A thesis submitted to the Department of Environmental Sciences and Policy
of
Central European University in part fulfilment of the
Degree of Master of Science

COASTAL MANAGEMENT IN COSTA RICA UNDER A CHANGING CLIMATE

Elías Domingo CARRANZA MAXERA

May 2013
Budapest, Hungary

Erasmus Mundus Masters Course in Environmental Sciences, Policy and Management

MESPOM

This thesis is submitted in fulfillment of the Master of Science degree awarded as a result of successful completion of the Erasmus Mundus Masters course in Environmental Sciences, Policy and Management (MESPOM) jointly operated by the University of the Aegean (Greece), Central European University (Hungary), Lund University (Sweden) and the University of Manchester (United Kingdom).

Supported by the European Commission's Erasmus Mundus Programmed

Education and Culture

Erasmus Mundus

Notes on copyright and the ownership of intellectual property rights:

(3) For bibliographic and reference purposes this thesis should be referred to as:

Carranza Maxera, E.D. 2013. *Coastal Management in Costa Rica Under a Changing Climate*. Master of Science thesis, Central European University, Budapest.

Further information on the conditions under which disclosures and exploitation may take place is available from the Head of the Department of Environmental Sciences and Policy, Central European University.

Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Elías Domingo CARRANZA MAXERA

CENTRAL EUROPEAN UNIVERSITY

ABSTRACT OF THESIS submitted by:
Elías Domingo CARRANZA MAXERA for the degree of Master of Science and entitled: *Coastal Management in Costa Rica under a changing climate*. Month and Year of submission: May 2013.

Climate change will considerably impact coastal areas. Coastal management has to take into account the pressures that a changing climate represents to coastlines. To assess the vulnerability and adapt to climate change, different information and adaptive responses have been recognized.

In Costa Rica's internal legislation there is practically no mention of a changing climate. However, the country has approved regional and national climate change strategies. These describe coastal areas as priority sectors for climate change vulnerability assessment and adaptation. Even though Costa Rica has approved these strategies, some of its sectors continue to cause more risk in coasts, which are some of the most vulnerable areas to climate change. The country's latest coastal planning proposals continue to ignore the pressures represented by a changing climate.

Costa Rica does not have many resources to invest in adaptation to a changing climate. In addition, the country is part of a region that is one of the most vulnerable to climate change. However, the country has good chances to adapt to a changing climate, because the majority of its coastline has experienced a minimum development and the first 200-meters from high tide are of public domain.

If Costa Rica wants to reduce the associated risks of a changing climate, it would have to adjust the nature of its coastal development. The old planning practices would have to be modified and adapted to the new climate reality. Bigger setbacks should be established, building codes have to be amended, coastal development must be concentrated in the areas less vulnerable to climate change and more resources should be invested in climate science. If the strategies described in this research are effectively implemented, Costa Rica will have a better opportunity to reduce future costs and damages caused by climate change.

Keywords: Adaptation, Climate Change, Coastal Management, Costa Rica, Vulnerability.

Acknowledgements

To my family and specially my parents, who always supported and encouraged me to continue studying.
To the European Commission and the MESPOM Consortium for giving me the opportunity to be part of this program.
To CEU who gave funding for my research.
To my supervisors Michael McGinnis and Laszlo Pinter who gave valuable guidance through all my research.
To Donald and Gitta for always helping me with my technological problems.
To Emilio, Ernesto and Orlando who helped me improve my English.
To Edwin for helping me with the GIS analysis of the local coastal plans.

Table of Contents

Table of Figures

Table of Tables

1. INTRODUCTION

Climate change is producing and is expected to cause a range of socio-economical and biophysical impacts, some of which could be potentially devastating (Hawkins *et al.* 2008). Society will need to drastically reduce green house gas (GHG) emissions to mitigate and adapt to climate change. However, many changes are unavoidable, so we must also enhance our adaptive capacity to the inescapable impacts of a changing climate, such as an increase in temperature or a rising sea level.

Mitigating and adapting to climate change requires changes in coastal management practices, and financial investments in social infrastructure. However, in the long term, it is cheaper to invest in precautionary management strategies rather than to ignore climate change (Stern 2007).

Coastal government agencies and planners need to understand the risks and vulnerabilities that climate change represents in their coastal plans and daily management activities (Mastrandrea and Luers 2012). Studies have shown that relatively few countries are committed to pro-active coastal planning (Nicholls and Klein 2005). For example, it was determined that few European countries are involved in pro-active planning or that few of California's coastal planners used projections of sea level rise or climate change (Caldwell and Holt 2007; Nicholls and Klein 2005; Tribbia and Mosser 2008).

This thesis focuses on coastal areas, climate change and sea level rise in Costa Rica. Costa Rica is located in the Central America region, which emits only a minimal part of the global GHGs (ECLAC *et al.* 2010), but has been described as the most vulnerable tropical area in the world (Carazo *et al.* 2012). This vulnerability is due to a combination of economic factors and geographic variations (World Bank Group 2011). The country's coastal low-lying areas will possibly suffer major changes from a changing climate and associated rise in sea level. Without considering these projected changes in climate and in sea level rise, there will be enormous long-term social, economic, and ecological costs (Costa Rica 2000).

Because the majority of Costa Rica's coastline has experienced little urban development (Fonseca 2012), and because the country is in the early stages of growth, it is still possible to plan for the country's coastal development in light of the changes in climate and the rises in sea level, as a way of reducing future costs and damages (Brouder and Volenec 2008; Costa Rica 2000).

This research focuses on Costa Rica's coastal planning in conjunction with a changing climate. It aims to answer if Costa Rica's coastal management takes into account the changing climate and sea level rise impacts on its coastlines. Climate change and a rising sea level will likely cause various impacts in different sectors of Costa Rica's coasts. This study focuses in the following sectors:

a) Coastal settlements.
b) Water supply.

a) Biodiversity.

These are the three sectors that have been chosen because much of the literature about coastal planning, climate change and sea level rise relates with them. It is also important to focus on biodiversity, because Costa Rica is a biodiversity hotspot. The increase in temperatures has been demonstrated to alter the abundance and the distribution of its species and to cause the upward migration of them (Pounds *et al.* 1999); migrations in the future that would be conditioned by the connectivity of protected areas.

To focus on the impacts of climate change on the water resource is significant, because different Costa Rican coastal regions are currently experiencing water shortages or allocation disputes (for example Conchal and Sardinal) (Agüero 2013; Carranza 2009; Roman 2007), conflicts that would probably increase with the reduction in rainfall precipitation that is expected.

The sector of coastal human settlements is analyzed because the rise in sea level could have potentially devastating consequences to them. In addition, is believed that Costa Rica has a good chance to implement regulations to deal with this issue because the first 200 meters from the medium tide are public property.

This research intends to answer the following questions:

- What are the climate change and sea level rise vulnerability information and adaptation measures that Costa Rica's local coastal plans currently provide?
- Are diverse municipal places responding differently to climate change?
- What changes could improve Costa Rica's coastal planning and climate change legal framework?

The methods used in this research consist of documentary analysis of peer-reviewed literature, technical and government report documents, interviews to government and private specialists, and the assistance to lectures related to the topic.

After assessing the latest coastal plans that are being promoted in the country, it can be concluded that climate change is not taken into account in the country's coastal management. The vulnerability assessment information or the adaptive measures that the local coastal plans provide are minimum. It can also be concluded that diverse municipalities are not responding differently to climate change, both coastal municipalities that were studied ignore the threats that a changing climate and a rising sea level represent to their jurisdictions.

Costa Rica has subscribed Regional and National climate change policies. However in its internal legislation climate change is an issue that is ignored. Approving a climate change law would assist in the country's adaptation to a changing climate. Local coastal plans and its EIA's could also be used as a driver for climate change adaptation. Adapting to the pressures that a

changing climate represents will demand the implementation of different strategies. If these strategies are effectively implemented, the damages and costs that climate change will cause to Costa Rica will be considerably diminished.

2. CLIMATE CHANGE

Earth's temperature is increasing and the primary cause is GHGs emissions (IPCC 2007c; Doran and Zimmerman 2009). Different factors such as the burning of fossil fuels, land use change and industrialization significantly contribute to the increases in carbon dioxide concentrations in the atmosphere (Brouder and Volenec 2008). In Figure 2 can be seen the share that the different sectors contributed with GHGs emissions in the year 2004.

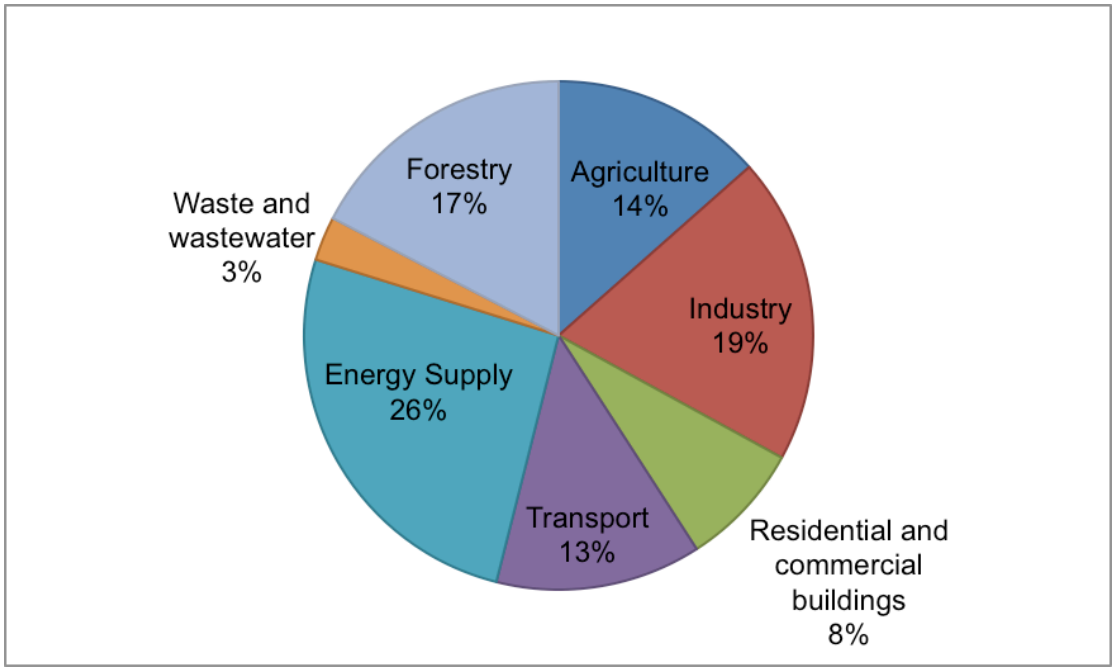


Figure 1. Share of different sectors in total anthropogenic GHGs emissions in 2004 in terms of CO2-eq. (forestry includes deforestation). Data retrieved from IPCC 2007c.

The IPCC estimates that by the end of the present century, the Earth's mean temperatures will rise between 1.4°C and 5.8°C (IPCC 2007c). Other studies predict a worse case scenario and estimate that this rise could range between 3°C and 6.5°C (Green *et al.* 2003). If the current promises and international commitments such as the Kyoto Protocol are not fulfilled, a warming of 4°C could occur by the 2060's (World Bank 2012).

Various perceived changes on the Earth' biological, human and physical systems are accredited to a changing climate (Harrison *et al.* 2006; IPCC 2007c; Madelyn *et al.* 2009; Thomas *et al.* 2004). Climate change is expected to cause different impacts in all the regions and ecosystems of the planet, which will vary globally, and would probably affect poor people and developing countries more (Hawkins *et al.* 2008; Klaus Meyer and Shaw 2009; Moser and Ekstrom 2012).

Coastal ecosystems are going to be most impacted by a changing climate and rise in sea level. Coastal areas are one of the most economically and ecologically valuable environments (Harley *et al.* 2006). Together with marine environments, coastlines are calculated to provide approximately half of the global ecological services value (Costanza *et al.* 1997). Figure 3 depicts many of the ecosystem services that coastal and marine areas provide.

Figure 2. Coastal Ecosystem Services. **"**Ecosystems provide a wide variety of economically valuable services, including waste treatment, water supply, disturbance buffering, plant and animal habitat, and others " (Costanza *et al.* 2006). This Figure depicts many of the ecosystems services that coasts and marine areas provide. Source: McGinnis 2013.

2.1 Coastal Areas and Climate Change

The changing climate is causing and is expected to produce different impacts on coastlines; some of these effects will continue to impact these areas for hundreds of years even if GHGs emissions become stable at current levels

(IPCC 2001). The impacts depend on the magnitude of climate change and its interaction with other factors that have deteriorated coastlines and that continue to negatively affect them (Klein *et al.* 2001; Nicholls *et al.* 2009; Mawdsley *et al.* 2009). Table 1 provides a summary of the most important pressures that affect coasts.

- Climate Change
- Overexploitation of resources
- Pollution
- Increasing nutrient fluxes
- Decreasing fresh-water availability
- Sediment starvation
- Urbanization

Table 1. Pressures on coastal ecosystems. In addition to the pressure that climate change and sea level represent to coastal systems, others factors interact with it and decrease the resilience of these ecosystems. Source: Klein *et al.* 2001.

Examples of cases in which climate change has caused serious impacts in coastal regions of the world are two communities on Kiribati in the South Pacific, which have been evacuated due to sea level rise (WWF 2006). Additionally, the increase in sea level rise has contaminated underground water sources in different countries located in the Caribbean Sea, in the Indian and Pacific Oceans, among other countries (Hawkins *et al.* 2008).

Research on the changing climate predicted significant impacts on coastal areas, include: changing runoff patterns and precipitations; increase in coastal storms; rise in sea level, coastal erosion, floodings and air temperature; habitat and species shifts; ocean acidification; increased salinization of

groundwater (with a subsequent reduction of freshwater accessibility) and estuaries; intensification in invasive species and potential alteration of the sex ratios in temperature sex determination species that nest in the beaches (for example marine turtles); among other effects (Fuentes *et al.* 2011; Hulin *et al.* 2009; IPCC 2007b; Quevauviller 2011; Poloczanska *et al.* 2009; Scavia *et al.* 2002). In Table 2 can be seen the climate related impacts that will affect coastal sectors.

Coastal socio-economic and ecological sector	Temperature rise (air and seawater)	Extreme events (storms, waves)	Floods (sea level, runoff)	Rising water tables (sea level)	Erosion (sea level, storms, waves)	Salt water intrusion (sea level, runoff)	Biological effects (all climate drivers)
Freshwater resources	X	X	X	X	-	X	x
Agriculture and Forestry	X	X	X	X	-	X	x
Fisheries and aquaculture	X	X	x	-	x	X	X
Health	X	X	X	x	-	X	X
Recreation and tourism	X	X	x	-	X	-	X
Biodiversity	X	X	X	X	X	X	X
Settlements/ Infrastructure	X	X	X	X	X	X	-

X= Strong, x= weak, - = negligible or not established

Table 2. Summary of climate-related impacts on socio, economic, and ecological sectors in coastal zones. Adapted from IPCC 2007a.

All scenarios of the Intergovernmental Panel on Climate Change (IPCC 2007b) forecast a considerable growth in human inhabitants living in coastal

regions, which will increase problems that are connected to the decline of coastal ecosystems (United Nations *et al.* 2011).

Some coastal countries will likely have a greater challenge adapting to climate change. Under the IPCC (2007) coastal scenarios, a developing country's adaptation will be more difficult than a developed one, due to limitations on their adaptive capacity (IPCC 2007b). These limitations are caused by the lack of institutional capacities and financial resources (IPCC 2007b). One developing country that will face great impacts on its coasts caused by climate change is Costa Rica, a country that powerfully relies on its coasts for different activities, such as tourism, real estates, fishing and trade.

2.2 Costa Rica's Coasts

Costa Rica has coasts in the Caribbean and Pacific Oceans, which have an expansion of 1.466 kilometres. The Pacific Coast has an area of 1254 kilometres; it has large mangrove areas, which comprise 19% of the total Pacific Coastline. The Caribbean Coast has an area of 212 kilometres; coral reefs of great significance are found in it (MINAET *et al.* 2000). In Figure 4 one can see an image of Costa Rica's Pacific and Caribbean coastline and its administrative division.

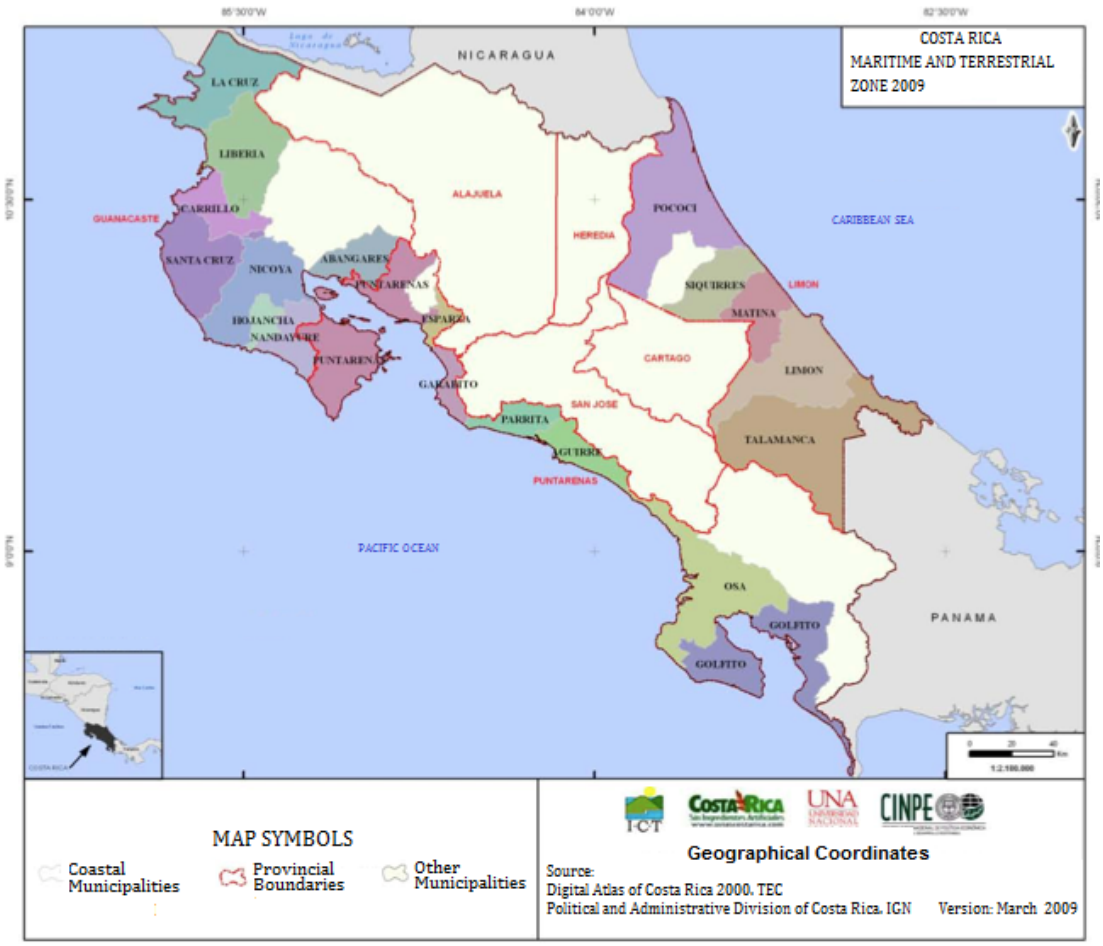


Figure 3. Costa Rica. In this image can be seen how Costa Rica is divided in seven provinces, of which 3 have coasts. It can also be seen the municipalities that have coastal jurisdiction. Finally can be observed that the Pacific coastline is much bigger than the Caribbean coastline. Adapted from: ICT *et al.* 2009.

Costa Rica is a country in which a significant share of its economy comes from tourism, economic activity that has gained importance since the 1980's. Tourism is the second most important economic activity (in 2008 tourism activities represented 8.5% of Costa Rican Growth Development Product (GDP)) and it significantly depends on its coasts. In 2010, 46% of the foreigner tourist informed they did some activity related with beaches, what represents more than 950,000 foreign tourists (ICT 2010). In many areas, livestock and agriculture in coastal areas have been abandoned, and at present the country's coast is predominantly reserved for tourism and real

estate development. Fishing has been downgraded to a second level of economic significance (Fonseca 2012; Gonzalez and Vilaboa 2010).

In Costa Rica's maritime and terrestrial zone (200 meter strip from the ordinary water high tide) have been constructed 389 hotels, which account for a total of 5865 rooms. This number represents 15% of the total hotels and 13% of the total rooms of the country (Fonseca 2012). Costa Rica's National Development Tourism Plan 2010-2016 aims to increase tourism activity. It established 28 centres of priority development in the maritime and terrestrial zone.

Foreign investment in coastal properties has been rising very fast since the 1990's. However, it decreased after the 2008 global economic crisis (Programa Estado de la Nación 2012). In Figure 5 it can be seen that the area constructed in Costa Rican Coastal Municipalities has experienced a big decline.

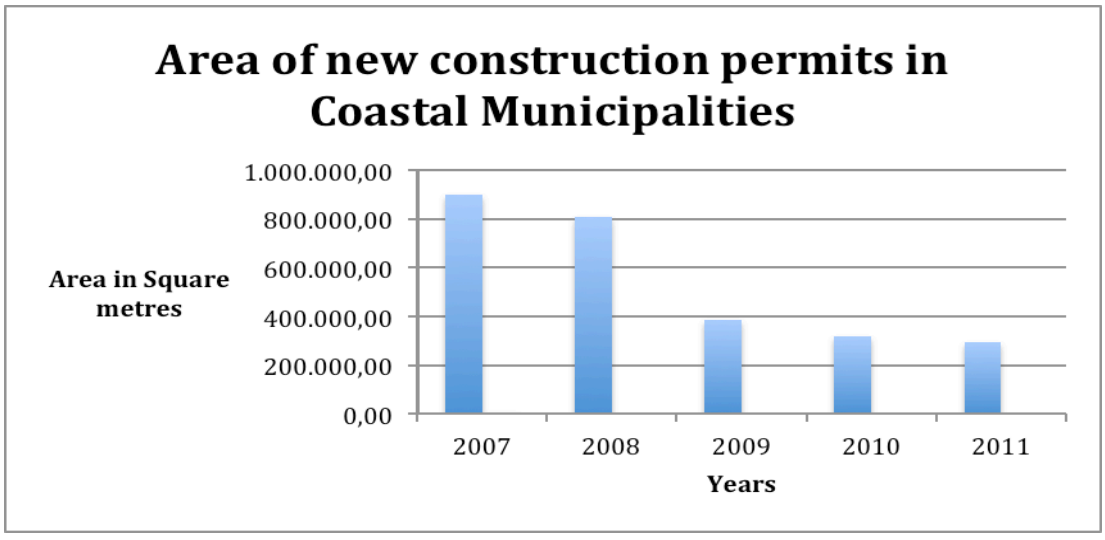


Figure 4. Area of new construction permits in Coastal Municipalities. Data Source: Programa Estado de la Nación 2012.

2.3 Costa Rica's Coasts and Climate Change

Adaptation capacity is reduced when ecosystems are used to living in stable conditions (United Nations *et al.* 2012). Costa Rica's coasts mainly consist of tropical beaches in front of mangrove swamps and alluvial plains. These types of beaches are particularly vulnerable to climate change and a rise in sea level. The adaptation capacity to reduce these impacts are questionable; because these ecosystems are used to living in conditions in which there are no big diurnal and seasonal changes and slowly react to moderately fast transformations in the climate (Costa Rica 2000; United Nations *et al.* 2012).

The changes in the climate are negatively affecting and impacting Costa Rica's coast in many different ways. These impacts include but are not limited to a rise in sea level, the salinization of aquifers, a rise in mean temperatures, changes in coastal ecosystems and biodiversity, the modification in the precipitation patterns, a rise in the strength of tropical storms and hurricanes (MINAET *et al.* 2000; Drews and Fonseca 2009; INBIO 2009; Gutierrez and Espinoza 2010). Some research has been carried out regarding the current and forecasted impacts of sea level rising on Costa Rican coastline. Additional studies have been conducted about the predicted impacts that a changing climate could cause in water availability or with the country's coastal biodiversity. Table 3 summarizes how climate change related pressures will impact Costa Rican water resources, biodiversity, and coastal human settlements.

Sector	Possible Impacts Caused by Climate Change
Water Resources	- Modification in the precipitation patterns. - Increase in frequency and intensity of meteorological extreme events (floods, droughts, El Niño and La Niña) - Changing runoff patterns. - Salinization of aquifers. - Reduction of water availability in some coastal regions (e.g. North Pacific).
Biodiversity and Ecosystems	- Modifications of coastal zones and migration of biodiversity to higher latitudes. - Bigger occurrence of forest fires in some regions (e.g. North Pacific). - Wetlands loss. - Decrease in biodiversity populations. - Increase in extinction rates.
Settlements	- Increased risk of flooding. - Magnification of the heat islands in urban settlements. - Increased costs for insurance. - Increased occurrence of mud slides in steep areas. - Higher energy needs to control temperatures.

Table 3. Summary of the impacts of climate change in water, biodiversity and human settlements. Sources: MINAET *et al.* 2000; Drews and Fonseca 2009; INBIO 2009; Gutierrez and Espinoza 2010; Jimenez *et al.* 2011.

2.3.1 Costa Rica's Coastal Settlements and Sea Level Rise

Research show that the nexus among the maximum astronomical tide, the rise in sea level caused by el Niño Effect, and the increase in mean global temperature, could be the reason for the faster erosion process that Costa Rica's coast is undergoing. Twenty-one changes in its Pacific coastline have been documented (Malavassi 2008), and an erosion process also has been described in its Caribbean coast (Lizano 2011). It was concluded that these same three causes are responsible for a faster erosion process in Damas Island, which caused it to split in two (Lizano and Salas 2001).

All Costa Rica's coastline will be impacted by sea level rise (United Nations *et al.* 2012), an increase that could be of 1 meter by 2100 (World Bank Group 2011). Under a scenario of a one-meter increase in sea level, all Costa Rica's shoreline might move and increase the areas exposed to tidal floods (World Bank Group 2011).

Two scientific studies included a model of possible sea level rise inundation scenarios in different locations in Costa Rica. MINAET *et al.* (2000) predicted that with a 0.3-meter increase in sea level, water could penetrate an average of 150 meters inland from its actual limits in Puntarenas City, an area that in 1998 constituted 60% of its residential sector. With a one meter sea level rise, the sea water would penetrate an average of 500 meters from its actual limits, which would flood an approximate of 300 hectares, an area that in 1998 constituted 90% of its residential sector (MINAET *et al.* 2000). In Figure 6 one

can see the expected rise of sea level in Puntarenas under Costa Rica different sea scenarios.

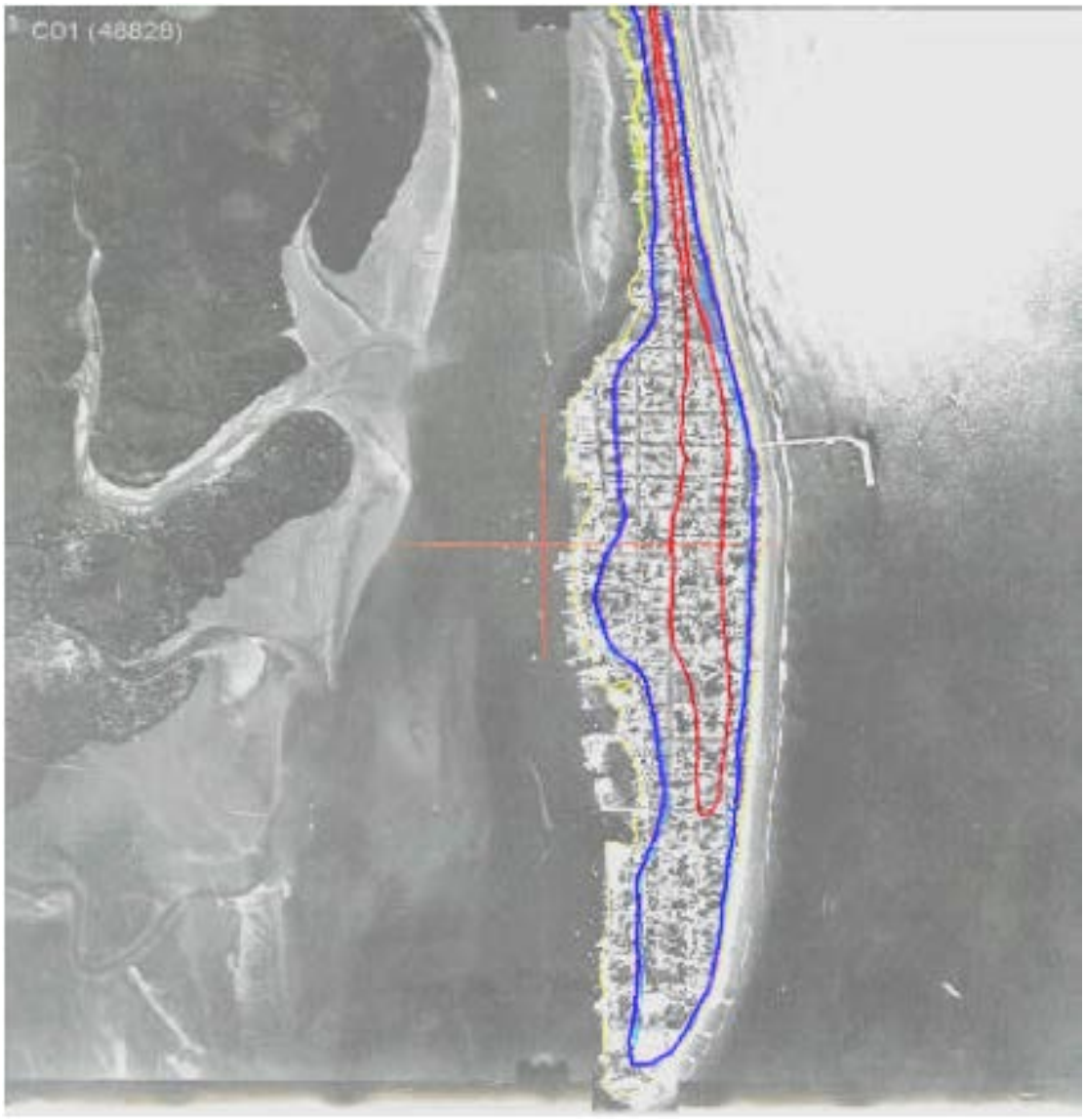


Figure 5. Expected rise of sea level in Puntarenas City, under Costa Rica different sea scenarios. The yellow line represents the actual border, the blue line represents the expected border with a 0.3 meters rise in sea level, and the red line represents the expected border with a one-meter rise in sea level. Source: MINAET *et al.* 2000.

Puntarenas City is undergoing a faster erosion process, which is taking the sediments that protect its coasts. CIMAR (2012) recently suggested that to stop the erosion of its beach, Puntarenas City urgently needs a seawall. This problem has worsened after the earthquake that happened in Costa Rica on

September 5th of 2012, because the city sank an approximate of 40 cm. This subsidence interacts with the rise in sea level that climate change causes, which currently ranges between 3 and 5 millimetres (Herrera 2012).

A second study (Drews and Fonseca 2009) predicted that with a one-meter rise in sea level, Playa Grande's coastline would retreat 50 meters. This would affect major areas that some landowners intend to develop inside this protected land (Drews and Fonseca 2009). This beach is part of Las Baulas National Park, an area that is the major nesting place for leatherback turtles in the Oriental Pacific, a species classified as critically endangered by IUCN (The Leatherback Trust 2003)). The study concluded that no constructions should be permitted in the protected area, in order to allow the coastline to retreat. Thus leatherback turtles continue to have a nesting site in the future (Drews and Fonseca 2009).

If the developments are allowed, the constructions will impede inland retreat of the shoreline, which will eliminate the turtles nesting sites and could also cause coastal access problems such as the ones described by Caldwell and Segall (2007). In Figure 7 one can see Playa Grande in 2009 and how it would look at the end of the current century.

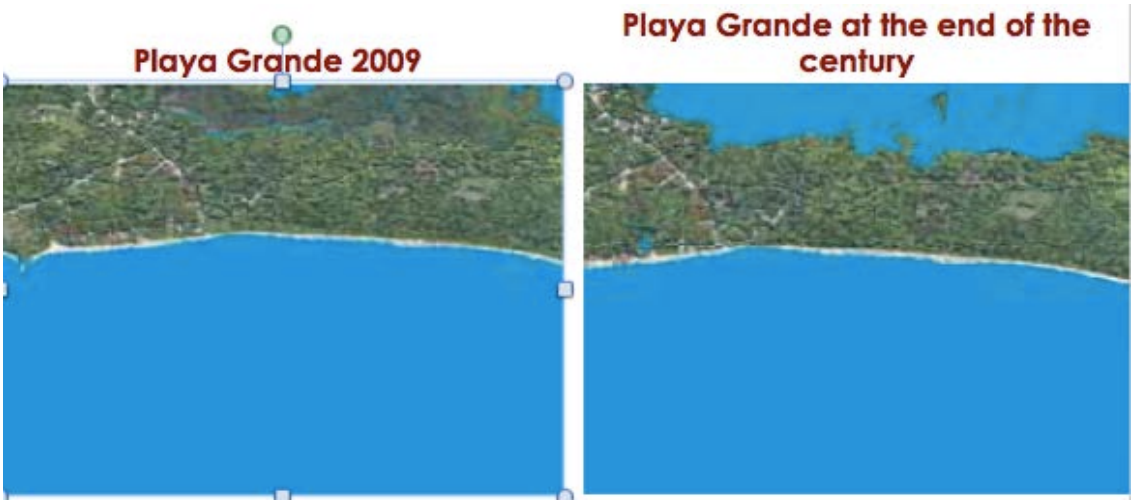


Figure 6. Playa Grande in 2009 and prediction of how it will look at the end of the century by sea level rise. The major inundation of the coast will come from the Tamarindo Stuary. Source: Drews and Fonseca 2009.

2.3.2 Costa Rica's Water and Climate Change

Climate change could drastically modify the raining season, and, thus water availability. Possible changes will vary between the different regions of Costa Rica. By the year 2030 Costa Rica's North Pacific (the driest region of the country that hosts many of important coastal areas for tourism) could experience a 10% reduction in rainfall. Costa Rica could also experience the shortening of its currently continuous raining season that lasts an approximate of 7 months (MINAET *et al.* 2012b).

Additionally, by the year 2100 the South and Central Pacific Regions could experience 15% intensification in rainfall while the North Zone, the North Pacific, the Caribbean and the Central Regions could experience a 30% reduction in rainfall (MINAET *et al.* 2012a). Other studies describe more severe scenarios (Costa Rica 2000). For example Guanacaste a province

used as a primary coastal tourism destination, could experience a 63% decrease in rainfall by 2100 (Costa Rica 2000). This decline will affect water availability and accessibility, because aquifers replenishment depends on rainfall. It can be seen in Figure 8, how some coastal regions of Costa Rica will experience an increase in rainfall while others will suffer a decrease in annual precipitation.

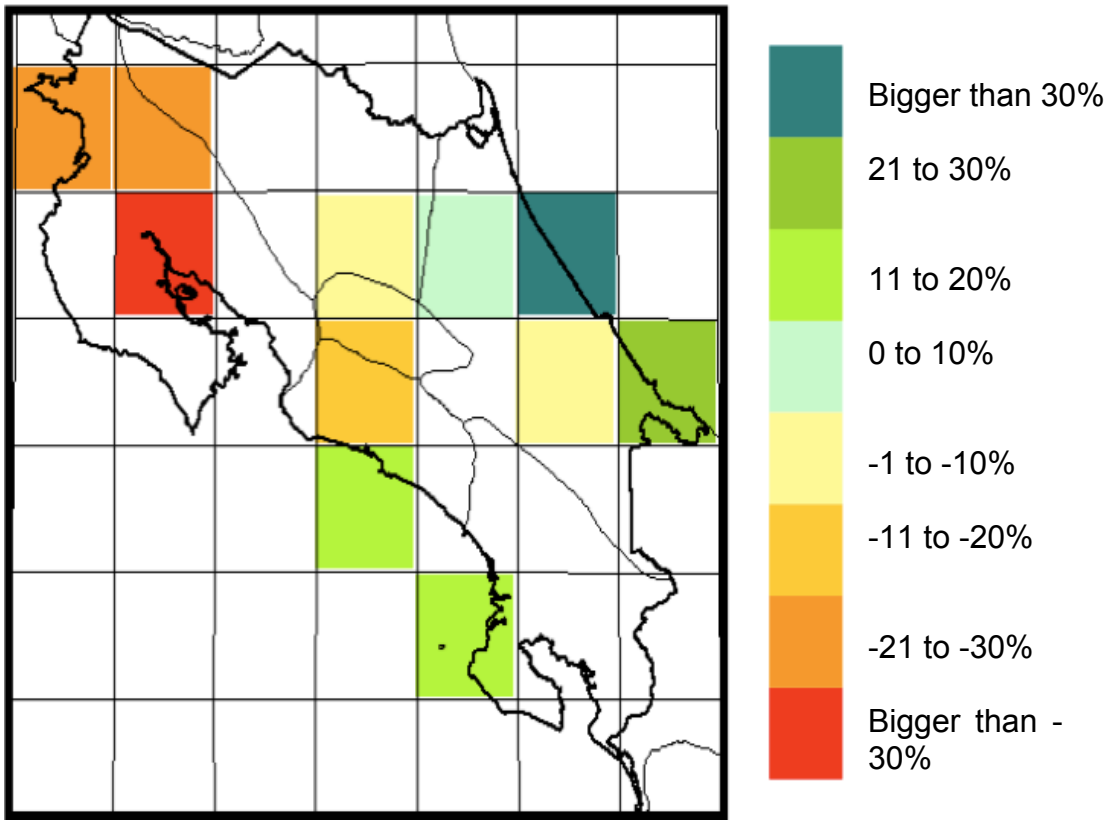


Figure 7. Variation in Costa Rica's annual precipitation with climate change. Comparison between the period 1961-1990 and the period 2081-2100. Source: MINAET 2009.

Because of their conditions of infrastructure, services and development, Costa Rica's coasts and frontier zones are the areas that in general terms show the greatest vulnerability with respect to climate change impacts on water availability (MINAET *et al.* 2011). Although many of the coastal zones host

important tourism destinations, this has not translated into a considerable increase in development for coastal cities and its inhabitants. Currently, the Central Valley continues to have better rankings in human development, services, and infrastructure.

2.3.3 Costa Rica's Biodiversity and Climate Change

Costa Rica has under conservation 26.21% of its terrestrial land (SINAC 2012). Nevertheless, just 2.42% of its maritime jurisdiction is under some category of protection, area that is not enough to accomplish a real conservation of the country marine resources (Rodríguez 2011). Despite the national efforts, it is still far from effectively conserving the diverse habitats found in its land, or the necessary ecological processes for a healthy state of its ecosystems (INBIO 2009).

The predicted increase in precipitation variability and the decrease in precipitation represent considerable threats to Costa Rica's Biodiversity (World Bank Group 2011). Coastal wetlands and coral reefs are expected to be one of the most impacted ecosystems from climate change. These coastal and marine ecosystems could experience considerable variations, with direct and indirect results on the humans that depend on them (INBIO 2009). Coastal wetlands and coral reefs provide many different services for coastal residents, such as food provision, coastline protection, and are major tourist attractions.

In the majority of climate change modelled scenarios, has been predicted a reduction in dry, humid and very humid tropical forests. The decline in these coastal zones could represent a threat for the biodiversity (Alpízar *et al.* 2000).

The four marine turtles that nest in Costa Rica's coast are seriously threatened by a changing climate. Climate change will impact marine turtles by, altering the sex ratio of turtle hatchlings, driven higher hatchling mortality, compromising the beaches in which they nest (Fish *et al.* 2008; INBIO 2009; Santidrián *et al.* 2012). Table 4 summarizes different impacts that a changing climate will have on the life stages of marine turtles.

Turtle Life Stage	Habitat and Distribution	Warming Air and Ocean Temperatures	Alteration of rainfall storms and cyclones	Rising Sea Level	Alterations of wind and ocean currents	Alteration of large scale ocean atmosphere patterns	Ocean acidification
Incubation and Hatching	Sandy beaches in the tropics and subtropics	Yes/ Air	Yes	Yes		Yes	
Breeding and nesting	Coastal waters in the sandy beaches in the tropics and sub-tropics	Yes/ Ocean	Yes	Yes		Yes	
Oceanic Juvenile and Adults	Open oceans, tropics to cool-temperate latitudes	Yes/ Ocean			Yes	Yes	Yes
Neritic juveniles	Coastal and shelf	Yes/ Ocean	Yes	Yes		Yes	Yes

and adults	waters, tropics to temperate latitudes						
Migrations	Shelf seas and open oceans, hundreds of kilometres to across ocean basins	Yes/ Ocean			Yes	Yes	

Table 4. Summary of marine turtle life stages, habitat and potential major changing climate effects on the various life stages. Source: Poloczanska *et al.* 2009.

A changing climate and sea level rise will intensify problems that Costa Rica's coastline will likely face. Current coastal plans have yet to be developed to address these threats and pressures in Costa Rica. Climate change will be a major challenge to the country's coastal planners and managers.

A great deal of literature focuses on how to assess coastal vulnerability and adapt to climate change and sea level rise projected impacts on coasts. This thesis describes a number of these adaptive strategies in the next sections.

2.4 Climate Change, Sea Level Rise and Coastal Planning

2.4.1 General Concepts about Vulnerability Assessment and Adaptation

We should understand vulnerability as "a system's susceptibility to harm or change. Vulnerability is the combined result of exposure, sensitivity, and adaptive or response capacity and as such a function of the character, magnitude, and rate of climate change to which a system is exposed, as well as of non-climatic (social and environmental) characteristics of the system,

which determine its sensitivity and adaptive capacity" (Moser and Ekstrom 2012, 1).

Adaptation can be classified as autonomous (biological response that doesn't involve society intervention) or planned adaptation (that concerns strategies implemented by society) (West *et al.* 2009). This thesis focuses on this latter form of adaptation, with an emphasis in the need for "intentional human action to prepare for climate change, both to realize gains from opportunities and reduce the damages" (Moore *et al.* 2012, 6). Adaptive measures are classified as reactive or proactive (depending on the time that these measures are implemented), or as private or public (depending if the economic resources to pay them come from the public administration or private individuals, companies or households) (Iglesias *et al.* 2009).

The adaptation measures that are funded by public agencies can be implemented at national, regional or local levels. Examples of adaptation measures that correspond to the regional or national level can be the encouragement that includes better water management practices or the use or river basins as the water management unit. Examples of adaptation measures implemented at a local level are improvements to urban planning/management or to water supply infrastructure (Iglesias *et al.* 2009).

Adaptive capacity can be defined as "the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the

consequences" (IPCC 2007a). In the case of coastal communities, its adaptive capacity to a changing climate declines if there is an absence of institutional capacities and economic resources to diminish risks associated to a changing climate (IPCC 2007b).

In order to design effective coastal planning adaptive measures, planners and authorities have to be aware of the growing risks associated with a changing climate and a rise in sea level (CRNA 2009). Vulnerability assessments must be integrated with daily coastal management practices (Klein and Nicholls 1999) and adaptive capacity has to be enhanced (Mawdsley *et al.* 2009).

2.5 Vulnerability Assessments to Climate Change and Sea Level Rise

To assess the vulnerability of Costa Rica's coastal regions, biodiversity and human populations to climate change and rise in sea level, it is important to possess the following information: complete maps of the coastline that incorporate measures of physical hazard, specified list habitats that could be at risk (Hanak and Moreno 2012), geospatial information on uncommon species disseminations and land cover maps (Mawdsley *et al.* 2009), demographic data of the human populations that inhabit the location, local important economic segments and vital infrastructure and community services (Moser and Ekstrom 2012).

Coastal planners have recognized that it is also important to identify the following information in vulnerability assessments:

- Interpretation of sea level rise height projection into shoreline retreat, beach erosion, and bluff retreat rates.
- Climate and wave data that can be incorporated in bluff retreat models.
- Coast profile studies that assist finer prediction of climate change impacts on coastline modification.
- Likely climate change estimates with quantifiable indicators of variation over time.
- Mapping of flood areas below diverse sea-level rise estimates.
- Forecasting of El Niño events and modifications in the regularity or gravity of those events with a changing climate, incorporating effects on coastline retreat speeds (Tribbia and Moser 2008).

2.6 Adaptation Measures to Climate Change and Sea Level Rise

There is considerable importance in identifying practical coastal management approaches or adaptation policies that could help decrease climate change and sea level rise negative impacts on water availability, coastal ecosystems and human settlements. With the objective of not implementing maladaptive responses, this adaptation measures should be recognized as best practices. Because of global resource shortages in public agencies, it is central to distinguish low price opportunities (Moore *et al.* 2012). Costa Rica is a middle-income country that is currently experiencing a fiscal crisis. Because of this crisis, the Central Government requested its public agencies to reduce expenditures. The fiscal crisis that the country is experiencing emphasizes the

significance of low price adaptation responses to a changing climate.

2.6.1 Adaptation Measures for Biodiversity with a Changing Climate

Biodiversity adaptive capacity to climate change is a key coastal management issue. Because coastal ecosystems have suffered deterioration from other anthropogenic pressures, coastal species will have more difficulty adapting to a changing climate (McGinnis and McGinnis 2011). The main threats that have been described for Costa Rica's marine and coastal biodiversity resources are, pollution, unplanned coastal development infrastructure, unregulated navigation and illegal and unregulated exploitation of marine resources (SINAC 2008). Figure 9 depicts Costa Rica's most important sites for coastal and marine biodiversity.

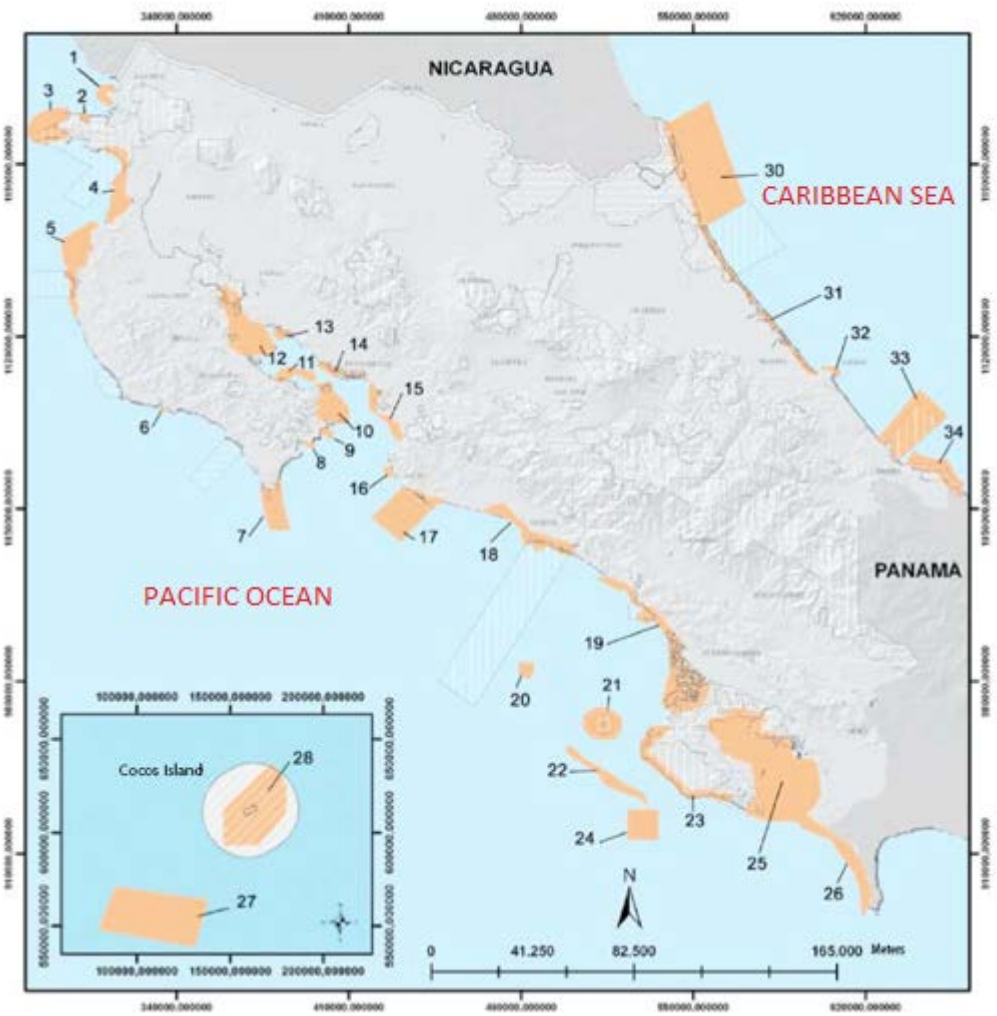


Figure 8. Location of Costa Rica's important sites for marine and coastal biodiversity. 1 Descartes; 2 Bahía Santa Elena; 3 Punta Santa Elena; 4 Golfo de Papagayo; 5 Punta Gorda-Punta Pargos; 6 Punta el Indio; 7 Cabo Blanco; 8 Punta Tambor; 9 Curú-Islas Tortugas; 10 Negritos-San Lucas; 11 Caballo-Venado; 12 Chira-Tempisque; 13 Estero Culebra; 14 Aranjuez; 15 Caldera-Tárcoles; 16 Herradura; 17 Punta Judas; 18 Damas-Savegre; 19 Dominical-Sierpe; 20 Plataforma de Coronado; 21 Isla del Caño; 22 Plataforma de Osa; 23 Corcovado; 24 Montañas submarinas de Osa; 25 Golfo Dulce; 26 Punta Burica; 27 Montañas submarinas del Coco; 28 Isla del Coco; 29 Domo Térmico; 30 Barra del Colorado; 31 Canales de Tortuguero; 32 Uvita; 33 Cahuita; 34 Gandoca; 35 Ostional. Adapted from: SINAC 2008.

In Table 5 can be seen some measures that coastal planners should take into account for biodiversity management with climate change. Improving landscape connectivity (to help species movement) is the most frequent recommended measure in scientific literature for biodiversity adaptation to a changing climate (Heller and Zavaleta 2009).

Adaptation Measures for Biodiversity with Climate Change
Preservation of important coastal areas.
Eliminating obstacles for the dispersion of species
Incorporating of a changing climate into all planning proposals
Restoration of wetlands, rivers and other degraded areas
Focusing on species that can become extinct
Reduction of land clearing
Improving landscape connectivity

Table 5. Adaptation measures for biodiversity management with climate change. These measures have been recommended in scientific articles and government reports. These are the measures that Costa Rican coastal planners could implement in their planning proposals. Sources: Driscoll *et al.* 2012; Groves *et al.* 2012; Heller and Zavaleta 2009; INBIO 2009; Mawdsley *et al.* 2009.

2.6.2 Adaptation Measures for Coastal Cities and Mangroves to Sea Level Rise

Societies have two traditional approaches to deal with a rising sea level: allow the coastline to retreat or sustain back the sea (Scavia *et al.* 2002). Holding back the sea can be achieved through seawalls, dikes, revetments and bulkheads (hardening methods). Holding back the sea generally sacrifices coastal wetlands and beaches (Scavia *et al.* 2002), cut sand supply from eroding bluffs, have direct visual impacts, reduce or eliminate coastal access and demands considerable investments (Caldwell and Holt 2007). Large sea walls can cost as high as $32,800 per linear meter, or as much as $500,000 per land (Hanak and Moreno 2012).

An option to shoreline engineering methods involves “living shoreline”, management practice which tackles erosion via the recovery or protection of

shoreline habitats. This technique involves the usage of wetlands, robust plants and natural stones along the shoreline as a defensive approach. Living shorelines could deliver superior wave protection than hardening methods (Hanak and Moreno 2012).

Concerning the retreat strategy, it has to be distinguished if we are dealing with existing or new coastal developments. With existing ones can be applied with planned abandonment or a decision to let “an asset go when nature takes its course” (Hanak and Moreno, 57). Planned relocation or assets that are considered too valuable to be lost are moved farther inland is another option. New coastal developments should require greater setbacks or rolling easements (contract that prevent structures which lead to loss of wetlands or coastline) (Scavia *et al.* 2002; Hanak and Moreno 2012).

Mangroves will need to migrate inward when agricultural or urban land does not limit them (United Nations *et al.* 2012). To make possible the natural migration of mangroves as sea level increases, can be implemented the same measures that are used for shorelines, such as: greater setbacks, rolling easements or prevention of development in vulnerable areas (Scavia *et al.* 2002).

Another adaptive measure that has been proposed to deal with sea level rise are housing designs that can better respond to coastal flooding. This can be implemented through land use guidelines and building codes (World Bank Group 2011). Costa Rica’s first national communication to the United Nations

Framework Convention Against Climate Change (UNFCCC) recommends not developing infrastructure in an area of 200 meters from mangroves, and that future developments should be 600 meters from the coast to maintain a buffer area between the developed land and the ones that are intended for conservation. To avoid developments in areas that are prone to floods, local coastal plans need to address the need to relocate residential areas that are prone to flooding to places that are located in higher altitudes (Costa Rica 2000). Table 6 summarizes and describes available policy tools to address sea level rise, which is one pressure associated with a changing climate.

Policy Options	Subcategory	Description
Managed Retreat	Rolling Easement	Creating open coastal space in order to allow publicly-owned tidelands to migrate inland as the sea rises; either through development removal, targeted land purchase, donation, or other easement mechanism.
	Prescriptive easement	Legally securing public use of a private coastal area through demonstration of historical and continuous use by the public
	Statutory restrictions on shoreline armoring	Prohibition of coastal armouring for all coastal development activities in order to mitigate beach loss and avoid increased erosion
	Shoreline Armor Removal	Removal or shoreline armor in order to avoid loss of public coastal land due to sea level rise
	Development Planning	Mandating that all applications for new development of a beach, beachfront, or bluff-top property must account for projected sea level rise.
		Requiring dune restoration, sand nourishment, and other design criteria on beaches in order to protect new or existing development.
		Considering accelerated sea level rise when calculating development setbacks.
	Wetland restoration	Creation or expansion of wetlands in order to store floodwaters and mitigate future sea level rise.
	Removal and relocation of	Removing and relocating buildings threatened by sea level rise and increased

	buildings	coastal erosion
Elevation of Land and Structure	Beach Nourishment	Placement of suitable (adequate particle size) sand, usually a large initial fill followed by periodic renourishment to make up for losses
	Raising Existing Land or Structures	Raising height of low–lying land or structures to avoid flood-related damages
Shoreline armoring	Seawalls, bulkheads and revetments	Concrete, wood, steel, or rock used to "armor" the coast in order to prevent wave erosion.
	'Living Shoreline" Coastal Protection	Utilizing habitat restoration and/or bank stabilization through strategic placement of plants, stone, sand fill and other structural and organic materials in order to minimize coastal erosion and maintain coastal processes.
	Groins	Structures built perpendicular to the shore to trap sand transported alongshore by waves and/or to hold existing sand from being transported away.
	Dikes	A dike or levee is an earth fill mound, usually having a trapezoidal cross-section, which is placed along the land/water edge to prevent water from flooding the lower dry land area.
	Offshore Breakwaters	Abovewater structures parallel to the shore that reduce both wave heights at the shoreline and along the shore by intercepting a large portion of the incident wave energy and thereby decreasing the offshore and alongshore sediment transport capacity of waves.
	Perched beach	A continuous submerged structure built offshore and parallel to shore, with beach built between the structure and shore by artificial nourishment. The structure retains the toe of the beach and perhaps diminishes wave energy by causing larger waves to break.

Table 6. Policy tools that are available to address sea level rise. Source: McGinnnis *et al.* 2009.

2.6.3 Adaptation Measures for Water Resource with a Changing Climate

Different measures are recommended to adapt to the impacts that climate change and sea level rise will cause to the water resource. Some of the

measures that coastal planners should take into account consists of regulations and incentives to encourage water and energy saving, registries of present drinkable water infrastructure and of the actual capacity of the watershed, systems to capture rainfall and to recover wastewater (Mastrandrea and Luers 2012; ProDus 2011), desalination and appropriate restrictions (Driscoll *et al.* 2012), connecting all citizens to potable water pipelines (MINAET *et al.* 2012b), or the usage of river basins as the water management unit (Iglesias *et al.* 2009).

3. OBJECTIVES OF THE RESEARCH

It is important to undertake urgent and exhaustive revision of local coastal plans to ensure that coastal authorities address and respond to a changing climate and sea level rise (Caldwell and Holt 2007). Costa Rica's existing coastal planning legal framework should be carefully reviewed (INBIO 2009). Today no one has studied Costa Rica's local coastal plans in light of the expected impacts of climate change and sea level rise. Additionally, no investigations have proposed concrete recommendations that could be implemented to adapt or mitigate these pressures and threats.

This research intends to fill some of those information gaps by focusing on Costa Rica's coastal planning legal framework. It aims to examine the extent to which Costa Rica's coastal planning recognizes and addresses predicted climate change and sea level rise impacts to coastal ecosystems and economies.

The research has the following objectives:

1. To describe the institutional, legal and policy landscape for coastal planning and climate change adaptation in Costa Rica;
2. To assess climate change and sea level rise vulnerability information and adaptation measures that Costa Rica's local coastal plans currently provide;
3. To compare diverse municipal plans and their response to climate change and sea level rise;
4. To recommend changes that improve Costa Rica's coastal planning and climate change legal framework and practices.

3.1 Research Approach

First, Costa Rica's institutions that deal with coastal planning and climate change are described. Second, the country's most important laws that deal with planning are identified and briefly characterized. Third, the thesis outlines the most important Costa Rica's climate change policies and adaptive strategies.

To review Costa Rica's existing coastal management framework, a checklist was developed to assess Costa Rica's local coastal plans. As a prerequisite for any vulnerability and adaptation effort assessment, it is important to develop climate-related pressures on Costa Rica's coastal areas. The thesis also included an analysis of literature on vulnerability assessments and

strategies to deal with those pressures. The checklist also includes a list of adaptive strategies and responses that are needed in local coastal plans.

The logic to develop this checklist follows the structure of the Pressure, State and Response (PSR) model, which can be used to assess public policy programs (OECD n.d.). The PSR model is based on causality; human activities put pressures on the environment and change natural resources quantity and quality (state). Society replies to these alterations through sectoral, economic and environmental responses (responses) (OECD n.d.). In Figure 10 it can be seen the logic that the PSR model follows.

Figure 9. Pressure, State and Response Model. The pressures that are chosen are climate change and sea level rise and how they affect two Costa Rican natural resources and its coastal settlements. The responses that are annalyzed are the ones that can be implemented in local coastal plans. Adapted from OECD n.d.

This checklist includes information that planners should have to assess the vulnerability to climate change and the impacts of sea level rise on coastal human settlements, water and coastal biodiversity. The list also includes adaptation measures to climate change and sea level rise, which have been recognized as useful for coastal planning in the peer reviewed literature,

technical and government report documents. The following table presents the checklist that was developed to assess Costa Rica's local coastal plans:

	Integral Local Coastal Plan Avellanas-Junquillal	Integral Local Coastal Plan Hermosa- El Coco- Bahia Azul
Vulnerability assessment information		
- Demographic information on the inhabitants		
- Information on local important economic sectors		
- Information on the valuable infrastructure and community services		
- Flooding models of the planned area under different sea-level rise scenarios		
- Information on the current and expected erosion rates		
- Coast profile studies that contribute to a more accurate prediction of climate change impacts on coastline modification		
- Likely climate change estimates with quantifiable indicators of variation over time		
- Forecasting of El Niño events and modifications in the regularity or gravity of those events with a changing climate		
- List of ecosystems and species that could be threaten in the planned area		
- Geospatial information on uncommon species disseminations and land cover maps		
- Information on the condition of the aquifers and of the actual capacity of the watershed		
- Records on current drinking water infrastructure		
Adaptive responses for coastal biodiversity		
- Preservation of important coastal areas		
- Elimination of obstacles to the dispersion of species		
- Incorporation of a changing climate into all planning proposals		
- Restoration of wetlands, rivers and other		

degraded areas		
- Focusing on species that can become extinct - Reduction of land clearing		
- Setbacks behind estuaries, mangroves or riversides - Improvement of landscape connectivity		
Adaptive responses for coastal settlements		
- Setbacks on the coastline		
- Housing designs that can better respond to coastal flooding		
- Coastal armoring		
Adaptive responses for water resource		
- Systems for the treatment of sewage water		
- Systems for the capturing of rainfall		
- Regulations to encourage energy saving - Regulations to encourage water saving - Use or river basins as the water management unit		

√= Yes, X= No, - = Partially present

Table 7. Checklist to assess Costa Rica's local coastal plans. Some responses are useful for the adaptation of more than one resource. For example, establishing bigger setbacks behind the mangroves helps this ecosystem to migrate and at the same time gives more protection to human settlements.

With this checklist is reviewed two local coastal plans and its Environmental Impact Assessment (EIA). This is meant to determine what vulnerability information or adaptation measures are included on each coastal planning proposal.

Because the local coastal plans that are approved are located in areas that belong to different coastal municipalities, it is compared if there are

differences in the information that each municipality uses or with the type of adaptive measures that they approve.

Based on the results of the assessments, the thesis will determine modifications that improve Costa Rica's coastal planning legal framework and practices with a changing climate.

3.2 Methods

The methods used in this research are the following:

- Documentary analysis: To describe the pressures that Costa Rican coasts will suffer, and the responses that the coastal managers can implement; it was consulted peer-reviewed literature, and technical and government report documents. Also analyzed were two comprehensive coastal plans and their respective EIA's. In addition, the legal and policy framework that regulates Costa Rican coastal management and climate change was reviewed.

- Interviews: Different interviews were held with the head of the Maritime and Terrestrial Zone Department of the Municipality of Carrillo, the personnel of the Maritime and Terrestrial Zone Department of the Municipality of Santa Cruz, the Director of the NGO Verdiazul, that works on environmental projects in the Junquillal area, and Costa Rican experts in water issues.

- Lectures: The following lectures related to the topic of the research were attended:

a) "Women and Water". A lecture organized by CEDARENA which was delivered on April 10th, 2013.

b) “Challenges and Opportunities for Risk Management and Future Climate Change Adaptation.» A lecture organized by FLACSO, CNE and EIRD-UN that was delivered on April 18th, 2013.

c) “Where Will the Water Come from in the Future?” A lecture organized by OET that was delivered on May 20th, 2013.

3.3 Case Studies

Two planning proposals originally promoted by the ICT were assessed. These proposals already have their respective EIA approvals by SETENA and were submitted in the year 2011 for consideration by the coastal municipal terms. If the latter approve these planning proposals, the final step in the process will be a public hearing with the local communities and interested parties.

The criteria for selecting these two case studies are the following:

1) These two planning proposals are the most recent that ICT is promoting and are at the final stage of their approval process.
2) The two areas of study are considered of priority for tourism development.
3) The two areas are considered of importance for coastal biodiversity.

The case studies are briefly described in sections 3.4 and 3.5:

3.4 Junquillal-Avellanas Comprehensive Coastal Plan

This area is located in the Municipality of Santa Cruz, Guanacaste Province. It belongs to the Guanacaste North Tourism Planning Unit. This local coastal plan comprises the following beaches: Blanca, Pargo, Negra, Arbolito, Pochote, Callejones, Majagua, Avellanas, Lagartillo and Junquillal (ICT 2011a). The location of this area can be seen on the next figure.

Figure 10. Location of Junquillal-Avellanas. Can be seen that the area is located in the Northern Pacific region of the country. Adapted from ICT 2011a.

The urban development in the area is low compared to other nearby coastal regions. The area has a total population of 882 inhabitants distributed throughout the entire sector. Approximately 50% of the population live in the area located between Avellanas-Junquillal; 31.4% in the sector Callejones-Junquillal; and the remaining 18.6% in Playa Negra-Callejones (ICT 2011a).

Regarding natural resources, the area has mangrove swamps and sections that are covered by forest. One of the most important nesting sites for the critically-endangered Pacific leatherback turtle (*Dermochelys coriacea*) is Junquillal beach. Turtles of the threatened species Pacific green (*Chelonia mydas agassizii*) and olive Ridley (*Lepidochelys olivacea*) nest also on this beach (Francia 2013). Figure 12 shows one of the mangrove swamps located in this area.

Figure 11. Junquillal mangrove. In this picture can be appreciated the mangrove and some of the ecosystem services that it provides. Source: Author.

The Paraiso Association for The Rural Aqueduct (ASADA) supplies the water for human consumption. ASADA has four wells, of which two are active, one is going to be activated soon and one is held as a reserve. It is undeniable that the area needs more investment in infrastructure for the distribution and storage of water. The sector of Avellanas does not have a water supply service, so water is drawn from registered or unregistered wells. The area of Junquillal-Avellanas has no sewerage and treatment system (ICT 2011a).

Junquillal is an example of a place that is already feeling the impact of a changing climate. Due to the rise in temperatures that the area is experiencing, in only a small section of its coast sand temperature remains sufficiently cool for nests to survive. Furthermore, in a period of two years from 8 to 15 meters of beach were lost to an advancing sea, as recorded (Fonseca 2010).

Under the forecasted sea-level rise scenarios, Junquillal estuary will be the most flooded area . More than half of Junquillal is built upon an old sand bar, a factor that increases the risk of flooding and erosion (Fonseca 2010).

3.5 Hermosa-Bahia Azul Comprehensive Coastal Plan

This area is located within the municipal term of Carrillo, Guanacaste Province. It also belongs to the Northern Guanacaste Tourism Planning Unit. This local coastal plan includes the following beaches: Hermosa, Penca, Calzon de Pobre, Pedregosa, El Coco, Blanca, Jicote, Gringo, Ocotal, Pez Vela, and Azul (ICT 2011b). Figure 13 shows the location of this area.

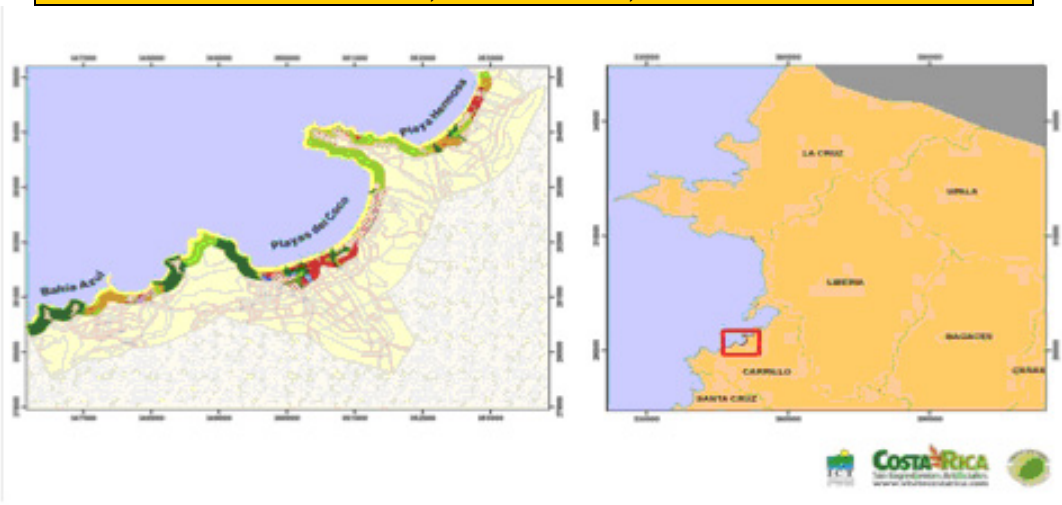


Figure 12. Location of Hermosa-Bahia Azul. The area, as can be seen, is in Costa Rica's Northern Pacific Region; it is in the jurisdiction of the Carrillo municipal term. Adapted from ICT 2011b.

This sector has a total population of 3,296 inhabitants distributed throughout the area. El Coco concentrates 86.2% of the total population; 9.4% live in Hermosa and 4.4% reside in Ocotal. This sector has recently experienced a considerable urban growth that is mainly concentrated in El Coco. This urban development is exerting considerable pressure on the public services, mainly on its water supply (ICT 2011b).

This area also has public forests and some mangrove swamps that are smaller than the ones at Junquillal-Avellanas. Although this area is not considered of importance as a turtle nesting site, in the past some turtles have nested in Hermosa and Ocotal, and turtle tracks can sometimes be seen at Gringo Beach. Figure 14 shows one of the beaches that are located in this area.

Figure 13. Ocotal Beach. Source: Author.

.

Three water supply facilities provide water for human consumption, two of which are managed by the Costa Rican Water and Sewerage Agency (ICAA), while the third one is managed by a local rural association. Since the water supply system at El Coco is saturated, there is a rationing of water in the dry season. It is undisputable that this sector also requires more investment in the distribution and storage of water. The area of Hermosa-Azul also lacks a sewerage and treatment system (ICT 2011b).

3.6 Limitations

This research has the following limitations:

a) Time: Because of a time constraint only two local coastal plans and its EIA could be reviewed.
b) The conclusions stated in the study made by Alpizar (2013) about the forestry cover in Junquillal-Avellanas and Hermosa Azul have yet to validated in the field.

4. RESULTS

The results of this research are presented in three chapters. Chapter 5 provides the main features of the institutions, the coastal management laws and policies, and climate change mitigation and adaptation in Costa Rica. Chapter 6 describes the main findings, which were attained analyzing two local coastal plans with the checklist. Chapter 7 contains different recommendations that will improve the manner in which Costa Rica's institutions and managers deal with coastal planning subject to a changing climate.

5. COSTA RICA'S COASTAL MANAGEMENT AND CLIMATE CHANGE. THE INSTITUTIONAL, LEGAL AND POLICY SCENARIO

5.1 Costa Rican Institutions that Deal With Coastal Management

Costa Rica has a diverse legal framework that regulates coastal management, which gives competency to different public institutions in the different scales of planning. The Costa Rican Institute on Tourism (ICT), as the governing agency for the development of tourism in the country, has to define whether a coastal section is suitable for tourism (art. 27 Law 6043). Municipal terms that include coastal sections, in coordination with ICT and the National Housing and Urban Development Agency (INVU), are in charge of preparing and approving local coastal plans (Law Number 6043).

The Ministry of the Environment, Energy and Telecommunications (MINAET) has different roles in Costa Rican coastal management. The regional offices of the System of Conservation Areas (SINAC) are the ones that have to define natural property of the State (those areas that are devoted only to conservation that belong to the State and cannot be developed). Its National Technical Secretariat (SETENA) is in charge of reviewing and approving the Environmental Impact Assessment (EIA) of the local coastal plans (Environment Act).

The National Ground Water, Irrigation and Drainage Service (SENARA) is the institution that has to conduct research on ground water resources. ICAA is in charge of providing potable water to the communities, for which it has to develop the necessary water supply infrastructure. MINAET's Water Management Authority (*Dirección de Aguas*) has to coordinate water management at a national level.

5.2 Costa Rican Coastal Management Legal Framework

Costa Rica has a specific law that regulates coastal management; however, other regulations that are not specific to this area are included into the national coastal management legal framework.

5.2.1 The Maritime and Terrestrial Zone Law

The main regulation that governs Costa Rica's coastal management is the Maritime and Terrestrial Zone Law (Law Number 6043), which was passed in

1977. This norm confers competencies to ICT, INVU and the municipalities with coastal jurisdiction.

The maritime and terrestrial zone (ZMT) belongs to the State of Costa Rica (article 1, Law 6043). This zone can be defined as the two-hundred-meter wide strip along the entire length of the Atlantic and Pacific coasts of the country, measured horizontally from the high tide line. The maritime and terrestrial zone also comprises the islands, islets and any land or natural formation protruding from the sea level, within the territorial sea of the Republic (article 9, Law 6043).

The ZMT consists of both, public and restricted zones. The public zone is the fifty-meter-wide area by the regular high water tide and the areas that are exposed at low tide. Public zone is also all the area occupied by the mangrove swamps and estuaries along the continental and island coastline of the country. The restricted zone comprises the remaining one-hundred-and-fifty-meter strip (Law 6043).

This law establishes the local coastal plans as the management instrument of the ZMT. The local coastal plans include only the regulation of the public and restricted zones of the ZMT. The land that is not a part of the ZMT has to be regulated through urban development plans that each municipal term should have. The public zone cannot be given in concession. After a local coastal plan is approved, concessions for future developments can be granted in the restricted zone.

Law 6043 establishes a local-level management of the ZMT based on a regional management concept that is in turn seconded by the vision and goals of the National Tourism Development Plan. Figure 15 shows the different levels of strategy and planning that relate to ZMT management, and the specific articles of Law 6043 on which they are based.

Figure 14. Different levels of strategy and planning that relate to ZMT management. Adapted from ICT 2011a.

5.2.2 The Urban Planning Law

Also of significance in Costa Rica's coastal management, is the Urban Planning law (law number 4240 that was passed in 1968). This law confers

specific competencies in urban planning to INVU, to the Planning Ministry, and to the 81 Costa Rican municipalities.

This law establishes the general guidelines for the elaboration of the National Plan of Urban Development, the Regional Plans and the Municipal Land Use Plans. It also establishes different regulations about the content that planning proposals must have (for example zonation maps, building regulations, public roads and communal areas). The Urban Planning Law also has different regulations that pertain to the approval process of local plans (e.g. about the institutions involved and public hearings).

5.2.3 Organic Law of the Environment

The Organic Law of the Environment (law number 7554 of 1995) establishes different general principles for the conceptualization of a sustainable terrestrial planning. This law confers competencies in terrestrial planning to MINAET, to the Ministry of Agriculture and Livestock (MAG), and to the Costa Rican local governments.

5.2.4 Forestry Law

The Forestry law (law number 7575 that was approved in 1996) has the goal of conserving and managing the national forests. It defines MINAET as the guiding agency in forestry issues.

The Forestry law has different provisions that should be considered in coastal management. For example, it provides that all forests located on public land should be protected and managed by MINAET; this rule takes away the authority to manage maritime and terrestrial-zone forests from municipal governments (article 13, Forestry Law). It also establishes that the assets of the nation cannot be given in concession or transferred in any form (article 15, Forestry Law). The Forestry Law has different provisions regarding riparian areas. For example, it establishes a protection area in rural zones of 15 meters on each bank of the river, gully or stream and of 50 meters if the terrain is steep (article 33, Forestry Law).

5.2.5 The Waters Law

Law number 276, the Water Law, that was passed in the year 1942, is the main law relative to Costa Rica's water resources. It has various provisions that have to be taken into account in coastal management, such as the public domain of the beach area, maritime zones, flowing water and ground water.

5.2.6 Biodiversity Law

Different provisions of importance for the country's coastal planning are found in the Biodiversity Law (law number 7788 of 1998). For example, it entrusts the Costa Rican State with the duty to maintain ecological processes, to which effect it has to issue the necessary planning or environmental rules (article 49). It also provides that land use plans have to include the conservation and

sustainable use of biodiversity (article 52), or that MINAET and other public institutions undertake the restoration of ecosystems and species (article 53). Lastly, it establishes that the State's conservation programs have to give priority to species that are at risk of extinction (article 55).

5.2.7 National Law of Emergencies and Risk Reduction

The National Law of Emergencies and Risk Reduction (law number 8488 of 2006) defines the National Policy and National Plan for Risk Management as cross-curricular subjects in the work of Costa Rica's State agencies. This law establishes the National System for Risk Management, which is directed by The National Commission of Emergencies (CNE).

5.2.8 Decree Number 32967-MINAE

This decree refers to the introduction of the environmental variables into the local plans and into other land use planning instruments. According to this decree, any planning done concerning land use in the country, including that which relates to the local coastal plans, must include the environmental variable.

The integration of the environmental variable must follow the "Procedure for the Introduction of the Environmental Variable in the Local Plans or Other Land Use Planning", which is also established in the same decree. This

procedure is based on the methodology about Environmental Fragility Index and in the Theory of Strategic Environmental Evaluation.

5.2.9 Manual for the elaboration of local coastal plans

The ICT's Board of Directors approved this manual (resolutions numbers SJD-616-2012, and SJD-039-2013). This manual describes in detail the information that the local coastal plan must have; the approval process of the planning proposals, and the type of uses that can be approved as per the ZMT, among other things.

This manual establishes that the scope of the environmental, physical, socioeconomic, and tourism aspects of the planning proposals is what will determine the critical issues to be assessed. For each one of these critical issues, it must be a projection of the expected scenario in 5 to 10 years, listing the opportunities and limitations for future management and the respective intervention measures recommended for each case.

5.2.10 Decree Number 37623- PLAN-MINAET-MIVAH

By means of this decree The National Policy for Terrestrial Planning 2012-2040 was approved. This documents aims to integrate a framework of common objectives between the different institutional actors, and at the same time to be a guide for Costa Rican terrestrial planning.

This decree establishes risk reduction and climate change as cross curricular subjects that have to be taken into account by the different institutions involved with terrestrial planning. This norm mandates that terrestrial planning should have a preventive approach to avoid future hazards, and that planning proposals should incorporate measures to create resilience in human settlements that recurrently are exposed to risk.

5.2.11 Costa Rican Coastal Planning Legal Framework and Climate Change

Until the Decree Number 37623- PLAN-MINAET-MIVAH was passed on November 27th, 2012, there was no law, decree, or other legal rule that explicitly requires coastal municipal authorities or public institutions to address the range of climate-related impacts in local coastal plans. The lack of this requirement can be partly explained given the date on which most of those rules were put into effect. However, Costa Rica has approved different international agreements, and regional and national strategies that deal with climate change mitigation and adaptation.

5.3 Climate Change Policy in Costa Rica

Costa Rica is a signatory to the United Nations Framework Convention on Climate Change that was ratified by the Congress of Costa Rica in 2002. Since 1994 the country has been actively participating in the negotiation process and in Convention Party meetings at which different agreements such as the Kyoto Protocol (1997), the Marrakech Agreement (2001), the Nairobi

Work Plan (2006), and the Action Plan of Bali (2007) have been approved. Costa Rica's preparedness for climate change has been encouraged by the above-mentioned international agreements, as well as by the following plans or strategies:

5.3.1 Costa Rican National Development Plan

The orienting framework policies for public institutions are established in the Costa Rican National Development Plan (PND) 2011-2014. The 2011-2014 PND defines the environment and terrestrial planning as two of its pillars. The protection of the environment should be achieved through the following actions: economic growth, the promotion of carbon dioxide neutrality, the rational use of resources, and the incorporation of the environmental variables and the assessment of vulnerability in terrestrial planning (MINAET *et al.* 2012)

According to the Law on Financial Administration of the Republic and Public Budgets (law number 8131 of 2001), the PND constitutes the framework that has to guide operative institutional plans of public institutions like ICT, IGN or MINAET (article 4, law 8131), but not the operative plans of local governments.

5.3.2 Regional Climate Change Strategy

All Central American countries approved the Regional Climate Change

Strategy. This agreement has as one of its objectives the reduction of the negative impacts of climate change on biodiversity, water resources, and coastal infrastructure. This has to be achieved through the increase of resilience and adaptive capacity. The Regional Strategy provides for actions that should be implemented by government agencies, the private sector, and the society.

To achieve the reduction of vulnerability and enhance adaptive capacity, different measures should be implemented. Some of the measures that are worth noting are summarized in Table 8:

- To design and implement risk analysis and management regulations in urban planning.
- To assess water resource vulnerability to a changing climate and to implement measures for its adaptation.
- To put together expected sea level rise scenarios for the years 2015, 2020, 2030, and 2050 with an indication of the impact thereof on, coastal populations, water resources, tourism infrastructure, and sea ports.
- To design and implement effective adaptive measures for sea-level rise.
- To integrate the results of scientific climate change studies into coastal and marine management.

- To promote tourism developments in areas not vulnerable to a changing climate.

Table 8. Measures that should be implemented by Central American countries to assess vulnerability and adapt to climate change pressures. Source: Regional Climate Change Strategy 2010.

5.3.3 National Climate-Change Strategy

On August 1st, 2007 the Cabinet of the Government of Costa Rica issued a resolution urging all public institutions and local governments to prepare and implement an action plan establishing specific actions on how to achieve the 5 objectives of the National Climate-Change Strategy. The initiative would receive support from MINAET's Office of Climate Change, which is in charge of the coordination of climate-related issues in Costa Rica (National Climate-Change Strategy).

The objectives of the National Climate-Change Strategy are mitigation and adaptation, the development of capacities and technology, public education and cultural change, and obtaining the necessary financial resources to achieve these objectives (MINAET 2009). The seven key sectors that the National Climate-Change Strategy identifies for vulnerability and adaptation action are biodiversity, coastal zones and fishing, water, agriculture and livestock, energy, health, and infrastructure (MINAET 2012a).

6. ASSESSMENT OF LOCAL COASTAL PLANS

The first local coastal plans approved in Costa Rica were limited to the regulation of one beach or a part of it. One hundred fifty-two local coastal plans have been registered along the Pacific Coast, of which many don't include the whole beach, and some are partially enforced or not applied at all (Fonseca 2012).

The concept of comprehensive coastal plans has recently been introduced with the aim of using the land in coastal areas in a more integrated manner; in it several beaches are introduced into the same planning proposal. The ICT, in coordination with the respective coastal municipal governments, has designed 10 comprehensive local coastal plans covering together an area of approximately 4,647.72 hectares that represents 23% of the ZMT total area (Fonseca 2012).

As it was described in the methodology, the comprehensive coastal plans that comprise the sectors Junquillal-Avellanas and Hermosa-Azul and their EIAs were assessed. The results that were attained are described in the next section.

6.1 Information on the Comprehensive Coastal Plans Provided

	Avellanas-Junquillal Comprehensive Coastal Plan	Hermosa- El Coco- Bahia Azul Comprehensive Coastal Plan
Vulnerability assessment information		
- Demographic information on the inhabitants	√	√
- Information on local important economic sectors	-	-
- Information on the valuable infrastructure and community services	-	-
- Flooding models of the planned area under different sea-level rise scenarios	X	X
- Information on the current and expected erosion rates	X	X
- Coast profile studies that contribute to a more accurate prediction of climate change impacts on coastline modification	X	X
- Likely climate change estimates with quantifiable indicators of variation over time	X	X
- Forecasting of El Niño events and modifications in the regularity or gravity of those events with a changing climate	X	X
- List of ecosystems and species that could be threaten in the planned area	-	-
- Geospatial information on uncommon species disseminations and land cover maps	-	-
- Information on the condition of the aquifers and of the actual capacity of the watershed	-	-
- Records of current drinking water infrastructure	-	-
Adaptive responses for coastal biodiversity		
- Preservation of important coastal areas	-	-
- Elimination of obstacles to the dispersion of species	X	X
- Incorporation of a changing climate into all planning proposals	X	X

- Restoration of wetlands, rivers and other degraded areas	-	-
- Focusing on species that can become extinct	X	X
- Reduction of land clearing	-	-
- Setbacks behind estuaries, mangroves or riversides	-	-
- Improvement of landscape connectivity	X	X
Adaptive responses for coastal settlements		
- Setbacks on the coastline	X	X
- Housing designs that can better respond to coastal flooding	X	X
- Coastal armoring	X	X
Adaptive responses for water resource		
- Sewage treatment systems	X	X
- Rainfall collection systems	X	X
- Regulations to encourage energy saving	X	X
- Regulations to encourage water saving	-	-
- Use of river basins as the water management unit	X	X

√= Yes, X= No, - = Partially present

Table 9. Results of the assessment of the local coastal plans with the checklist

Concerning the 28 items that were assessed with the checklist, in one case the planning proposals include the information or adaptive measure; in 11 cases this is included in a partial manner, and in the remaining 16 cases it is not considered at all.

The following comments are of importance with respect to the vulnerability assessment information examined:

- Both planning proposals include detailed information of the inhabitants of the

respective areas. Each comprehensive coastal plan provides statistics about socio-economic and demographic indicators on the residents of the area, such as male and female population, income, education, and housing.

- The proposals examined contain some information on the local important economic sectors (tourism, real estate, fishing, among others); however, how much each sector contributes to the local economy or how many people are employed in each sector are not specified.

- The two comprehensive coastal plans provide information on the community services available in both of the planned areas but neither provides any data on what could be considered valuable infrastructure.

- None of the comprehensive local coastal plans includes flooding models under different sea-level rise scenarios. As concerns Junquillal-Avellanas flooding models for Junquillal beach (video available at URL: http://www.youtube.com/watch?v=o5ovnY2pfs4) had been made by the World Wildlife Fund (WWF) which were presumably given by WWF personnel to the contractors that drafted the planning proposals (Fonseca 2010, Francia 2013).

- None of the comprehensive coastal plans includes any data on the current erosion rates. The Junquillal-Avellanas proposal is the only one that mentions this issue. It recognizes that there is a considerable erosion process going on and that erosion rate studies should be conducted in the area to define the defensive structures that should be constructed.

- There are no coast profile studies that could help make a more accurate prediction of the impact that a changing climate could have in terms of modification of the coastline.

- Although studies have been conducted to estimate the increase in temperatures, and the alteration in rainfall patterns that the different regions of the country will experience due to climate change, neither one of the two comprehensive coastal plans contains an estimate of climate variation over time.

- During the El Niño years rainfall and consequently water availability were considerably reduced in Costa Rica. Although a changing climate will make these events more common and intense, neither of the two comprehensive coastal plans takes into consideration the effects that El Niño has.

- The two planning proposals list the Junquillal-Avellanas and Hermosa-Azul ecosystems. Although in some of the areas there are currently species that are in risk of extinction or threatened (e.g. leatherback, olive ridleys and Pacific green turtles at Junquillal), none of the comprehensive coastal plans mentions the threatened species found in the area.

- The two planning proposals provide land cover maps of the areas. However, none of them have any geospatial information about uncommon species that live in or visit the areas.

- The two planning proposals give information about the actual capacity of the wells from which the water for the community is taken, or about the vulnerability to contamination of the watershed. However, none of the comprehensive coastal plans provides any information on the actual levels of pollution in the watershed, whether it is affected by saline intrusion, or whether the exploitation of the watershed is sustainable in the long term.

- Costa Rica maintains records of the wells legally authorized to provide water for national human consumption. However, these records don't provide a accurate picture due to the fact that illegal wells are also used to supply the water (Astorga 2013). The planning proposals provide no information on illegal wells, even though they recognize that some are in operation.

The following comments are of importance with respect to the measures of adaptation to a changing climate provided for in the comprehensive coastal plans:

- Some of the most important coastal areas for biodiversity are preserved given that the two comprehensive local coastal plans take into consideration the mangrove swamps, estuaries, forests, and 15 meters to each side of the rivers as conservation areas that should be managed by MINAET. The design of the conservation areas is based on rules established by the Forestry and the Maritime and Terrestrial Zone laws. It is important to acknowledge that the boundaries of the natural property of the State in some areas covered

by both planning proposals could be wrong, and this threatens public forests that risk being converted for infrastructure development (Alpízar 2013).

-None of the comprehensive coastal plans takes into account the ecological needs of the biodiversity present in the areas when it comes to defining land use in both areas, and therefore obstacles that affect the dispersion thereof are not taken into consideration in any of the planning proposals.

- Climate change is not included into any of the coastal planning proposals. The only time that a changing climate is mentioned is in the EIA of the Junquillal-Avellanas comprehensive coastal plan, when it says that the area is suffering a serious erosion process caused by global warming and a notable sinking of the Nicoya Peninsula (at the rate of approximately 25 millimeters per year).

- The promoters of the proposals allege that if the comprehensive local plans are approved and implemented, the local governments of Carrillo and Santa Cruz would have more resources to invest for restoration purposes. However, no specific plans for the restoration of degraded areas are detailed.

- None of the planning proposals provides any special measure for the conservation or adaptation of the species that could go extinct in the area. The fact that the Junquillal-Avellanas comprehensive coastal plan does not establish any protective measures for the marine turtles that nest in the area, such as regulations on lighting, height of buildings, or setbacks in the

coastline that allow them to retreat, is a threat to the conservation thereof. The only requirement about lighting that the EIA establishes, is that it should be minimal to avoid negative impacts on the species of the area, a requirement that is too vague and insufficient to guarantee the protection of the marine turtles.

- Concerning the reduction of land clearing, both proposals prohibit land use change in forest areas, estuaries, mangrove swamps, and on the riverbanks. Development is permitted only in areas that are not covered by these kinds of ecosystems. However, as described by Alpízar in his GIS analysis of the establishment of boundaries of forest areas in the Junquillal-Avellanas and Hermosa-Bahia Azul local coastal plans, approximately 21 hectares in Hermosa-Bahia Azul, and 56 hectares in Junquillal-Avellanas that have been classified by the local coastal plans as areas for development of infrastructure, are apparently covered by forest (Alpízar 2013).

- As established in the Forestry Law, both proposals provide for a setback of 15 meters on the riverbanks. With respect to the estuaries and the mangrove swamps, the setbacks are regulated according to the rules of Law 6043, which orders a three-meter distance to be maintained between the limits of these ecosystems and the developments. None of these distances were defined taking into consideration a changing climate, and therefore these setbacks do not guarantee that the estuaries and mangrove swamps can adapt to climate change and sea level rise.

- Improving landscape connectivity: Although this is the most recommended measure for biodiversity adaptation to climate change, the comprehensive coastal plans do not establish any connectivity between the forest areas, leaving them isolated (Alpízar 2013). As described by Alpizar, the Junquillal-Avellanas public zone could be used for connectivity purposes (Alpizar 2013). However, the local coastal plan does not define landscape connectivity as an objective of the public zone.

- The coastline setbacks of the comprehensive coastal plans are regulated according to Law 6043, which establishes a three to five-meter distance that has to be maintained between the boundary marker of the public zone and buildings. This distance was not defined considering a rising sea level, so it will clearly not guarantee that the coastline can move inward. This will have an effect on species like marine turtles that would not be able to continue nesting in places like Junquillal-Avellanas. It could also affect the usage of the beach (Caldwell and Holt 2007).

- None of the coastal planning proposals includes any regulation about designs that can better respond to coastal flooding. The housing designs of the areas are set according to the national building codes, which take into account natural hazards such as earthquakes but not climate change.

- None of the planned areas has any coastal armoring defense. Because of the erosion process that Junquillal-Avellanas is suffering, its EIA mentioned that after the comprehensive coastal plan is approved, erosion-related studies

should be conducted, to determine the appropriate coastal armoring methods that must be implemented. This is contrary to an ideal process, which would first assess the vulnerability of the area caused by coastal erosion and other climate-related pressures, and then plan the development of the area according to its potential and limitations.

- Both of the coastal planning proposals describe that there is no sewage treatment facility in any of these areas, which is causing water pollution. It is alleged that after the comprehensive coastal plans are implemented, the local governments of Santa Cruz and Carrillo would have more financial resources for the construction of sewage treatment facilities. However, these proposals don't indicate how the sewage-treatment facilities should be built, how much they will cost, who will operate them; nor do they define where the sewage-treatment facilities should be located.

- Because of its seven-month-long rainy season Costa Rica has a great rainfall collection potential. However, none of the comprehensive local coastal plans establishes any regulations with regards to the usage of rainfall collection systems.

- More than 90% of Costa Rica's electricity comes from renewable sources, mostly hydropower plants (Chinchilla 2013). A changing climate could affect water availability for electricity production, however, none of the comprehensive local coastal plans includes any regulations about energy saving.

- The area where a large quantity of Hermosa-Azul water comes from is the locality of Sardinal, an area that recently faced a water allocation dispute between the local community and the developers. It is an area affected by water shortages during the dry season. On top of that, a changing climate will reduce rainfall in both of the planned areas, which will aggravate this water dispute. However, the only regulation about water saving that the comprehensive coastal plans has states that treated water should be used for irrigation or in outdoor cleaning. Both of the planning proposals allow golf courses, swimming pools, and the planting of exotic species, non-essential activities that demand considerable water consumption.

- Costa Rica's water management standards were established by law in 1942; this rule did not provide for river basins to be the water management units. Water management in Costa Rica falls under the administrative management of local governments, districts, counties, provinces, and also of conservation areas (Cuadrado 2013).

6. 2 Comparison Between the two Local Coastal Plans

The comprehensive coastal plans of Hermosa-Azul and Junquillal-Avellanas are almost identical, and practically only change in specific information from each of the areas that is itemized (for example, maps, information on the residents, or the land use proposed). Some parts of these planning proposals could be described as a "copy-paste" from each other (e.g. introduction and objectives). On page 63 of the Hermosa-Azul comprehensive coastal plan, it

is mentioned that the municipal government of Santa Cruz will stop any development that is done in violation of land use rules established in the planning proposal, when the one that actually has the authority over that area is the city government of Carrillo. This mistake proves that some parts of both proposals are copied.

Both planning proposals contain the same vulnerability assessment information and adaptation to climate change measures. The reason that there is no difference in content could be due to the fact that the same professional team at ICT prepared both local coastal plans, and the company that prepared the EIA's (ECOPLAN) is also the same.

The coastal plans do not take into account the pressures that climate change and sea level rise will cause. The only vulnerability assessment information or adaptation measures that the local coastal plans include are intended for the assessment of other types of pressures that Costa Rica's coasts are under and that are also useful to assess the vulnerability and adapt to a changing climate.

7. RECOMMENDATIONS THAT IMPROVE COSTA RICAN COASTAL MANAGEMENT WITH A CHANGING CLIMATE

"Successful risk reduction is about changing the nature of development" (Pelling 2013). To change its nature, land use planning has to be different in the present century. It has to be born in the regions, it has to include the

characteristics of each area; it has to be a democratic process (Gallardo 2013), and it has to take into account the pressures that a changing climate represent.

Under the current climate change scenario, coastal areas will be drastically modified. These changes call for urgent action by the respective Costa Rican government agencies; they have to plan the country's coastal borders according to this reality (Lizano 2011).

Costa Rica has played an important role supporting different climate change agreements that have been approved by the international community. It has committed to be a carbon-neutral economy by 2021 and could become the first developing nation to have a national market to compensate for GHGs emissions (Chinchilla 2013). The country also has approved regional and national climate change policies. These policies mandate public institutions to assess climate change vulnerability and take the appropriate adaptive measures.

Although the country has undertaken global, regional and national commitments, and it is part of a region that is one of the most vulnerable to climate change, it continues to increase its vulnerability by promoting development in risk zones, like coasts. Even though there is more available information on climate change effects, many sectors continue to ignore this issue and don't include risk variables into their planning proposals (Girot 2013).

After having assessed two of the latest local coastal plans promoted in Costa Rica that were presented after the country approved its Regional and National Climate Change Strategy, it has become clear that there is a discrepancy between the Costa Rican government climate change speech and practice. The Central Government asserts that climate change vulnerability assessment and adaptation is a national goal and urges all public institutions to take climate change into consideration in their daily work, but the comprehensive coastal plans that are promoted by its Minister of Tourism continue to ignore this pressure.

Central American countries do not have much in terms of financial resources to invest on climate change adaptation. In addition, the labeling of Costa Rica as a middle-income country causes it not to qualify for international cooperation when facing a hazard of considerable impact (Gallardo 2013). However, despite the country's lack of resources, Costa Rica has many opportunities to face the pressures that a changing climate represents. Many adaptive strategies that could be implemented do not require more funds and do not chase away investment. On the contrary, assessing the vulnerability and adapting to climate change will increase the return of the investments in the long term (Girot 2013).

After assessing the Costa Rican coastal management and climate change legal framework, it can be concluded that in the country's internal legislation there is practically no recognition of a changing climate. Consequently, at

present there is no enforceable regulation that can make municipal governments prepare for climate change. Still, there are different laws and regulations that could be used for climate change adaptation. These include the obligation of municipal governments to prepare local coastal plans and urban plans, or the obligation that all public institutions have to implement actions to protect human health, the environment, and biodiversity (Celliers *et al.* 2013).

The Environmental Impact Assessments could be used as driving forces for climate change adaptation. EIAs could help decision makers, planners, and all interested parties identify and reduce the negative environmental and social impacts and to increase positive benefits such as biodiversity conservation (INBIO 2009).

To include climate change into Costa Rican legislation would contribute to government agency and coastal municipal government action (Celliers *et al.* 2013). However, up to this date there has not been a climate change bill submitted to Costa Rica's Congress. In addition, no initiative has been acknowledged to amend the Manual for the Preparation of Local Coastal Plans or Decree Number 32967-MINAE in order to be able to include climate change as a variable that has to be considered into local coastal plans.

In the current climate-change scenario, it is clear that the Costa Rican legal framework that deals with coastal, water, and biodiversity management must be reviewed (INBIO 2009). Some legal initiatives that are already under

discussion by Costa Rica's Congress would help some sectors adapt to climate change. For example, the New Water Law bill establishes river basins as the water management unit. The next sections detail specific strategies that should be implemented for climate change adaptation of each of the assessed sectors.

7.1 Climate Change Strategies by Sectors

The strategies listed below were adapted from "2009 California Climate Adaptation Strategy: A Report to the Governor of the State of California in Response to Executive Order S-13-2008".

The following sections focus on each sector, respectively:

- Biodiversity
- Coastal Settlements and Resources
- Water Supply

7.2 Biodiversity

Strategy 1: Establish a System of Sustainable Protected Areas

At present, the conservation areas that are established in each local coastal plan are determined by the boundaries set to the natural property of the State and to other areas that are reserved for conservation. However, additional information for the establishment of the protected areas in each planning proposal should be considered, such as connectivity, the important places for the local biodiversity, or the important areas to preserve with climate change

(e.g. areas that could be used for tidal wetland restoration).

Strategy 2: Management of Watersheds, Habitat, and Vulnerable Species

a. Include Climate Change into Field Management – The government agencies whose work is related to land managing and the coastal municipal terms should review and change the existing resource and land use management goals and practices, with the aim of reducing environmental pressures and improving ecosystem services and watershed conditions.

b. Restore Aquatic Habitats: Management actions for biodiversity that diminish current stressors include:

1. Connecting the rivers, streams and floodplains.

2. Protecting riparian areas and springs: The areas of 10 and 15 meters established in the Forestry Law that have to be protected in riparian areas are not enough to guarantee ecological processes. Larger protected areas that imply no additional cost because of their being should be established in the riparian zones located within the ZMT.

3. Restoring estuaries and mangrove swamps.

a. Managing Endangered, Vulnerable, Endemic and Other Priority Species – The movement patterns of threatened, vulnerable and key species should be identified, with the purpose of informing activities that help in the management of ecosystems and species. Local coastal plans and their EIA's have to consider these species in their planning proposals, which they have so far not done.

b. Identify the impacts that a changing climate inflicts on threatened,

vulnerable, and declining species. Integrate adaptive climate change measures into the management of these species.

Strategy 3 - Regulatory Requirements

a) Collaboration – Government agencies have to work in close collaboration with coastal municipalities to adopt climate change adaptive measures for land use, conservation and research.

Strategy 4 - Research

I. Climate Change Models – The Government should continue supporting and encouraging climate change studies, including modeling that supports the management and conservation of Costa Rican biodiversity.

Strategy 5 - Education and Outreach

Public Communication – It is essential to make climate change a promise for a continuing public communication effort. The pressures that climate change exerts on the local area and the adaptive responses that could be implemented should be discussed at public hearings on each planning proposal.

Strategy 6 – Implementation of Adaptation Strategies

a. Policy Development – All the government agencies and municipal governments must review current laws, policies and practices to start adaptive responses to the pressures that a changing climate represents.

b. Capacity and Continuity – With the objective of accomplishing and maintaining the required actions associated to the adaptive responses, the Climate Change Office of MINAET, the local governments and other government agencies should identify new funding resources to provide support to new public employees that would be devoted to a changing climate adaptation.

7.3 Coastal Settlements and Resources

Strategy 1: Establish a National Policy to Avoid Future Hazards

a. Hazard Avoidance Policy – Government agencies and coastal municipal terms should prevent important new development in coastal areas that cannot be effectively protected from erosion and flooding due to a changing climate and sea-level rise.

b. Innovative Designs – If local governments and government agencies allow considerable new development in critical coastal areas, state-of-the-art engineering and design solutions should be employed, so that the new constructions are resilient to erosion and flooding, and built in such a manner that they could be removed or relocated inland to adapt to a rising sea level.

c. Habitat Protection – MINAET in coordination with the environmental NGOs and other interested parties, should recommend that land be purchased and preserved in the country's areas that have been described as the most important for marine and coastal biodiversity. Significant development should be prohibited in undeveloped areas that contain critical habitats, and in those zones that have an opportunity for habitat migration, buffer zones or tidal wetland restoration.

Strategy 2: State Agencies Should Prepare Sea-Level Rise and Climate Change Adaptation Plans

Coastal municipal terms and government agencies that are responsible for the management of coastal infrastructure subject to a rising sea level should prepare specific adaptation plans and guidance.

Strategy 3: Support Regional and Local Planning for Addressing Sea-Level Rise Impacts

a) Public Outreach – Coastal municipalities and other government management agencies like ICT and INVU, should meet publicly with residents of the coastal areas to discuss adaptation measures in preparation for climate change and a rising sea level.

b) Funding Mechanisms – MINAET, in coordination with its Climate Change Office, should collaborate with local governments, ICT and INVU to identify possible funding resources to undertake local coastal plan reviews.

c) Local Government Guidance – ICT, INVU, MINAET, the National Emergency Commission (CNE) and other relevant government agencies should collaborate with coastal municipal governments to establish the following measures when updating local coastal plans:

i. Setbacks – Mandatory construction setbacks must be imposed to prohibit development in coastal areas that will be impacted by a rising sea level. The current setbacks that are established according to the rules of Law 6043 were not designed for a changing climate; thus, bigger setbacks must be imposed.

ii. Clustered Coastal Development – Coastal development should be concentrated in areas of low vulnerability to a changing climate and to a rising sea level.

iii. Rebuilding Restrictions – Rebuilding should be restricted when structures built in the ZMT are damaged by coastal storms and sea-level rise.

iv. New Development Techniques – Building regulations and codes must be amended to ensure that new coastal developments include characteristics that will make them resistant to a changing climate and a rising sea level.

v. Relocation Incentives – Tax incentives or public funding to relocate facilities out of hazard areas should be considered in coastal areas in which the ZMT was registered as private property.

vi. Rolling Easements – Policies and funding to enable easements in private coastal properties should be secured in order to a) remove infrastructure as climate-related risks make inroads into developed

areas, b) move valuable infrastructure inland, c) ease landward displacement of coastal ecosystems caused by climate change and sea-level rise and d) protect larger areas on the riverbanks.

vii. Engineering Solutions – As the sea level continues to rise, new engineering features will need to be applied to marinas, harbors and other coastal infrastructure located along the shoreline.

d. Amend Local Coastal Plans to Address Climate Change Adaptation: All local governments with coastal jurisdictions, in coordination with ICT, INVU, MINAET, SENARA, CNE, and other relevant state agencies, should start amending their local coastal plans taking into consideration the pressures that a changing climate and sea-level rise will cause.

Strategy 4: Complete a Nationwide Sea-Level Rise Vulnerability Assessment

a. Vulnerability Assessment – The respective government agencies, in coordination with all the local governments in coastal jurisdictions, should produce a national coastal vulnerability assessment.

b. For as long as this coastal vulnerability assessment is not produced and climate change variables are not incorporated into coastal planning, no new local coastal plans or significant developments in coastal areas will be approved.

Strategy 5: Support Essential Data Collection and Information Sharing

Although some efforts have been made to collect essential data and produce climate change studies, more research and data are needed to perform coastal vulnerability assessments on climate change. Government agencies should work in coordination to seek funding for the collection of essential data and the production of climate change research.

7.4 Water Supply

Strategy 1: Provide Sustainable Funding for Integrated Water Management

Financing Mechanisms – An assessment of national financing mechanisms should be conducted by the respective Costa Rican water management agencies, in order to provide a stable source of resources to support climate change resilience programs.

Strategy 2: Establish River Basins as the Water Management Unit

The old water management instruments established in 1942 must be changed. River basins should be established as the water management units, this is what is proposed in bill number 17,742, which was presented to Congress 13 years ago, and for which 150,000 support signatures were collected (Astorga 2013; Cuadrado 2013).

Strategy 3: Aggressively Increase Water Use Efficiency and Saving

a. National Reduction in Water Use: Strategies to attain a nationwide 20 percent decrease in per capita water use by the year 2020 should be implemented.

b. Establish standards for water-associated infrastructure. Building codes should be modified to include features that promote water saving (e.g. systems to harvest water).

c. Non-essential water-intensive activities in coastal areas such as golf courses and swimming pools should be restricted; in its defect orders should be issued to the effect that the water for such activities come from desalinization plants.

d. Energy Efficiency – Energy efficiency must be increased nationwide. Building codes should be amended to require that new developments include energy-saving features.

Strategy 4: Practice and Promote Integrated Flood Management

Land Use Policies – Coastal municipal terms and the respective government agencies should establish policies that reduce flood risk.

Strategy 5: Organize Human Settlements and Economic Activities According to Future Water Availability

Design and organize coastal human settlements and economic activities in accordance with water availability and watershed dynamics.

Strategy 6: Preserve, Upgrade and Increase Monitoring, Data Analysis and Management

Different studies on water availability in a changing climate have been conducted recently. However, more research is needed to assess the vulnerability and adapt to climate change. Further research should focus on climate monitoring, atmospheric observations, water use feasibility studies and water use accountability. In addition, further studies that determine the state of the aquifers in coastal areas and on registries of water use are needed.

8. CONCLUSIONS

There is a strong consensus that Earth's climate is changing (IPCC 2007; Doran and Zimmerman 2009). Coastal areas will be greatly impacted by this change, impacts such as a rise in sea level, an increase in temperatures, an alteration in rainfall patterns, and a significant affectation of coastal biodiversity.

Coastal management has to take into consideration climate change and sea-level rise. Information and measures of different types are needed by coastal managers in order to assess the vulnerability and adapt to climate change and sea-level rise impacts on coastal resources as has been described.

Costa Rica is a country that heavily relies on its coastal areas. At present, the coastal areas are mainly devoted to tourism and real estate. Tourism is one of the most important economic activities in the country. It is also an economic activity that is highly exposed to shock and that will be heavily impacted by climate change. It is really important to build resilience in this sector and improve its adaptive capacity (Schatan *et al.* 2010; Revi 2013).

Costa Rica has a Regional and a National Climate Change Strategy that recognizes coastal areas as a priority sector for climate change adaptation. These policies call public institutions to consider climate change into their daily work, to produce vulnerability assessments and to take the respective measures to adapt to the hazards of a changing climate.

Two of the latest coastal planning proposals in the country were assessed to determine what climate change vulnerability assessment information and adaptive measures they provide. After reviewing these local plans, one can conclude that climate change is ignored in the latest coastal planning proposals. The results of this assessment demonstrate that some sectors of the country continue to ignore risk reduction and climate change adaptation.

Also, the country continues to increase the risk in areas most vulnerable to the threats that a changing climate represents.

After assessing the legal framework that deals with coastal management in Costa Rica, it can be concluded that no enforceable regulation mandates that municipalities prepare for the pressures that climate change represents. This proves that the national coastal planning laws should be revised and adapted to the current and future conditions that they will be addressing. However, no climate change law proposal has been presented thus far to deal in a better way with coastal planning, climate change and sea-level rise.

Different strategies should be implemented for the adaptation of the biodiversity, coastal resources, and water supply sectors to a changing climate. To implement these adaptive strategies, more resources will have to be invested on climate change science and on public servants devoted permanently to this area. In addition, current laws and planning practices will have to be changed and adapted to the new conditions that a changing climate and a rising sea level will cause.

Costa Rica is part of a region that is among the most vulnerable to climate change. However, despite the country's lack of resources, it has good opportunities to adapt to this change. Local coastal plans and EIA's can be used as drivers for climate change adaptation. In addition, the public domain of the ZMT and that large part of the coastline of the country is not developed or has experienced minimum urban development. This represents great

opportunities to plan the country's coastal development in accordance to a changing climate reality.

Costa Rica has good opportunities to reduce and adapt to the negative impacts of a changing climate; however, in order for this to happen the current pattern of coastal development will have to be changed. The current policies that have declared most of the Costa Rican coastline as suitable for tourism will also have to be changed. Tourism and urban development will have to be concentrated on the areas that are less vulnerable to a changing climate; larger setbacks will have to be required, and building codes and facilities will have to be modified.

Costa Rica has just been experiencing the early stages of the big changes that the climate is going to show in the future. We are at a critical point of history where decisions have to be made to reduce future damages and costs. If the strategies that were described in this research paper are implemented, the country will have a better chance to cope with the negative effects of climate change in coastal areas.

9. REFERENCES

- Agüero, M. 2013. AyA prevé que racionamientos de agua afectarán a más usuarios [AyA expects that water rationings will affect more users]. La Nación (San José) January 31. URL: http://www.nacion.com/2013-01-31/ElPais/AyA-preve-que-racionamientos-de-agua-afectaran-a-mas-usuarios.aspx [consulted 24 May 2013].

- Alpízar, E., Castro, G., Elizondo, L.H., Jiménez, Q., Rodríguez, E. and Vásquez, A. 2000. Estudios de Cambio Climático en Costa Rica. Componente Bosques. Vulnerabilidad de los Bosques Costarricenses al

Cambio Climático. Periodo de Predicción 1999-2030. In Instituto Meteorológico Nacional. Estudios de vulnerabilidad ante el cambio climático. Informe Final 2030 [Studies on Climate Change in Costa Rica. Forests Component. Vulnerability of Costa Rican Forests to Climate Change. Prediction Period 1999-2030. In National Meteorological Institute. Studies on vulnerability to climate change. Final Report 2030]. National Meteorological Agency, Ministry of the Environment and Energy 71-103. URL: http://cglobal.imn.ac.cr/sites/default/files/documentos/vulnerabilidad_en_bosques.pdf [consulted 24 May 2013].

- Alpízar, E. 2013. Análisis de la cobertura forestal, según la zonificación de los planes reguladores de Playa Hermosa de Carrillo y Junquillal de Santa Cruz, Guanacaste, Costa Rica. [Assessment of the forestry cover, according to the proposed land use in the local coastal plans of Hermosa-Bahia Azul and Junquillal-Avellanas, Guanacaste, Costa Rica]. Available from Edwin, Alpizar. San José, Costa Rica.

- Astorga, Y. 2013. Las Mujeres y el Agua. [Women and Water]. Paper read at the Lecture on Las Mujeres y el Agua, 10 April, at Costa Rican Congress, San José, San José, Costa Rica.

- Barbour, E., and Kueppers, L. 2008. *Conservation and Management of Ecological Systems in a Changing California*. California: Public Policy Institute of California.

- Brouder, S.M. and Volenec, J.J. 2008. Impact of climate change on crop nutrient and water use efficiencies. *Physiologia Plantarum* 133: 705–724.

- Caldwell, M. and Holt Segall, C. 2007. No Day at the Beach: Sea Level Rise, Ecosystem Loss, and Public Access Along the California Coast. *ECOLOGY LAW QUARTERLY* 34: 533-578.

- California Natural Resources Agency (CRNA) 2009. 2009 California Climate Adaptation Strategy. A Report to the Governor of the State of California in Response to Executive Order S-13-2008. URL: http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF . Consulted May 10, 2013.

- Carazo, E., Figueroa, A. and Penztke, C. 2012. *Cambio Climatico y Ecosistemas en Centroamerica: una oportunidad para la accion. Proyecto Estado de la Region* [Climate Change and Central American Ecosystems: an opportunity for action. State of the Region Project]. San José: Centro de Estudios y Publicaciones Alforja.

- Carranza, E. 2009. Problemas Graves en las Costas de Costa Rica [Serious Problems in Costa Rica's Coasts]. *Revista de Ciencias Juridicas* 120: 89-107.

- Celliers, L., Rosendo, S., Coetzee, I. and Daniels, G. 2013. Pathways of integrated coastal management from national policy to local implementation: Enabling climate change adaptation. *Marine Policy* 39: 72–86.

- Central American Commission for the Environment and Development (CCAD) and System for the Integration of Central America (SICA) 2010. *Estrategia Regional de Cambio Climatico. Documento Ejecutivo.* [Regional Strategy of Climate Change. Executive Document]. San Salvador: SICA.

- Chinchilla, L. 2013. Informe de Labores de Gobierno. Alocucion a la Asamblea Legislativa. 1 de mayo 2013. [Government Work Report. Speech to the Congress. May 1st 2013]. Report read to Costa Rica's Congress, 1st May, at the Congress of Costa Rica, San Jose, San Jose, Costa Rica. URL: http://www.presidencia.go.cr/index.php/112-slide-principal/2175-informe-de-labores-2012-2013 Consulted May 3, 2013.

- Contraloría General de la República 2004. Informe No. DFOE-AM-42/2004 [Report Number DFOE-AM-42/2004]. URL: http://www.cgr.go.cr/ [consulted 15 January 2009].

- Costanza, R., Arge, R. D., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. J., Sutton, P. and Van Den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253–260.

- Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S. and D'Agostino, J. 2006. *The Value of New Jersey's Ecosystem Services and Natural Capital*. Burlington: Gund Institute for Ecological Economics, Rubenstein School of Environment and Natural Resources, University of Vermont Burlington.

- Doran, P.T., Zimmerman, M.K. 2009. Examining the scientific consensus on climate change. *EOS. Transactions American Geophysical Union* 90: 22–23.

- Drews, C. and Fonseca, A. 2009. Increase in sea level due to climate change in Playa Grande, Parque Nacional Marino las Baulas, Costa Rica. Technical Report. WWF/Stereocarto, San Jose, Costa Rica. URL: http://awsassets.panda.org/downloads/aumento_del_nivel_del_mar_por_cambio_climatico_en_playa_grande.pdf [consulted 23 November 2012].

- Driscoll, D.A., Felton, A., Gibbons, P., Felton, A.M., Munro, N.T. and Lindenmayer, D.B. 2012. Priorities in policy and management when existing biodiversity stressors interact with climate-change. *Climatic Change* 111: 533–557.

- Economic Commission for Latin America and the Caribbean (ECLAC), United Kingdom Department for International Development (UKaid), Central American Commission for the Environment and Development (CCAD) and System for the Integration of Central America (SICA) 2010. *The Economics of Climate Change in Central America: Summary 2010*. Mexico City: FOC S.A. de C.V.

- Fish, M.R., Cote´, I.M., Horrocks, J.A., Mulligan, B., Watkinson, A.R., and Jones, A.P. 2008. Construction setback regulations and sea-level rise:

Mitigating sea turtle nesting beach loss. *Ocean & Coastal Management* 51: 330-341.

- Fonseca, A. 2010. Marine Turtles and Communities Adaptation to Climate Change in Junquillal. In *Case study on a project of the World Wildlife Fund*. Ed. Gregg, R. M. URL: http://www.cakex.org/case-studies/2696 [consulted 15 April 2013].

- _____. 2012. Informe Final. Gestion Marino Costera. Decimoctavo Informe Estado de la Nación en Desarrollo Humano Sostenible [Final Report. Marine and Coastal Management. Eighteenth State of the Nation Report in Sustainable Human Development]. San José: Programa Estado de la Nación. URL: http://www.estadonacion.or.cr/images/stories/informes/018/ponencias/Armonia/PDF/Fonseca%2C%20A.%202012.%20Gestion%20marino%20costera.pdf. Consulted: November 29, 2012.

- Fuentes, M., Limpus, C.J. and Hamann, M., 2011. Vulnerability of sea turtle nesting grounds to climate change. *Global Change Biology* 17: 140–153.

- Gallardo, R. 2013. Desafíos y oportunidades para la gestión del riesgo y la adaptación al cambio climático en el futuro [Challenges and opportunities for risk management and climate change adaptation in the future]. Paper read at the lecture Desafíos y oportunidades para la gestión del riesgo y la adaptación al cambio climático en el futuro, 18th April, at FLACSO, Curridabat, San Jose, Costa Rica.

- Girot, P. 2013. Desafíos y oportunidades para la gestión del riesgo y la adaptación al cambio climático en el futuro [Challenges and opportunities for risk management and climate change adaptation in the future]. Paper read at the lecture Desafíos y oportunidades para la gestión del riesgo y la adaptación al cambio climático en el future, 18th April, at FLACSO, Curridabat, San Jose, Costa Rica.

- Gonzalez, C. and Vilaboa, R. 2010. Informe Final de Investigacion. Tendencias del Desarrollo en el Canton de Santa Cruz, Guanacaste. Periodo 1979-2009 [Final research report. Development trends in Santa Cruz County, Guanacaste. 1979-2009 period]. San José: UNED. URL: http://web.uned.ac.cr/ifcmdl/attachments/article/213/CONTENIDO.pdf [consulted 23 January 2013].

- Green, R., Harley, M., Miles, L., Schliemann, J., Watkinson, A. and Watts, O. 2003. *Global Climate Change and Biodiversity. Summary of papers and discussion*. Bedfordshire: The RSPB, UK Headquarters. URL: http://jncc.defra.gov.uk/pdf/MJHGlobalclimatechange_14.08.03.pdf [consulted 24 May 2013].

- Groves, C.R., Game, E.T., Anderson, M.G., Cross, M. Enquist, C., Ferdañ a, Z., Girvetz, E., Gondor, A., Hall, K.R., Higgins, J., Marshall, R., Popper, K., Schill, S. and Shafer, S.L. 2012. Incorporating climate change into

systematic conservation planning. *Biodiversity Conservation* 21: 1651–1671.

- Government of Costa Rica (Costa Rica) 2000. Primera Comunicacion a la Convencion Marco de las Naciones Unidas sobre Cambio Climatico [First Response to the United Nations Framework Convention on Climate Change]. URL: http://cglobal.imn.ac.cr/ [consulted 1 December 2012].

- Hanak, E. and Moreno, G. 2012. California coastal management with a changing climate. *Climatic Change* 111: 45–73.

- Harley, C.D.G., Hughes, A.R., Hultgren, K.M., Miner, B.G., Sorte, C.J.B., Thornber, C.S., Rodriguez, L.F., Tomanek, L. and Williams, S. L. 2006. The impacts of climate change in coastal marine systems. *Ecology Letters* 9: 228–241.

- Hawkins, B., Sharrock, S. and Havens, K. 2008. *Plants and climate change: which future?* Richmond, UK: Botanic Gardens Conservation International.

- Heller, N. and Zavaleta, E. 2009. Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation* 142: 14-32.

- Herrera, L. M. 2012. Puntarenas necesita rompeolas para repeler la invasion del mar [Puntarenas needs a seawall to stop the sea invasion]. La Nación (San José) December 23. URL: http://www.nacion.com/2012-12-23/ElPais/Puntarenas-necesita-rompeolas-para-repeler--invasion--del-mar.aspx. [consulted 24 May 2013].

- Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A. and Hatziolos, M.E. 2007. Coral Reefs Under Rapid Climate Change and Ocean Acidification. *Science* 318: 1737-1742.

- Hoskins, B.J., Joos, F., Jouzel, J., Kattsov, V., Lohmann, U., Matsuno, T., Molina, M., Nicholls, N., Overpeck, J., Raga, G., Ramaswamy, V., Ren, J., Rusticucci, M., Somerville, R., Stocker, T.F., Whetton, P., Wood, R.A. and Wratt, D. (IPCC) 2007: Technical Summary. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

- Hulin, V., Delmas, V., Girondot, M., Godfrey, M.H. and Guillon, J.M. 2009. Temperature-dependent sex determination and global change: are some species at greater risk? *Oecologia*160: 493–506.

- Instituto Costarricense de Turismo (ICT) 2010. *Anuario Estadístico ICT* [ICT Statistical Yearbook]. ICT. San José, Costa Rica. URL:

http://www.visitcostarica.com/ict/backoffice/treeDoc/files/6F96_Anuario_de_Turismo_2010.pdf [consulted 24 May 2013].

- _____ 2011a. Junquillal-Avellanas, Santa Cruz, Guanacaste. Comprehensive coastal plan proposal. February, 2011. URL: http://www.visitcostarica.com/ict/paginas/modEst/estudios_zona_maritimo_terrestre.asp?ididioma=1 [consulted 24 May 2013].

- _____ 2011b. Playa Hermosa-El Coco-Bahia Azul, Carrillo, Guanacaste. Comprehensive coastal plan proposal. February, 2011. URL: http://www.visitcostarica.com/ict/paginas/modEst/estudios_zona_maritimo_terrestre.asp?ididioma=1 [consulted 24 May 2013].

- Iglesias, A., Garrote, L., Quiroga, S. and Moneo, M. 2009. Impacts of climate change in agriculture in Europe. PESETA-Agriculture study. Luxembourg: Office for Official Publications of the European Communities. URL: http://ftp.jrc.es/EURdoc/JRC55386.pdf [consulted 24 May 2013].

- Instituto Nacional de Biodiversidad (INBIO) 2009. Proyecto 0033342. Segunda Comunicacion Nacional a la Convencion Marco de las Naciones Unidas sobre Cambio Climatico.IMN-PNUD-GEF. Biodiversidad y Cambio Climatico en Costa Rica. Informe Final [Project 0033342. Second National Response to the United Nations Framework Convention on Climate Change. IMN-PNUD-GEF. Biodiversity and Climate Change in Costa Rica. Final Report]. URL: http://cglobal.imn.ac.cr/ [consulted 30 November 2012].

- Intergovernmental Panel on Climate Change (IPCC) 2001. *Climate Change 2001, Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

- Intergovernmental Panel on Climate Change (IPCC) 2007a. Climate Change 2007: Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

- Jimenez, R., Amit, R. and Vindas, R. 2011. Politicas de Cambio Climatico en Costa Rica, integrando esfuerzos para asumir los retos. Vicerrectoria de Investigacion. UNED [Climate change policies in Costa Rica. Uniting efforts to tackle the challenges. San José: UNED]. URL: http://investiga.uned.ac.cr/cicde/index.php/informes/37-cambioclimatico [consulted 24 May 2013].

- Klausmeyer, K.R. and Shaw, M.R. 2009. Climate Change, Habitat Loss, Protected Areas and the Climate Adaptation Potential of Species in Mediterranean Ecosystems Worldwide. *PLoS ONE* 4 (7).

- Klein, R.J.T. and Nicholls, R.J. 1999. Assessment of Coastal Vulnerability to Climate Change. *Ambio* 28 (2): 182-187.

- Klein, R.J.T., Nicholls, R.J. and Nobuo, A. M. 1999b. Coastal Adaptation to

Climate Change: Can the IPCC Technical Guidelines be applied? *Mitigation and Adaptation Strategies for Global Change* 4 (3-4): 239-252.

- Klein, R.J.T., Nicholls, R.J., Ragoonaden, S., Capobianco, M., Aston, J. and Buckleye, E.N. 2001. Technological Options for Adaptation to Climate Change in Coastal Zones. *Journal of Coastal Research* 17 (3): 531-543.

- The Leatherback Trust 2003. Playa Grande under threat. URL: http://playagrandeinfo.org/pages/threat.htm. [consulted 2 December 2012].

- Lizano, O. 2011. Erosion en las costas de Costa Rica [Erosion along Costa Rican coasts]. Published in Modulo de Informacion Geografica. URL: http://www.miocimar.ucr.ac.cr/erosioncostarica [consulted 18 February 2013].

- Lizano, O. and Salas, D. 2001. Variaciones geomorfológicas en los últimos 50 años de la Isla Damas, Quepos, Costa Rica [Geomorphological Variations in the last 50 years of Damas Island, Quepos, Costa Rica]. *Biologia Tropical* 49 (2): 171-177.

- Malavassi, E. 2008. Cambios geoformológicos en el litoral Caribe y Pacífico de Costa Rica. Caso del Complejo Déltico de Sierpe [Geomorphological Changes on Costa Rica's Caribbean and Pacific Coastline]. *Kurú: Revista Forestal* 5 (15): 1-10.

- Mastrandrea, M.D. and Luers, A.M. 2012. Climate change in California: scenarios and approaches for adaptation. *Climatic Change* 111: 5–16.

- Mawdsley, J.R., O'Malley, R. and Ojima, D.S. 2009. A Review of Climate-Change Adaptation Strategies for Wildlife Management and Biodiversity Conservation. *Conservation Biology* 23: 1080–1089.

- McGinnis, M.V., Su, W., Willsey, A. and Tiegs, J. 2009. *Developing Adaptive Policy to Climate Disturbance in Santa Barbara County.* Santa Barbara: Ocean and Coastal Policy Center, UC Santa Barbara.

- McGinnis, M.V. and McGinnis, C.E. 2011. Adapting to Climate Change Impacts in California: The Importance of Civic Science in Local Coastal Planning. *Coastal Management* 39 (3): 225-241.

- McGinnis, M.V. 2013. Introduction to Coastal Sustainability. Lecture given in the course "Sustainable Coastal Management", Monterey Institute of International Studies, California, United States of America.

- Ministerio del Ambiente, Energia y Telecomunicaciones (MINAET), Instituto Meteorologico Nacional (IMN), Coastal Zone Management Centre and Comite Regional de Recursos Hidraulicos 2000. Estudios de Cambio Climatico en Costa Rica. Componente Recursos Costeros. Evaluacion de la Vulnerabilidad de los Recursos Costeros al Cambio Climatico [Studies of Climate Change in Costa Rica. Coastal Resources Component. Valuation of Coastal Resources

to Climate Change]. San Jose, Costa Rica. URL: http://cglobal.imn.ac.cr/ [consulted 26 November 2012].

- Ministerio de Ambiente, Energia y Telecomunicaciones (MINAET) 2009. Estrategia Nacional de Cambio Climatico [National Strategy of Climate Change]. URL: http://www.minaet.go.cr/dcc/index.php/biblioteca-virtual/cat_view/2-publicaciones-sobre-cambio-climatico. [consulted 1 December 2012].

- Ministerio del Ambiente, Energia y Telecomunicaciones (MINAET), Instituto Meteorologico Nacional (IMN) and Proyecto de las Naciones Unidas para el Desarrollo (PNUD) 2011. Analisis del Riesgo Actual del Sector Hidrico de Costa Rica ante el Cambio Climatico [Analysis of the Costa Rican Water Sector Current Risk under Climate Change]. URL: http://cglobal.imn.ac.cr/ [consulted 28 November 2012].

- Ministerio del Ambiente, Energia y Telecomunicaciones (MINAET), Direccion de Cambio Climatico (DCC) and INCAE Business School 2012a. Costa Rica. Evaluación de Necesidades Tecnológicas ante el Cambio Climático (Technology Needs Assessment). Informe Final sobre Tecnologías en Adaptación [Costa Rica. Technology Needs Assesment under Climate Change. Final Report on Adaptation Technologies]. URL: http://www.minaet.go.cr/dcc/index.php/biblioteca-virtual/cat_view/2-publicaciones-sobre-cambio-climatico [consulted 1 December 2012].

- Ministerio del Ambiente, Energia y Telecomunicaciones (MINAET), Instituto Meteorologico Nacional (IMN) and Proyecto de las Naciones Unidas para el Desarrollo (PNUD) 2012b. Informe Final. Mejoramiento de las capacidades nacionales para la evaluación de la vulnerabilidad y adaptación del sistema hídrico al cambio climático en Costa Rica, como mecanismo para disminuir el riesgo al cambio climático y aumentar el Índice de Desarrollo Humano [Final Report: Improvement of the national capacities for the evaluation of the vulnerability and adaptation of the water system to climate change in Costa Rica, as a mechanism to diminish the risk of climate change and to increase the Human Development Index]. URL:http://cglobal.imn.ac.cr/documentos/informe-final-adaptacion-del-recurso-hidrico-al-cambio-climatico-en-costa-rica [consuted 26 November 2012].

- Moore, S., Zavaleta, E. and Shaw, R. 2012. *Decision Making Under Uncertainty: An Assessment of Adaptation Strategies and Scenario Development for Resource Managers*. California: California Energy Commission. Publication number: CEC 500 2012 027.

- Moser, S.C. and Ekstrom, J. 2012. *Developing Adaptation Strategies for San Luis Obispo County: Preliminary Climate Change Vulnerability Assessment for Social Systems.* California: California Energy Commission. Publication number: CEC-500-2012-054.

- Nicholls, R.J. and Klein, R.J.T. 2005. Climate change and coastal management on Europe's Coast. In *Managing European Coasts: Past, Present, and Future,* ed. Vermaat, J.E. *et al*., 199–225. Heidelber, Berlin, Springer-Verlag.

- Nicholls, R.J., Wong, P.P., Burkett, V.R., Codignotto, J.O., Hay, J.E., McLean, R.F., Ragoonaden S. and Woodroffe, C.D. (IPCC) 2007b. *Coastal systems and low-lying areas. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (eds.)]. Cambridge, UK: Cambridge University Press.

- Nicholls, R. J., Woodroofe, C., and Burkett, V. 2009. Chapter 24: Coastline Degradation as an Indicator of Global Change. In *Climate Change: Observed Impacts on Planet Earth*. Published by Elsevier B.V.

- Organisation for Economic Co-operation and Development (OECD) n.d.. Using The Pressure-State-Response Model To Develop Indicators of Sustainability. OECD Framework for Environmental Indicators. OECD Environment Directorate – State of the Environment Division. URL: https://www.google.com/search?q=-+OECD+(no+date).+Using+The+Pressure-State-Response+Model+To+Develop+Indicators+of+Sustainability.+OECD+Framework+for+Environmental+Indicators.&oq=-+OECD+(no+date).+Using+The+Pressure-State-Response+Model+To+Develop+Indicators+of+Sustainability.+OECD+Framework+for+Environmental+Indicators.&aqs=chrome.0.57.842j0&sourceid=chrome&ie=UTF-8 [consulted 24 May 2013].

- Pelling, M. 2013. Desafíos y oportunidades para la gestión del riesgo y la adaptación al cambio climático en el futuro [Challenges and opportunities for risk management and climate change adaptation in the future]. Paper read at the lecture "Desafíos y oportunidades para la gestión del riesgo y la adaptación al cambio climático en el futuro", 18th April, at FLACSO, Curridabat, San Jose, Costa Rica.

- Poloczanska, E.S., Limpus, C.J. and Hays, G.C. 2009. Chapter 2. Vulnerability of Marine Turtles to Climate Change. In *Advances in Marine Biology* 56: 151-211. doi: 10.1016/S0065-2881(09)56002-6

- Pounds, A.J., Fogdon, M.P.L., Cambell, J.H. 1999. Biological response to climate change on a tropical mountain. *Nature* 398: 611–615.

- Programa de Investigacion en Desarrollo Humano Sostenible (ProDus) 2012. Informe Final. Estudio para la identificación y priorización de medidas de adaptación del sistema hídrico ante los efectos adversos del Cambio Climatico en Costa Rica [Final Report. Assessment for the identification and prioritization of adaptation measures for the water system against the negative impacts of Climate Change in Costa Rica]. URL:

http://cglobal.imn.ac.cr/ [consulted 2 December 2012].

- Programa Estado de la Nación 2012. *Decimoctavo Informe Estado de la Nación en Desarrollo Humano Sostenible. Capitulo 4: Armonia con la Naturaleza.* [Eighteen Report of the State of the Nation on Sustainable Human Development. Chapter 4. Harmony with Nature]. San José: Programa Estado de la Nación. URL: http://www.estadonacion.or.cr/index.php/biblioteca-virtual/costa-rica/estado-de-la-nacion/informe-actual/informe-por-capitulo/armonia [consulted 27 November 2012].

- Quevauviller, P. 2011. Adapting to climate change: reducing water-related risks in Europe – EU policy and research considerations. *Environmental Science & Policy* 14 (7): 722-729.

- Revi, A. 2013. Desafíos y oportunidades para la gestión del riesgo y la adaptación al cambio climático en el futuro [Challenges and opportunities for risk management and climate change adaptation in the future]. Paper read at the lecture Desafíos y oportunidades para la gestión del riesgo y la adaptación al cambio climático en el future, 18th April, at FLACSO, Curridabat, San Jose, Costa Rica.

- Rodríguez, M. 2011. Conservando los Recursos Marinos en Costa Rica: Áreas Marinas Protegidas y Otras Figuras de Aprovechamiento Sostenible [Preserving the Marine Resources in Costa Rica: Marine Protected Areas and Other Figures of Sustainable Use] *Revista Parques* (1).

- Roman, M. 2007. Decimo Tercer Informe Sobre el Estado de la Nación en Desarrollo Humano Sostenible. Informe Final. Desarrollo turístico e inmobiliario costero y preocupaciones ambientales. [Thirteen Report on the State of the Nation in Sustainable Human Development. Tourism and Real State Development, Environmental Concerns]. San José: Programa Estado de la Nación. URL: http://unpan1.un.org/intradoc/groups/public/documents/icap/unpan030197.pdf [consulted 19 February 2013].

- Santidrián, T.P., Saba, V.S., Blanco, G.S., Stock, C.A., Paladino, F.V. 2012. Climate Driven Egg and Hatchling Mortality Threatens Survival of Eastern Pacific Leatherback Turtles. *PLoS ONE* 7(5).

- Scavia, D., Field, J., Boesch, D., Buddemeier, R., Burkett, V., Cayan, D., Fogarty, M., Harwell, M., Howarth, R., Mason, C., Reed, D., Royer, T., Sallenger, A. and Titus, J. 2002. Climate Change Impacts on U.S. Coastal and Marine Ecosystems. *Estuaries* 25 (2): 149–164.

- Schatan, C., Montiel, M. and Romero, I. 2010. Climate change and challenges for tourism in Central America. In *CEPAL - Serie Estudios y perspectivas - México - 123*. México, D. F.: Printed in United Nations, http://www.eclac.org/publicaciones/xml/7/42267/2010-075-Serie_123-L952-R2-ClimateChange-Tourism-EN.pdf [consulted 24 May 2013].

- Sistema Nacional de Áreas de Conservación (SINAC) 2008. *GRUAS II: Propuesta de Ordenamiento Territorial para la conservación de la biodiversidad de Costa Rica. Volumen 3: Análisis de Vacíos en la Representatividad e Integridad de la biodiversidad marina y costera* [National conservation area system (SINAC) of the Ministry of the Environment, Energy and Telecommunications (MINAET). 2008. GRUAS II: land management proposal for the conservation of biodiversity in Costa Rica. Volume 3: Analysis of gaps in the representativity and integrity of marine and coastal biodiversity]. San José, Costa Rica: Asociación Conservación de la Naturaleza. URL: http://www.google.co.cr/#output=search&sclient=psy-ab&q=-+Sistema+Nacional+de+Áreas+de+Conservación+(SINAC)+2008.+GRUAS+II:+Propuesta+de+Ordenamiento+Territorial+para+la+conservación+de+la+biodiversidad+de+Costa+Rica.+Volumen+3%3A+Análisis+de+Vac%C3%ADos+en+la+Representatividad+e+Integridad+de+la+biodiversidad+marina+y+costera+&oq=-+Sistema+Nacional+de+Áreas+de+Conservación+(SINAC)+2008.+GRUAS+II:+Propuesta+de+Ordenamiento+Territorial+para+la+conservación+de+la+biodiversidad+de+Costa+Rica.+Volumen+3%3A+Análisis+de+Vac%C3%ADos+en+la+Representatividad+e+Integridad+de+la+biodiversidad+marina+y+costera+&gs_l=hp.3...13296.13296.0.13883.1.1.0.0.0.0.0.0..0.0...0.1...1c.1.14.psy-ab.Sg2u1QyG6jY&pbx=1&bav=on.2,or.r_qf.&bvm=bv.47008514,d.eWU&fp=3fda62a05e87c05e&biw=1279&bih=628 [consulted 24 May 2013].

- Sistema Nacional de Áreas de Conservación (SINAC) 2012. Sistema Nacional de Areas Protegidas Website [national protected area system]. Available at the URL: http://www.sinac.go.cr/planificacionasp.php [consulted 10 March 2012].

- Solomon, S., Qin, D., Manning, M., Alley, R.B., Berntsen, T., Bindoff, N.L., Chen, Z., Chidthaisong, A., Gregory, J.M., Hegerl, G.C., Heimann, M., Hewitson, B., Hoskins, B.J., Joos, F., Jouzel, J., Kattsov, V., Lohmann, U., Matsuno, T., Molina, M., Nicholls, N., Overpeck, J., Raga, G., Ramaswamy, V., Ren, J., Rusticucci, M., Somerville, R., Stocker, T.F., Whetton, P., Wood, R.A. and Wratt, D. (IPCC) 2007c. *Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L. (eds.)]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

- Stern, N. 2007. *The economics of climate change: the Stern review*. Cambridge, Cambridge University Press.

- Thomas, C.D., Cameron, A. and Green, R.E. 2004. Extinction risk from climate change. *Nature* 427: 145–148.

- Tribbia, J. and Moser, S.C. 2008. More than information: what coastal managers need to plan for climate change. *Environmental Science and Policy*

11 (4): 315-328.

- United Nations, Comisión Económica para América Latina y el Caribe (CEPAL), Gobierno de España and Universidad de Cantabria 2011. *Efectos del Cambio Climatico en la Costa de America Latina y el Caribe. Dinámicas, tendencias y variabilidad climatica* [Effects of Climate Change in Latin America and the Caribbean Coastline. Dynamics, trends and climatic variability]. Santiago, Chile: United Nations Press.

- United Nations, Comisión Económica para América Latina y el Caribe (CEPAL), Gobierno de España and Universidad de Cantabria 2012. *Efectos del Cambio Climático en la Costa de América Latina y el Caribe. Vulnerabililidad y Exposición.* [Effects of Climate Change in Latin America and the Caribbean Coastline. Vulnerability and Exposure]. Santiago, Chile: United Nations Press.

- World Bank Group 2011. Climate Risk and Adaptation Country Profile. Vulnerability, Risk Reduction, and Adaptation to Climate Change. Costa Rica. Washington, DC: THE WORLD BANK GROUP. URL: http://sdwebx.worldbank.org/climateportalb/doc/GFDRRCountryProfiles/wb_gfdrr_climate_change_country_profile_for_CRI.pdf [consulted 24 May 2013].

- World Bank 2012. *Turn down the heat. Why a 4 Degrees Warmer World Should be Avoided.* Washington DC: THE WORLD BANK GROUP. URL: http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf [consulted 26 November 2012].

- WWF 2006. *Sea Level Rise*. URL: http://www.panda.org/about_wwf/what_we_do/climate_change/problems/impacts/sea_lev els/index.cfm. Consulted17 February 2008. Cited in Hawkins, B., Sharrock, S. and Havens, K. 2008. *Plants and climate change: which future?* Richmond, UK: Botanic Gardens Conservation International.

Laws and Decrees

- Ley de Aguas [Waters Law] 1942. *See* Costa Rica. Law number 276 of 1942.

- Ley de Biodiversidad [Biodiversity Law]. *See* Costa Rica. Law number 7788 of 1998

- Ley Forestal de Costa Rica [Forestry Law of Costa Rica] 1996. *See* Costa Rica. Law number 7575 of 1996.

- Ley de la Zona Marítimo Terrestre [Maritime and Terrestrial Zone Law] 1976. *See* Costa Rica. Law Number 6043 of 1976.

- Ley Nacional de Emergencias y Prevención del Riesgo. [National Law of Emergencies and Risk Reduction]. See Costa Rica. Law number 8488 of 2006.

- Ley Orgánica del Ambiente [Organic Law of the Environment] 1995. *See* Costa Rica. Law Number 7575 of 1995.

- Ley de Planificación Urbana [Urban Planning Law] 1968. *See* Costa Rica. Law number 4240 of 1968.

- Manual para la elaboración de planes reguladores costeros [Manual for the preparation of local coastal plans] 2013. Digital addendum number 58. La Gaceta official bulletin. 2 April 2013.

- Instituto Costarricense de Turismo (ICT), Centro Internacional de Política Económica para el Desarrollo Sostenible (CINPE) and Universidad Nacional (UNA) 2009. Manual para la gestión de Planes Reguladores Costeros [Manual for the management of local coastal plans]. San José, Costa Rica: ICT.

- Política Nacional de Ordenamiento Territorial [National Policy for Terrestrial Planning]. *See* Costa Rica. Decree number 37623- PLAN-MINAET-MIVAH.

- Procedimiento para la Introducción de la Variable Ambiental en los Planes Reguladores u Otros Instrumentos de Planificación [Procedure for the Introduction of the Environmental Variable in the Local Plans or Other Land Use Planning Instruments] 2011. *See* Costa Rica. Decree number 32967-MINAE.

Interviews

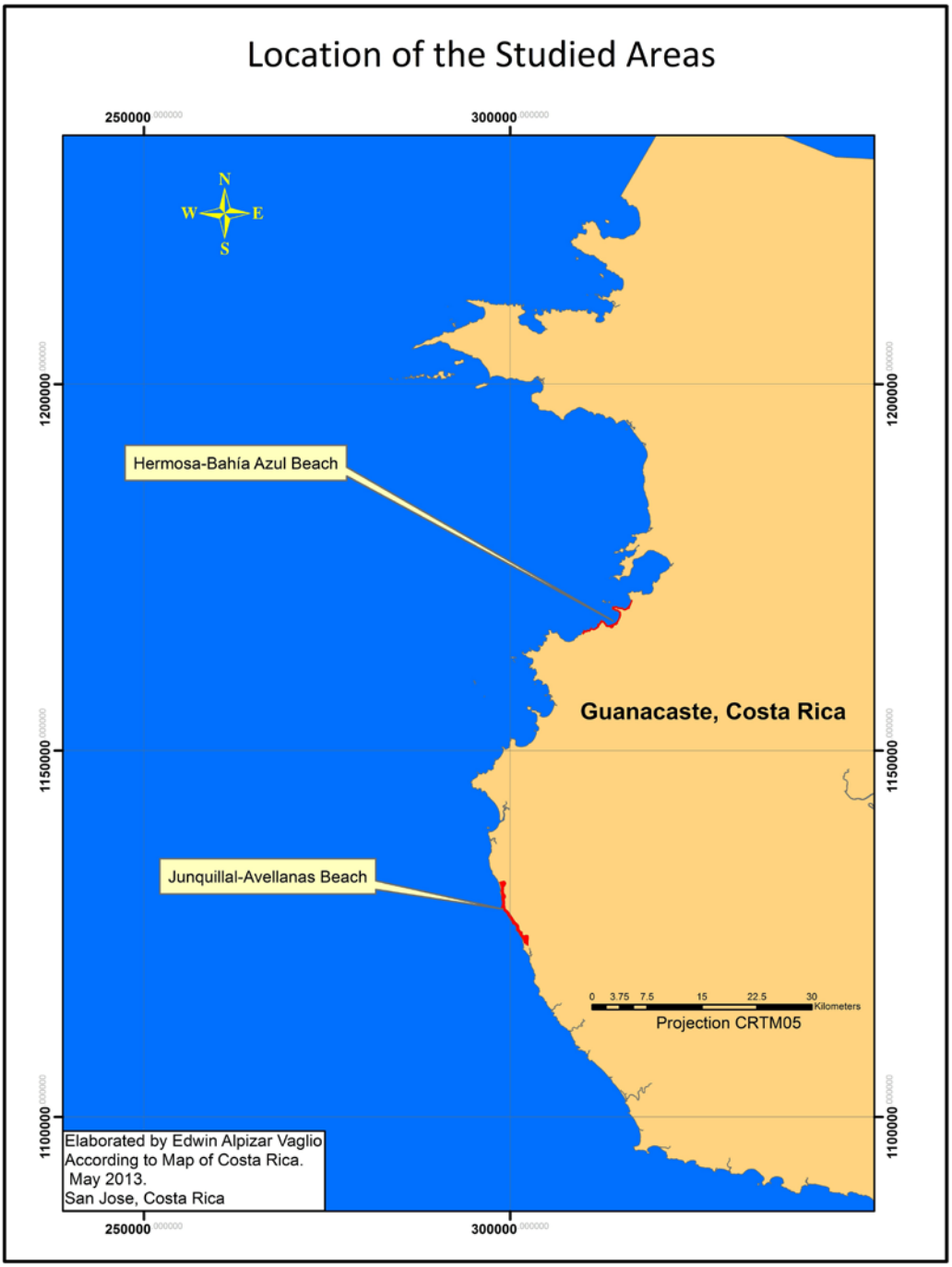
- Cuadrado, Gabriela. Lawyer expert in water issues. Former lawyer of CEDARENA. PHD candidate of the University of New South Wales. Skype Interview. San Jose, 22 April 2013.

- Francia, Gabriel. Biologist. Director of VerdiAzul NGO. Formal Interview. Junquillal, 3 April 2013.

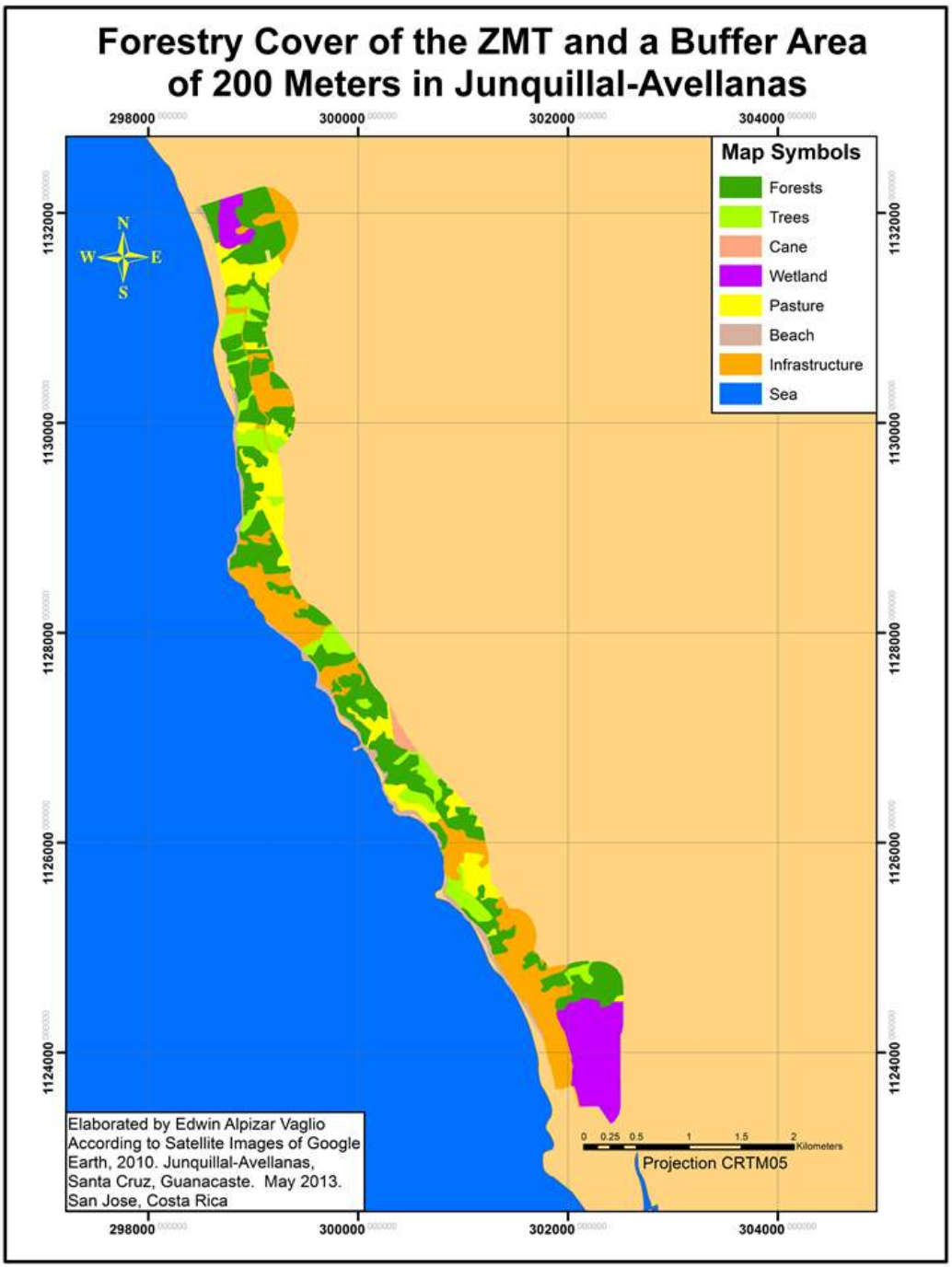
- Ortiz, Edwin. Technical Inspector of the Maritime and Terrestrial Zone Department of the Municipality of Santa Cruz. Former head of the Maritime and Terrestrial Zone Department of the Municipality of Santa Cruz. Formal Interview. Santa Cruz, 3 April 2013.

- Diaz, Jorge. Head of the Maritime and Terrestrial Zone Department of the Municipality of Carrillo. Formal Interview. Filadelfia, 4 April 2013.

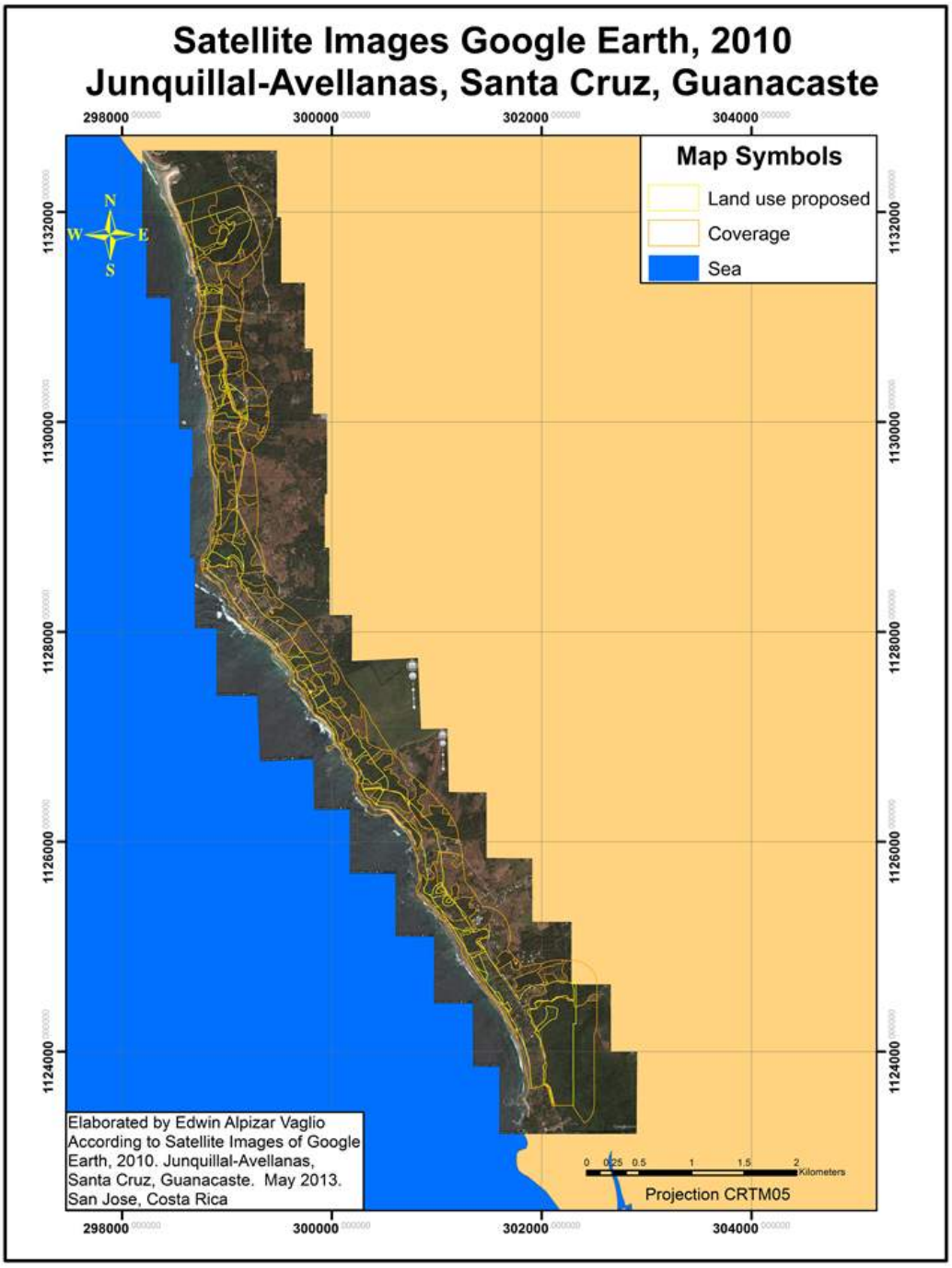
10. ANNEXES



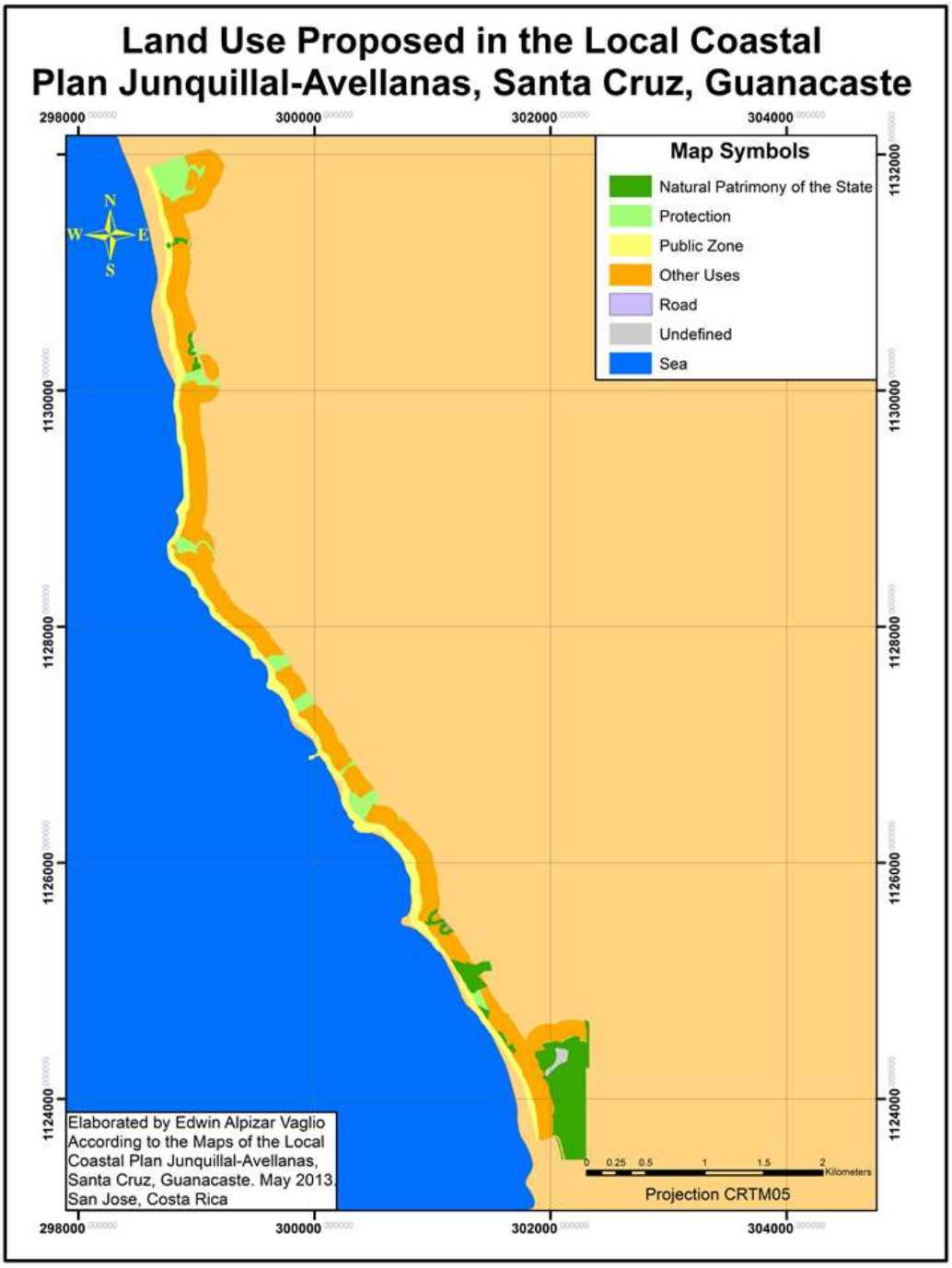
Annex 1. Location of Hermosa-Bahia Azul and Junquillal-Avellanas. Source: Alpízar 2013.



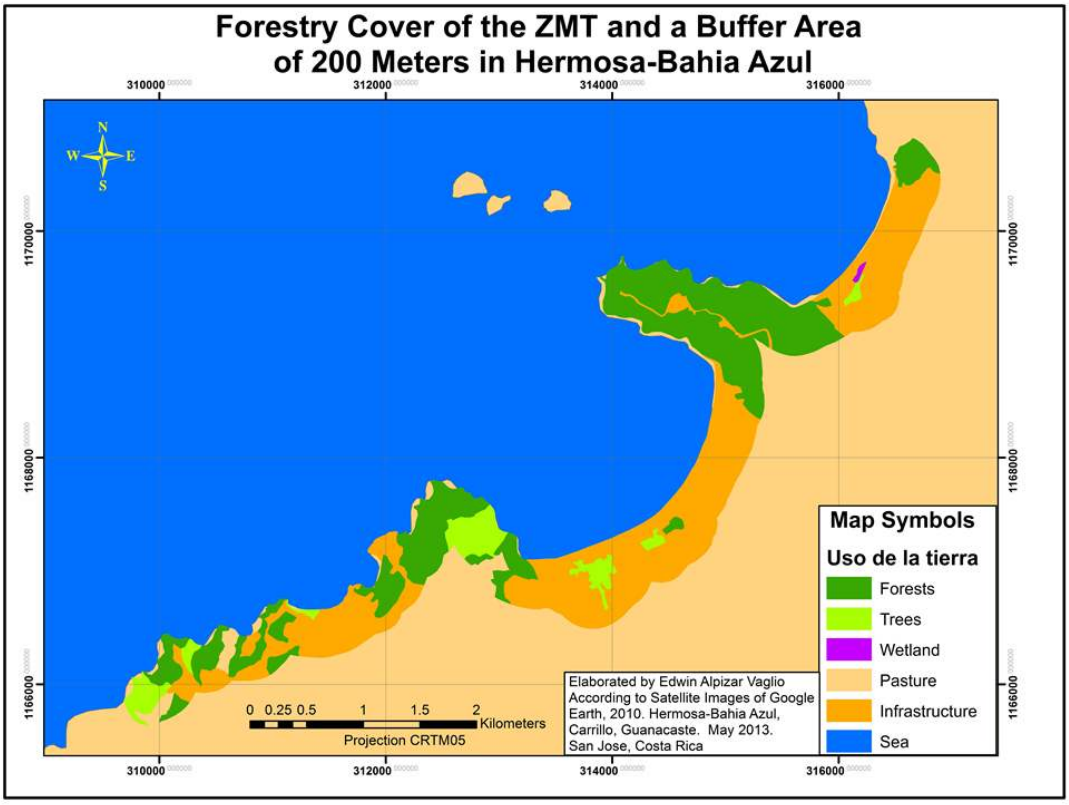
Annex 2. Forestry cover of Junquillal-Avellanas. Source: Alpízar 2013.



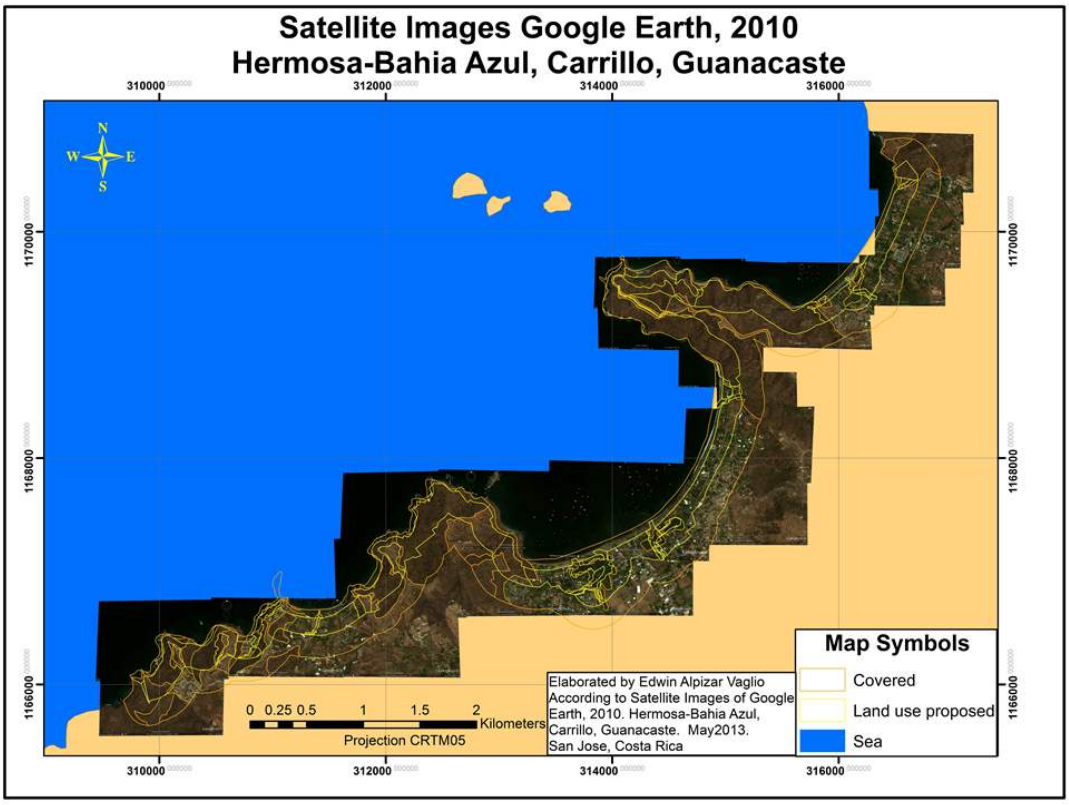
Annex 3. Satellite Images of Junquillal-Avellanas. Source: Alpízar 2013.



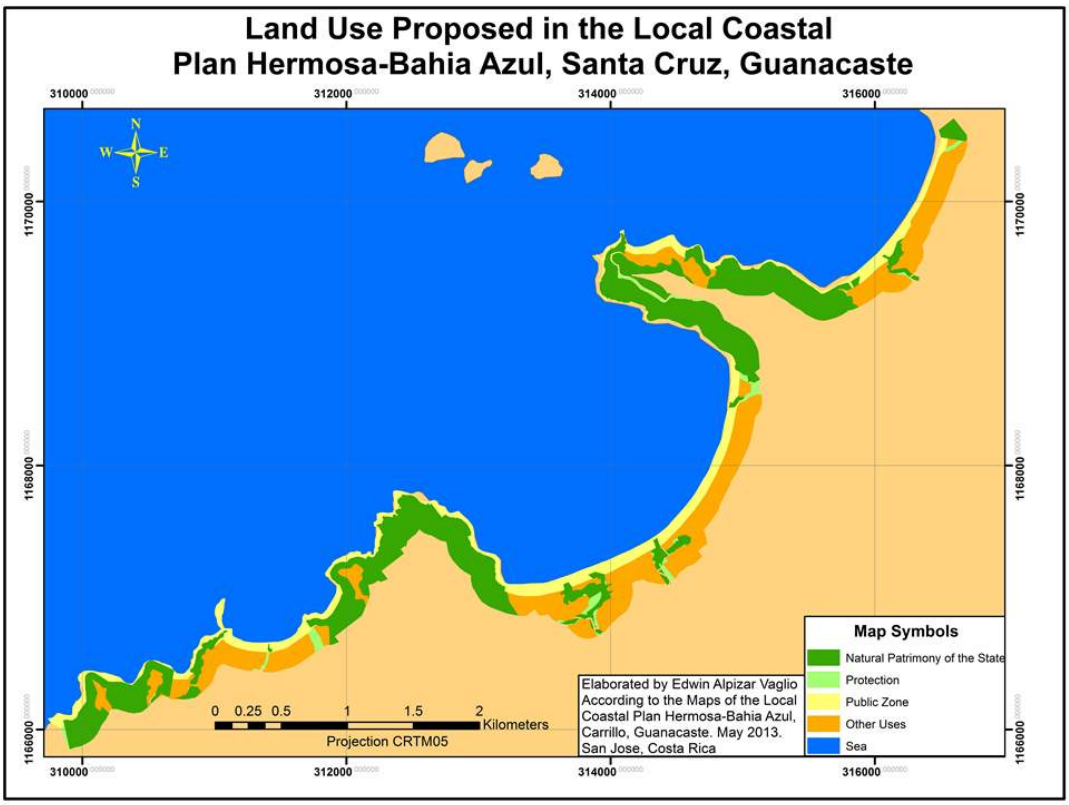
Annex 4. Land use proposed in Junquillal-Avellanas Local Coastal Plan. Source: Alpízar 2013.



Annex 5. Forestry cover of Hermosa-Bahia Azul. Source: Alpízar 2013.



Annex 6. Satellite Images of Hermosa-Bahia Azul. Source: Alpízar 2013.



Annex 7. Land use proposed in Hermosa-Bahia Azul Local Coastal Plan. Source: Alpízar 2013.