentation rate). The high uncertainty on the subject limits our ability to establish the responses that these ecosystems may have due to an ASLR in a non-protection and in a protection measure.

Using only as guidance and trying to make comparison with the social-economic component, an assumption based on the land use changes of the UMI Guapi-Iscuande model was used. On this model the assumption of an ecosystem migration as far as the physical conditions allow them, reflected a migration of 22% of the mangrove ecosystem for the area. This estimate was used to determine the values at change for the Pacific areas. The mangrove areas at the Caribbean were assumed as non-migrant due to the stressful situations under which are found nowadays.

The above result was extrapolated to all Pacific mangrove forest. The analysis at a national level shows the vulnerability of mangroves as critical for the situation without SLR and protection. However, after sea level rise, the mangroves cover is lesser which is traduced in a low vulnerability. A diminishing cover of these areas was calculated for both ASLR projections with and without protection and expressed on the vulnerability table 11 in terms of vulnerability classes. The results, however, were the same for both situations. This could be explained by the criteria defining the inundation model, which included all the geomorphological areas actually being flooded by SLR including the mangrove areas.

Due to these difficulties a proposal for assessing natural system vulnerability is explained herein.

Natural system vulnerability assessment

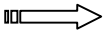
Natural system vulnerability assessment could be analyzed in terms of affected percentage area in relation of the total national cover and the autonomous adaptation of the system throughout the following expression:

Natural system vulnerability assessment could be analyzed in terms of affected percentage area in relation of the total national cover and the autonomous adaptation of the system throughout the following expression:

$$\textit{Natural system vulnerability} = \frac{\textit{Affected area}}{\textit{Autonomous adaptation}}$$

Where the affected area is expressed as low (<3%), medium (3-30%) or high (>30%), with the correspond values 1, 2 or 3. The autonomous adaptation (*Aa*) is measured as 1= low *aA* or 2= high *aA.*

	autonomous adaptation	
% area	high	low
low	1/2	1/1
medium	2/2	2/1
high	3/2	3/1



	autonomous adaptation	
% area	high	low
low	0,5	1
medium	1	2
high	1,5	3

Table 11. Vulnerability classes used to classify the natural systems elements

Low	Medium	High	Critical
0.5-1	1.5	2	3

This analysis determined a **High vulnerability** of the natural systems of the Colombian coastal zones as general result (Table 12).

Table 12. Natural systems vulnerability assessment

Natural system components	Categories	Vulnerability			
		Low	Medium	High	Critical
Tropical desert	2/1			☑	
Dry tropical forest	1/1	☑			
Humid tropical forest	1/2	☑			
Mangroves	3/1				☑
Beaches	3/1				☑
Coral reefs *	3/1				☑
Sea grasses	3/2		☑		
Sedimentary bottoms	2/2	☑			
Rocky shores	3/2		☑		

Protected areas values at change

Currently, Colombia has 9,200 Km2 of protected areas, more or less 8.5% of the whole extension of the country. This percentage is not sufficient according with the international strategy that states that 10% of the national extension is the desirable as the protected areas extension for a country.

According to this and the national initiative of adding 5,5 millions of hectares to the actual extension, changes areas for conservation were assumed for this study in order to determine their vulnerability. The results of the analysis within the both projections as well as for the situation with and without protection show the vulnerability of this criterion as low, in comparison to the total protected areas. However, this result should be reconsidered in terms of the unique ecosystems these areas are.

Socio-economic impacts

Values at loss, values at risk and response strategies are the three elements that have been included in this report in order to establish a quantitative analysis of the Colombian coastal zones vulnerability assessment. Values correspondent to such elements are the result of estimations under an optimistic and pessimistic development scenarios.

The capital value was calculated from the national GDP, which included agriculture, cattle, mining, forestry, industry and tourism sectors as well as the additional value of the affected accommodation. Vulnerability analysis comprehends the identification of two special scenarios (sea level rise and no sea level rise), which are divided, each one, on temporal scenarios (2001, 2030 and 2100) and two possible response strategies (no protection and full protection).

As a first insight from the analysis the differences between scenarios could be noticed and it is given by the cost of the strategy measured under the GDP participation, under this fact it would increase under a low economic grow. In terms of temporal scales it is also possible to identify different results due to the participation of the capital value at lost and the population to translate within the national totals would be incremented assuming a 0.30 cm and a 1 m ASLR. Such difference is reflected on the vulnerability classes' change from low to medium on the optimistic and pessimistic scenarios.

The analysis for years 2001, 2030 and 2100 let as evaluate the autonomous development changes of the study area under the formulated scenarios. This result shows a tendency of growth of the capital value and population at risk in a more accelerated rate in the optimistic scenario compared with the pessimistic one.

Under an optimistic ASLR scenario, the capital value at lost would be from 0.5% to 2.4% GDP between 2030 and 2100. On the pessimistic scenario, these values would pass from 0.5% to 1.9%. In both cases the vulnerability class would pass from low to medium. Taking into consideration the population needed to be retreated, these values would pass from 0.5% to 2% under a pessimistic scenario from years 2030 to 2100. Under a pessimistic scenario these values would be 0.5% to 3.1%.

If a full strategy option shall be included within the former analysis, on the optimistic scenario the capital value would be reduced to 0.2% and 0.5% on 2030 and 2100 respectively. The population to move would also be reduced (0.4% in year 2030 and 0.7% in year 2100 projections). On a pessimistic scenario a similar result can be observed with the difference of an increment strategy costs passing from 4% and 10% to 5% and 23% for the 2030 and 2100 projections respectively.

These results show that under intensification of the armed conflict and as a result of a diminishing on the economic growth of the country, it could be harder for Colombia to implement the necessary actions to reduce the risk of an ASLR.

Constrains related to the response strategies implementation feasibility

As it has been appointed by the IPCC methodology, the second part of the vulnerability assessment includes the identification of constrains to the implementation of response

strategies. Constrains identified comprehend vulnerability assessment of legislation and regulations, economy and financial aspects, technical staff vulnerability and social and cultural aspects. Among those categories, three different levels have been determined: level A, basic institutions and requirements existence; level B, implementation and operation aspects; and level C, effectiveness and function constrains.

Table 13. Vulnerability assessment of Colombia due to an accelerated sea level rise

Categories	With out sea level rise		1 m sea level rise	
	2001	2030	2001	2030
Capital value at risk area III as a percentaje of national GDP	Low	Low	Low	Low
Population at risk area III as a percentaje of national GDP	Low	Low	Low	Low
Without protection				
Categories	**With out sea level rise**		**1 m sea level rise**	
	2001	**2030**	**2001**	**2030**
Values at loss				
Capital value lost as a percentage of the national GDP	Low	Low	Medium	Medium
Population to be moved as a percentage of the whole national population	Low	Low	Medium	Medium
Values at risk				
Capital value at risk as a percentage of the national GDP	Low	High	Medium	High
Population at risk as a percentage of the whole national population	Medium	Medium	Medium	High
Population at risk (x 1000)	Critical	Critical	Critical	Critical
Costs of response measures (without aditional measures)				
Capital value of the response strategy as a percentage of the GDP	Critical	Critical	Critical	Critical
Anual cost of mantainance as a percentage of the GDP	High	Critical	High	Critical
Values at change				
Mangrove areas	Critical	Critical	Low	Low
Protected areas	Low	Low	Medium	Medium
with protection				
Categories	**With out sea level rise**		**1 m sea level rise**	
	2001	**2030**	**2001**	**2030**
Values at loss				
Capital value lost as a percentage of the national GDP	Low	Low	Low	Low
Population to be move as a percentage of the whole national population	Low	Low	Medium	Medium
Values at risk				
Capital value at risk as a percentage of the national GDP	Low	Low	Low	Low
Population at risk as a percentage of the whole national population	Low	Low	Low	Low
Population at risk (x 1000)	High	High	High	High
Costs of response measures (without aditional measures)				
Initital cost				
Capital value of the response strategy as a percentage of the GDP	Critical	Critical	Critical	Critical
Annual Cost				
Anual cost of mantainance as a percentage of the GDP	High	Critical	High	Critical
Values at change				
Mangroves areas	Critical	Critical	Low	Low
Protected areas	Low	Low	Low	Low

Table 13 represents a summary of the detailed analysis. It can be observed that as a general tool, with the exception of the economic and financial aspects category, all of the vulnerability categories are ranked as high. Hence, it can be conclude that the vulnerability of Colombian coasts to sea level rise is high.

The results of the vulnerability assessment in reference of the feasibility of the selected scenario for Colombia are resumed on Table 14. These results show that the legislative/institutional/organizational issues present a high vulnerability due to the lack of a national legal frame that involves Coastal Zone Management. The economical feasibility to implement the strategies, is critical, since the country is not prepared to assume the financial coasts of the consequences of SLR. Technical feasibility is considered high due to the lack of technical capacity among the institutions to assume the subject; a formal institution willing to develop. Cultural and social vulnerability assessment is high, because life quality conditions at the Colombian Coastal zones is low in terms of healthcare and public services, which are bellow the national mean. What is more important, the violence conflict affects a great area of the national territory and influences most of the economical activities.

Table 14. Colombian coastal zones vulnerability assessment to sea level rise in relation to the response strategies implementation feasibility

VULNERABILITY CATEGORIES	LOW	MEDIUM	HIGH	CRITICAL
Legislation, institution and organizations vulnerability assessment (VA-LIO)				☑
Economic and financial aspects vulnerability assessment (VA-ECF)				☑
Technical aspects vulnerability assessment (VA-TEC)			☑	
Cultural and social aspects vulnerability assessment (VA-CSO)			☑	

Step 7. Action Plan

Introduction

The current vulnerability and adaptation assessment (VA) is part and complement of the studies related to the Colombian National Response to Climate Change, which comprehends studies involving the effects of gases and the National Communication, among others.

The project has applied the common VA methodology developed by the IPCC in 1991 and modified in 1992, in which the vulnerability of coastal regions, impacts and adaptation in coastal regions of accelerated sea level rise (ASLR) is assessed during the prior six steps; in Step 7, a coastal zone action plan is produced, based on the prior results.

The plan is targeted to the country's decision makers and aims to hand conclusions, recommendations and proposals that outline short, medium and long term actions to address ASLR as a consequence of climate change (CC). For that reason, the action plan includes priorities and measures of vulnerable geographic areas and economic sectors, management

tools required to regulate the sustainable use of coastal zones and information required for present and future situations.

Part I. Imbedding of the action plan in the existing Institutional Framework

Phase I of the action plan aims to introduce the readers to the framework in which the project was originated and the location of the action plan within other National instruments that address coastal zones, planning and natural disasters attention. This phase also represents a summary of the interaction between the action plan and other instruments and shows its importance as an articulate mechanism. In part II and III, the action plan, and its articulation into accompanying instruments and entities will be described.

Methodology

Following that idea, in part I of the main document a short description of the IPCC assessment methodology and some key results are presented. Five advantages of the methodology have been identified:

- It is a methodological tool to assess a country's vulnerability to ASLR and to identify adaptation measures.

- It can be adapted to each country's particular situation.

- Its application saves resources to those countries where funding is a problem.

- It yields results that are globally comparable.

- It facilitates information aggregation.

The disadvantage of this methodology is that the information required to apply can be non-existing in some countries. At the moment, it is the most convenient and available tool.

The main objective of this VA project was to assess the vulnerability of Colombian coastal zones to SLR and to identify, evaluate and prioritise adaptation measures to minimise the negative impacts of ASLR. Vulnerability includes the assessment of environmental, economical, social and institutional issues that reflect the feasibility of a country to response to ASLR. The project also aims to produce databases that include the information collected, as well as to develop a preliminary qualitative model that allows the detection of changes due to ASLR. The results presented throughout this project will also be supplied to the National Environmental System (SINA) to support the PNAOCI (Environmental National Policy for the Sustainable Development of Colombian Oceanic Spaces, Islands and Coastal Zones). The results will help to generate conscience among the public, regarding the possible hazards related to SLR and to establish international cooperation with countries that have experience with integrated coastal zone management issues.

The VA project is part of the Netherlands Climate Change Studies Assistance Programme (NCCSAP), financed by the Netherlands Ministry of Foreign Affairs, Directorate General for Development Co-operation (DGIS). The Institute For Environmental Studies (IVM) of the

Vrije Universiteit in Amsterdam manages the NCCSAP. Twelve other countries are part of the NCCSAP: Bhutan, Bolivia, Costa Rica, Ecuador, Ghana, Kazakhstan, Mali, Mongolia, Senegal, Surinam, Zimbabwe and Yemen. The goals of the NCCSAP are to assist the participating countries in the preparation of their National Communications to the United Framework Convention on Climate Change (UNFCCC), to contribute to capacity building and awareness creation on climate change issues and to contribute to sustainable development. Furthermore, it is the objective that the studies will fit into national policy plans.

The Ministry of the Environment (MMA) in Colombia delegated the implementation of the project to INVEMAR. The project complements activities performed by IDEAM, as part of a project funded by the GEF/UNDP denominated "Capacitando Colombia para preparar su Comunicación Nacional Inicial en Respuesta a sus Compormisos con la UNFCCC". The current VA project will help to understand the climate change impact in coastal ecosystems and populations that will be affected by ASLR.

The MMA is the entity in charge of coordinating (financially and scientifically) all projects related to the UNFCCC. Co-ordination is lead by the MMA vice-minister's office, which coordinates all the communications between national institutions, governmental and non-governmental, as well as academy, both public and private.

Framework of the Colombian coastal zone action plan

International Framework

Colombia is signatory of the UNCED-2, the biodiversity convention, the Jakarta Mandate, and the Climate Change framework convention. As signatory of the CMNUCC, Colombia has compromised to submit a National Communication in which is assessed the vulnerability of the country to climate change and mitigation actions are presented.

The first National Communication was presented by the Colombian government at the beginning of year 2002, in which was included a chapter of vulnerability and adaptation in coastal zones and another regarding problems for applying the IPCC methodology (1996) in the Colombian coastal zones.[3]

In general, the action plan derived form the IPCC methodology would conduce to the formulation of a National Plan for Integrated Coastal Zone Management (ICZM). Colombia has already gotten a background on coastal management. A national institutional and administrative setting exists already, in which the action plan, herein proposed, has to articulate. That means that the action plan is not starting from scratch but from an advanced and complex situation. At national level, the Colombian government has recently produced instruments to promote and guide sustainable development. Among those documents, there are 5 that interact with the current action plan and other studies that are being developed on climate change issues.

[3] It is worth appointing that there is no mention of NCCSAP project in the National Communication although it presents information that was produced by the project.

Environmental National Policy for the Sustainable Development of Colombian Oceanic Spaces, Islands and Coastal Zones (PNAOCI). This policy is the result of an agreement process directed by MMA. It started in 1996 and finished in December 2000. In the PNAOCI, actors and sectors involve in environmental planning in the coastal regions were included.

The PNAOCI comprehends the main principles of environmental management, presented in Law 99 (1993). These principles are applicable to land planning in coastal zones and maritime areas. It considers SLR to be a natural phenomenon that should be coordinated by INVEMAR, the national Directorate for the Prevention and Attention of Natural Disasters – DGPAD -, and the General Maritime Directorate – DIMAR -. However, this PNAOCI is the only topic involving SLR. For this reason, the current VA project can be considered as an instrument to amplify and improve the PNAOCI. Hence, it is needed to search the appropriate means to insert the results, information and analysis generated throughout this VA project in the PNAOCI.

CONPES-PNAOCI Document, May 10, 2002: Action Plan 2002-2004 of the Environmental National Policy for the Sustainable Development of Colombian Oceanic Spaces, Islands and Coastal Zones (CONPES-PNAOCI). The National Council on Economic and Social Policy approved this document in which priority actions, responsible institutions, financial resources and coordination mechanisms were identified.

Among other national programs, the document has a program for risk management for the prevention and attention of natural disasters in coastal and oceanic areas. This program aims to establish instruments that allow prevention and minimization of natural disasters and involves three main activities:

- Formulation and implementation of regional plans on risk prevention and attention.

- Climate change effects vulnerability assessment and adaptation measures.

- National contingency plan divulgation and implementation.

This action plan is part of the PNAOCI implementation program directed by MMA and supported by INVEMAR, IDEAM and DNP (National Department of Planning).

National Plan for Disasters Prevention and Attention – (Dec-PNAPD). This program was created after the 1983 earthquake in Popayán and the mud avalanche in Armero in 1985. The plan's main objective is to orientate the government and society's actions on the prevention and mitigation of risk, as well as to prepare, attend and recuperate society in case of disasters. The plan comprehends four programs: 1) giving knowledge on potential risks from natural and human origin; 2) incorporation of risk prevention and reduction in planning initiatives; 3) institutional development strengthen; and, 4) programs for the disasters prevention and mitigation of social effects.

CONPES-PNPAD: document 3146, Dec, 2001. Strategy for the consolidation of the National Plan for Disasters Prevention and Attention –PNPAD – at short and medium term. This document defines the actions that the country should implement in order to prevent and attend disasters. However, more than a plan, it is a policy, since it does not articulate temporal elements or territories. CONPES-PNPAD defines responsibilities for the actions.

The strategy presented is divided in four programs that include: 1) Knowledge search, 2) Subjects insertion in planning; 3) Institutional strengthening; and 4) Education and divulgation programs improvement.

Both the Dec-PNPAD and the CONPES-PNPAD strategy mention natural and anthropogenic risks in a generic way, including the most known risks. However, the assessment of other risks such, as the ones produced by Global Climate Change are still not well defined in terms of responsibility. In this sense, the present Action Plan has a great impact on this field, by giving the country general basis on this kind of approaches.

National Integrated Policy for Oceans and Coastal Spaces (NIPOCS). This document is being prepared by the Colombian Commission of the Ocean (CCO) with the support of the ministries and entities involved with coastal and marine issues. The difference between this document and the PNAOCI is that it comprehends more than the environmental aspects of the coastal and marine regions; it complements the CONPES-PNAOCI and integrates its policies for other sectors. The integrated policy aims to create mechanisms for the articulation of the different productive sectors; promote development and economic growth in the sustainable framework proposed by the CVA-PNAOCI. NIPOCS also establishes the basis that the governance of a "maritime country" is fundamental as well as the institutional, legal, scientific and technologic systems that will execute it.

Climate Change Policy Guidelines. The DNP and the MMA are promoting the elaboration of a policy guideline to create a CONPES style document on Climate Change. It will be essential that the present VA project and the herein Action Plan are considered as a source for the Climate Change Policy Guidelines document.

Other Climate Change related projects. Some projects regarding gases and greenhouse effects, the national communication, adaptive measures to climate change and sustainable development mechanisms are currently being developed by the National Academy of Sciences, the MMA and the IDEAM.

Part II. Actions To Be Developed At National Level

The results from previous steps of the followed methodology have lead to the conclusion that natural systems are highly vulnerable to SLR, but also that there are great gaps in the knowledge of ecosystems' condition, possibilities for recuperation and adaptation capacities. Furthermore, the analysis shows a high vulnerability of the Colombian coastal zone, regarding population affected, economic costs of possible impacts of ASLR and response strategies (in terms of GDP) in affected areas.

Results from the analysis on response options and feasibility of implementation, measured by its legal, institutional, economic, financial, technical, cultural and social aspects, determine that the actual national capacity to respond to SLR is limited. These results place the country's vulnerability between high and critical; also, future perspectives urge to establish ICZM. Population in the Colombian coastal zone is expected to increase at a higher rate than the national average. In addition, large plans have been revealed to economically develop the coastal region at an increased rate.

Throughout part II of this coastal zone action plan, conclusions from the former 6 steps are viewed and actions for correction and prevention are proposed to address the problems that

explain the vulnerability of the nation to SLR. The actions proposed are considered at the National level. Most of them are answers to general problems of the country. The actions proposed have not been taken to regions or Coastal Environmental Units (UACs), because many of the problems are common to all regions and UACs. It is also important to point out that at the scale the VA project has been developed, local problems are not identified.

In part III the analysis is focused on those critical areas identified during Step 5 and that demand a priority attention in the near future.

Priority Actions - General Overview

ICZM in Colombia

The ICZM process in Colombia has developed quite different from other countries in the world. It was one of the first countries in Latin America to approach the subject during the 1980s, enabling to accumulate experience that finally evolved into the PNAOCI presented by the MMA in December, 2000.

This apparent advantage should optimise the process of adaptation and response to SLR; however none of the plans presented in part I, contemplate the vulnerability of coastal zones to SLR. None of them proposed specific measures for the prevention of the effects of SLR. That is the reason, the VA study developed by the current VA project is important. The VA project results are to be inserted in the national coastal zone national plans where instruments already exist, but where there is a deficit of information and analysis on possible impacts of vulnerability and adaptation to ASLR.

Another difference with other countries is that Colombia's coastal zone is not overpopulated, most of the development and population centres are located inland of Colombia. The country has an extent and complex coastal zone and oceanic space, for which the country has not yet developed management capacity. However, present tendencies show that growth is greater than the national average in these regions of the country and there are development plans that point a change in population distribution and development. This urges the establishment of ICZM.

Despite of past development trends, the analysis of former steps shows that the country's vulnerability to SLR is both high and critical. Nevertheless, these results have to be taken into consideration and bearing in mind the geographical and temporal scale used in the VA project. The results encountered are expressed as an impact to the national level/scale. They do not necessary represent an exact measure of each coastal area's needs in particular. For that reason, actions proposed in Phase II are general and for national application, focussing on common problems and deficiencies that will adversely affect any future initiative to diminish vulnerability to disasters. As explained before, in part III local actions for the identified critical areas are proposed.

The temporal scale, for the implementation of the proposed actions has to be accounted as well. Actions are assessed on an analysis of the situation in years 2030 and 2100. For long-term actions, works and required responses are identified in this proposed action plan, but should be evaluated in more detail under future circumstances in the future. Still, the assessment shows that it would be appropriate to undertake action at the short term. The action plan outlines relevant short-term actions directly related to actual problems

encountered. It will allow Colombia to start with the corrective measures needed to overcome the uncertainties and information lack, to improve governance capacity, to implement response strategies, to incorporate ASLR in planning instruments and to create conscience and educate public in the topic.

More specifically, the general actions proposed for the short term (phase II) are divided in six main groups:

- Actions related to knowledge and information.

- Actions related to planning.

- Actions related to institutional strengthen.

- Actions related to education, divulgation and socialization.

- Economic and financial aspects.

- Actions to be developed at international management scale.

- Actions related to knowledge and information – actual situation.

Information and knowledge for decision-making[4] are principal contributors to adequate disaster prevention and attention preparedness. The results from this project have revealed a deficiency, in the country, on information of basically two types: a)information to produce vulnerability assessment; and b)lack of information to establish a proper integrated coastal management process.

Even though there is technical capacity, the current lack of information only allows to model the potential impact of SLR due to climate change in a coarse way. Apart from the lack of required information, there is not available information and there is disarticulation between researchers and information sources. Actions proposed in this line are strongly related to other instruments such as the PNOACI and their developing programs.

Three topics have been proposed under this action line:

Research – Proposed actions

- Incorporate research proposals that cover the subject of SLR (impacts, vulnerability and adaptation) into the National System of Science and Technology.

[4] CONPES 3146 – Estrategia para el PNPAD – Pág. 7

- Produce inventories on the national and regional investigation capacity related to vulnerability and adaptation capacity of socio-economic systems and natural ecosystems to SLR. In this sense, the importance of natural land creating processes (e.g. mangroves or intertidal areas) should be acknowledged and studied.

- The national entities responsible for National cartography to give appropriate attention to studies related to detailed cartography on coastal areas, starting on critical areas and ecosystems, and will also aim for the standardization of the shoreline

- Build the scientific basis to generate knowledge on the marine and coastal ecosystem structure and functioning.

- Strengthen studies on coastal geomorphology.

- Strengthen the articulation between the National Environmental System SINA and the National System on Science and Technology – program Marine Sciences

- Improve the information supply in the national information accounts, so statistics related can be applied to productive sectors.

- Articulate inter-institutional efforts for the creation of scenarios.

- Develop research proposals aimed to identify, evaluate and prioritise adaptation options to climate change, framed on scenarios and armed conflict evolution.

Monitoring – Proposed actions

- Consolidate monitoring and alert nets on environmental and socio-economic variables identified as critical indicators of SLR.

- Design, establish and standardise environmental indicators on the ecosystems and marine and coastal resources state.

- Environmental and socio-economic monitoring of coastal resources to follow up and detect alarms related to SLR.

Information system – Proposed actions

- It is required to develop an integrated system of coastal information exchange and process related to SLR in particular.

- Develop the National Oceanic and Coastal Information System established by the PNAOCI as the baseline information to develop plans, programs and projects related to sustainable development of the country oceanic, coastal and marine areas.

- Incorporate to the SINOC's design the component related with the information required for reducing vulnerability to SLR.

Actions related to planning – Actual situation

SLR and climate change risks have not been included in any planning instrument or policy adopted by the governmental entities locally, regionally or at national level. The insertion of this topic into the actual framework is a way to start decreasing risks of climate change. Solutions must be participative and many levels of coastal management should be included, not just those institutions responsible of risks mitigation and attention (Urban planning, building codes, etc.).

Territorial land planning plans (POTs) at municipality level should incorporate the subject of disaster prevention as a general rule. SLR and 'climate variability' in general has not been included in any of the POT because of the lack of awareness, experience and knowledge regarding the subject in the country. It has not been included either in the economic sectors planning. Furthermore, references to particular events such as hurricanes, flooding, tsunamis or El Niño phenomenon are limited.

Two main topics have been included under this line:

Incorporation to territorial planning – Proposed actions

- POTs must become the means to sustainable development at long term. These instruments play an important role in actual risk reduction and avoiding the generation of new risks and to decrease vulnerability to climate change.

- Contingency plans are crucial parts of the POTs. Such contingency plans must include adaptive measures to SLR in those areas identifies as critical in the present study.

- It is required to strengthen support and orientation, especially in technical and training aspects to the regional territorial entities in order to include the SLR variable in their POTs, development plans and contingency plans.

- The execution of the PNOACIs' objective and strategy regarding UACs characterization.

- Divulgation of the PNOACI at all levels.

- SLR should be taken into account in the future Land Planning Law.

Sector-oriented planning inclusion – Proposed actions

- It is required to include the SLR variable into development plans as well as into sector-oriented expansion plans, specially in those involving directly coastal areas uses, such as ports, fisheries, aquaculture, tourism and urban planning among others.

- Ministries and national entities should include into their strategic management plans and their sectarian indicative plans, aspects related to vulnerability assessment, socio-economic impacts in their sector and the results of such studies in their development plans and sectarian expansion strategies.

- The PNAOCI identified seven economic sub-sectors and proposed specific actions in each one of them, and thus, being the basis for adaptation programmes and preparation for the sectarian areas.

- The PNPAD established the need to include different types of risks in the sector-oriented planning risks.

Actions related to institutional, legal and organizational strengthening – Proposed actions

- The SLR subject will be immerse in the action area of the National Program for Coastal Zones Management; even though in the country already exists institutions and legal instruments, the program is still emerging in the country and it urgently requires integration and strengthen of institutional mechanisms for its implementation.

- The institutional, legal and organizational constraints make the country highly vulnerable to SLR.

- There are enough legal documents related to coastal management, but they are isolated, sector oriented, and there is no integration between execution, monitoring and enforcement levels.

- There are competency and interests conflicts between the administrative entities as well as with the economic development sectors that benefit from coastal zones.

- There is also technical deficiency within the institutions to engage in the subject, and at the moment, there are no technology, information, design and execution strategies at the scientific, technical, social or economic level.

- One of the first actions would be to define the desired functions of the coastal zone.

Actions related to education, divulgation and socialization – Proposed actions

- The best prevention and mitigation tool that can be applied to any natural disaster is to capacitate communities and population affected or at risk. SLR is not an exception to it. However, there are no articulated programs for SLR in the educational system and community formation, although there have been some initiatives at local level.

- The vulnerability of cultural and social aspects was ranked high due to the low quality of life in most of the Colombian coastal areas. The armed conflict affects great proportion of the population and influences in almost all economic activities.

- There is a need to educate and train the population to make them aware of climate change and related ASLR effects through all the possible means, using formal and non-formal education and with the support of research institutes, and the MMA but coordinated by the Ministry of Education. It has been outlined as well the need to train the media on the production of scientific news and news related to natural phenomena and disasters.

Three main areas of action have been included in this line:

- Divulgation of information to the society.

- Stakeholders, actors and population that inhabit coastal areas and benefit from their resources should be considered in any SLR mitigation or adaptation program.

- Programs that divulgate information to the general public. Society has the right to know about the threats and vulnerabilities of the places where they live or where they invest capital.

Cultural and social aspects

- Coastal communities' participation should be enhanced using the present social structures. There is already legislation in the Pacific part of Colombia that promotes citizens' participation in this kind of process.

- Capacitating, education and divulgation programs adopted have to cover all the coastal population, including big cities and small villages, no matter how distant they are.

- The PNAOCI proposed a program involving communities in the education and participation process, in actions related to prevention and mitigation of sea level change. Such program suggests an active interaction between users, communities and ethnics groups in the coastal management process by means of education, participation, land planning and decision-making processes.

Formal education at all levels

- There is a need to include more sea-related information in secondary education programs at national level aimed to create a future conscience and support of the general public to coastal and marine territories. In addition, there should be more information on the topic of "Sustainable development" both for ICZM as for all territorial use in Colombia.

International negotiations strengthen capacity.

- It is important to improve the negotiation and management capacity of Colombia with international organizations that deal with climate change and sustainable development in general.

- The subject should be promoted at national and international level frequently.

- The MMA and the Foreign Relations office should participate actively with the CMNUCC and maintain their negotiation groups for considerable periods of time. There is a need to keep on negotiating international funding for research projects as well as for response strategy projects.

- It has been identified the need to project Colombia in the Pacific and Caribbean regions using the already established relations with the neighbour countries, and in order to develop cooperation projects for the regional evaluation of the SLR vulnerability, adaptation and mitigation possibilities. In that aspect, INVEMAR and MMA are already contacting neighbouring countries for developing ICZM processes based in the Colombian experience.

Economic and Financial aspects

- Program financial aspects for the future action are a very complex task at the moment. There is not enough available information and it would need to include natural resources, ecosystems and their functions evaluations without enough experience in the country and less involving marine systems. It would also include the application of discount rate at a long timescale adding uncertainty to any estimation.

For those reasons one of the main activities at short term is the collection of more and accurate information to diminish scientific uncertainties in a near future, so that decisions can be taken with improved basis.

A very important conclusion of this project is that there is an urgent need to focus future studies on the critical areas identified in the project, with a greater scale and more variables resolution. Results can lead to detail more concrete actions in this VA proposal.

With the current information, it is not possible to approach adaptation measures at national level. For each critical area, optimal and applicable solutions should be according to its characteristics, needs and conditions; financial, costs and benefits analysis on mitigation and adaptation measures will be quantified for each specific site.

Costs implied by the action plan proposed through this document are addressed to start the actions described above in a near future (2 to 3 years). Many of them are already incorporated in approved strategic Policy instruments and action plans that are referred in Part I.

It is required to give special attention to the additional threat involved with SLR that has not been explicitly included in such instruments, nor their budgets, and also, to calculate additional costs that can be generated to the national budget.

Proposed actions to address Natural Ecosystems, Economic and Implementation Feasibility Vulnerabilities

Among the principal outcomes of the VA study is the severe lack of accurate information that allows predicting or at least presuming the effects caused by SLR on the coastal zone ecosystems. The “can do” actions and the join instruments currently available to develop these activities are presented in the main document. The same analysis is made for the actual

economic situation (population, capital value and GDP), where a summary of actions and join instruments is presented.

Based on the recognition of the feasibility implementation aspect made on step 6, concerning the legislative/institutional/organization, economical, financial and technical aspects, an identification of actions and join instruments currently available is presented in the main document.

Lack of Information

One of the most recurrent problems during the development of the current project was the lack of relevant, sufficient and confident information, from which to produce the analysis and apply the common methodology. Many assumptions were required to supply the information gaps or make useful the scarce available information. For this reason, this action plan has included a section related to information gaps in order to outline areas where more research is required.

Considering the actual state of the Colombian coastal zones and the implementation status of the ICZM Policy, two types of information gaps have been identified. The first group of deficiencies involves those influencing or affecting the process of preparing a VA of Colombian coasts to SLR. The second group embraces information deficiencies that difficult the application of ICZM in Colombia.

The action plan outlines those information lacks together with actions/projects proposed to overcome such deficiencies. It is important to point out that some of the activities proposed have already started but there is not enough historical data that enables comparisons yet.

Although the action plan has emphasised on information gaps, there are other aspects involved with information management that represent significant problems: availability of existent information, incompatibility between information systems, disarticulation and overlapping between entities that produce information, and technical limitation to produce information.

Information sources for this project include research institutes, city councils, private and public universities, territorial authorities (CARs), public libraries and consulting firms. As a result, it has a large bibliographical base that can be analysed in more detail to complement the information presented and for further contributions.

Part III. COLOMBIAN COASTAL ZONES CRITICAL AREAS

In previous steps, critical areas were identified in the Colombian coastal zones that would be more affected by SLR as measured by the analysis of an “importance valuation matrix”. The variable “importance values” is defined as the numerical sum of assigned qualifications to each of the selected elements to characterise municipalities. That sum combines each municipality intrinsic characteristics and values of other characteristics that can be affected by inundation because of SLR. The identification was a result of the analysis of different intrinsic characteristics that occur in each coastal municipality and that could be potentially affected directly or indirectly by an increase in SLR. Coastal municipalities were classified

in three categories: the higher values were denominated critical areas, 1 = low importance (green), 2 = medium importance (yellow) 3 = high importance (red)---critical area

The analysis gave as a result seven critical areas: San Andrés, Providencia y Santa Catalina (Insular Caribbean), Cartagena, Barranquilla, Santa Marta and Turbo (Continental Caribbean), and San Andrés de Tumaco y Buenaventura (Pacific).

The resulted critical municipalities and their correspondent coastal environmental units – UAC - should be studied in detail in following vulnerability assessment projects that continue as a result or consequence of this project. Such projects should be developed at greater scale, with greater data resolution and focused on smaller areas; as result, more concrete adaptation, prevention and mitigation measures will be identified.

Specific Actions

Each of the critical areas identified can be objective of "vulnerability assessments – second generation" studies, applying the common methodology, improved and adapted to local experience obtained throughout the development of the NCCSAP project by INVEMAR. Also it should refer to new assessment methodologies such as the APF.

Each of those studies should delimitate new boundaries for the area of study, covering a smaller area that includes the municipality and its influential area and preferably where applicable its correspondent Coastal Environmental Unit. Studies will result in greater precision and resolution; baseline data can be extracted from the NCCSAP, Colombia, and it could focus on producing new specific information for each area of study.

Proposals for such projects should be formulated by INVEMAR as soon as possible with the support, participation and compromise of regional and local entities. Such projects should articulate and take into account the guidelines established by the PNAOCI, the PNPAD and their correspondent CONPES documents, feeding on their programs and strategies as well as searching for funds approved for their implementation when possible.