United Nations Educational, Scientific & Cultural Organization

Jeju Island Biosphere Reserve

Final Report of the Project on The Impact of Climate Change on Island and Coastal Biosphere Reserves

February, 2015

Jeju Secretariat
World Network of Island and Coastal Biosphere Reserves, UNESCO

Division of Ecological and Earth Sciences
Man and Biosphere Programme (MAB), UNESCO

Submitted to:

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February, 2015

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Chapter 1
Research Objectives

Since the 18th century, industrialization has given us material and cultural affluence, as well as many of the conveniences we now enjoy. Unfortunately, these benefits are achieved at enormous expense to nature, and produce worldwide environmental problems that threaten human existence. Humans are beneficiaries and victims of industrialization; a self-contradiction that lies between industrialization and the preservation of the environment.

The concept of environmental problem has three components; depletion of natural resources, pollution and/or destruction of the original quality of nature, and destruction of self-regulating system of nature (Jeong, 2004: 163-164). There are the two categories that classifies geological boundaries that are impacted from environmental problems; locally and globally. Local environmental problems are defined by the region that is impacted around the source of pollution and/or destruction, and global environmental problems are defined by a global level, regardless of the environmental problem source that has impacted the geographical region.

Global environmental problems include climate change, ozone depletion, acid rain, and desertification, etc. Due to its impact on both nature and human society, climate change is the most serious global environmental problem. Climate change is a coexisting mechanism; its impact on nature and human society is not independent, but reacts with one another simultaneously.

A wide range of strategies and policies responding to climate change have been established and implemented at a national, local, and global level. However, it is uncommon to establish and/or implement the strategy and/or policy for international protected areas, which includes Biosphere Reserve, World Natural Heritage, World Geopark, and Ramsar Wetland of International Importance, etc. Due to its unique ecosystem and geological features and its sensitivity to the change in the original state of environmental conditions, these areas require specific strategies and/or policies.

Even among worldwide internationally protected areas, ecological and geological features can differ.

Therefore, this research aims to establish strategies that respond to climate change for Island and Coastal Biosphere Reserves' conservation and sustainable use. Based on a global level of geological distribution, the Division of Ecological and Earth Sciences Man and Biosphere (MAB) Programme Natural Sciences Sector has designated these following five Island and Coastal Biosphere Reserves as research sites.

- o Jeju BR in South China Sea
- o Menorca BR in the Mediterranean
- o Macchabee-Bel Ombre BR in Indian Ocean
- o Príncipe Island BR in the Gulf of Guinea
- o St. Mary’s BR in Caribbean

The analysis of climate change impact on the Island and Coastal Biosphere Reserves is the prior prerequisite for establishing the strategies responding to climate change. Thus, two stages were composed for this research. The first stage is from March 2014 until February 2015. Its objective is to analyze the impact of climate change on the research sites. The second stage will be from March 2015 to February 2016 (provisionally to February, 2017), with an objective of establishing strategies in response to climate change based on the findings from the first stage of research.

This report is at the initial stage of research development. In order to achieve the research objectives, firstly, this research addressed the core socioeconomic, geological, and ecological characteristics of the five research sites. Secondly, the current state of climate change, the implementation of climate change policies, and the impact of climate change were analyzed. Finally, the similar and dissimilar vulnerable sectors to climate change within the five research sites were analyzed.

Chapter 2
Research Methodology

As stated in Chapter 1, the initial stage of this research covered five themes for achieving its objectives. Below are the methodologies employed for conducting each of the five themes.

1. Introduction to Core Socioeconomic, Ecological, and Geological Characteristics: This is an introductory chapter to help readers better understand not only about the five research sites, but also the logical and systematic linkage to (2), (3), (4), and (5).

The three core characteristics data were collected from existing publications. The core ecological and geological characteristics were gathered within the boundary of BR, while the socioeconomic characteristics were collected from the entire island where the research sites are located. In the case of Menorca BR, all three core characteristics data were collected from the entire island since the whole island is designated as a BR.

The items of core socioeconomic characteristics were focused on the number of population statistics, number of tourists, Gross Regional Domestic Product (GRDP), and industrial origin of GRDP. Time-serial data were collected from 1997 to 2012, during an interval of five years. With the exception of prescribed items, important and/or unique socioeconomic items were included in the data collection from the research site.

2. The Current State of Climate Change: The current state of climate change will differ by each island and BR's location. The different state will be used as the criteria to differentiate each BR's impact from climate change. Also it will be used to analyze the five research sites' similar and unique impacts of climate change. Data regarding the current state of climate change were collected from existing publications based on the entire island where each research site is located.

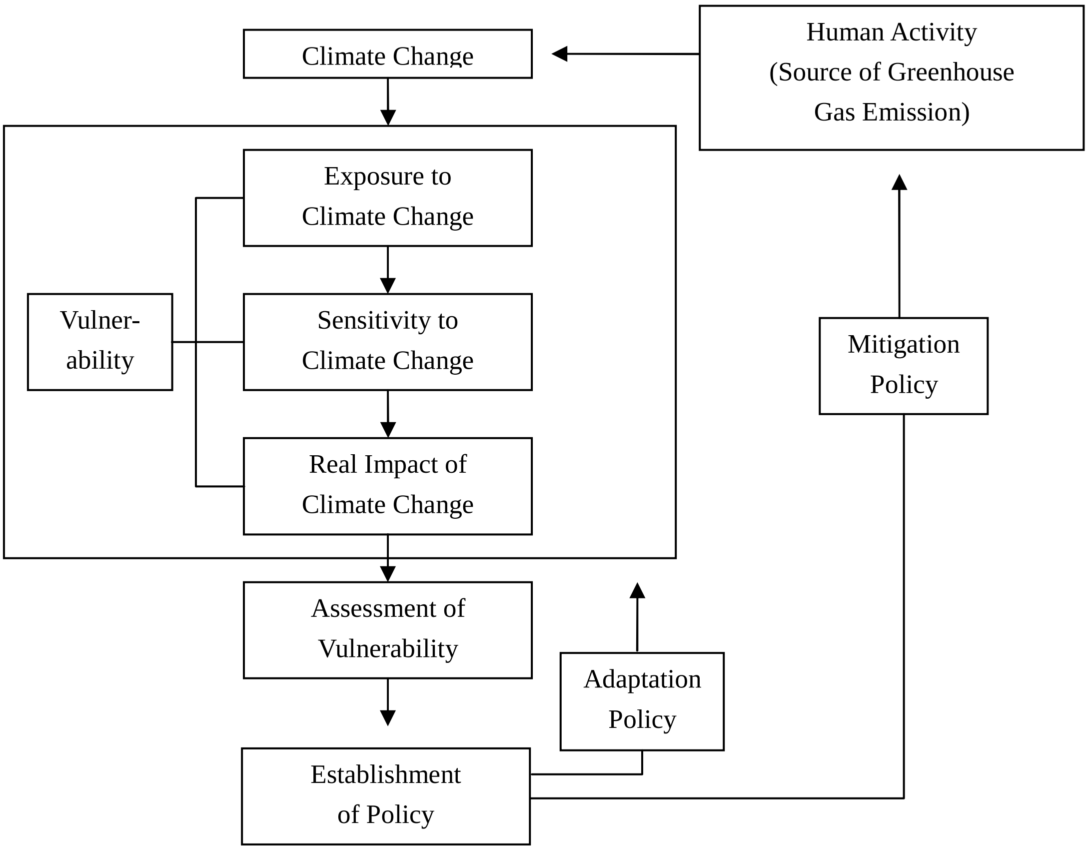
3. Analysis of the Climate Change Policies Being Implemented: Existing climate change policies that are implemented were collected for this research. In addition, its strategies and implications were examined in relation to the current state of climate change and its impact on the research sites.

Implementation of adaptation and mitigation policies throughout the entire island were collected within the research sites. If any, policies which were established but not yet implemented were also collected. Furthermore, its strategies and implications were also examined in relation to the current state of climate change and its impact on the research sites.

Prior to analyzing the established climate change policies, if available, time series of greenhouse gas emission data by sector were collected and interpreted.

4. Analysis of Climate Change Impact: Despite the five research sites' exposure to the same climate change, the real climate change impact is expected to differ. Each research site has different sensitivities to climate change and contributes to the different climate change impact, therefore, results in different vulnerabilities to climate change as an overall reality. The different vulnerabilities among the five research sites will appear by sector and the strength of climate change impact through different sensitivities to climate change.

Using <Figure 1>, vulnerable sectors to climate change at the five research sites were examined and analyzed.



<Figure 1> Analytic Diagram for Identifying Vulnerability to Climate Change

Even though the five research sites have the same vulnerable sectors, however, its climate change impact will be different. It is infeasible for this research to analyze the real impact of climate change on all vulnerable sectors, based on the diagram in <Figure 1>. This is caused by the limitation of the research period and budget. This is the reason why this research reviewed available existing publications on the impact of climate change at the research sites.

However, existing researches were not an overall analysis that included all vulnerable sectors, but were segmental research and were conducted with different depth of analysis. Existing segmental research on vulnerabilities to climate change, such as, decrease in biodiversity, change in habitat, endangered species, and invasion of exotic species, etc., were comprehensively combined in researching how climate change has impacted these research sites. Thus, vulnerable sectors and the intensity of climate change impact that is covered in this research were determined based on the availability of existing research.

The vulnerable sector target is not the whole island where each research site is located, but only the inner area of the research site. However, if socioeconomic activities, such as agricultural production and tourism are conducted in the transition areas at the research site, the climate change impact on socioeconomic sectors have been covered in this research. Meanwhile, in cases where the whole island is designated as a biosphere reserve, both environmental and socioeconomic sectors, such as biodiversity, forest, agriculture, fishery, water, and tourism, etc., were included in this research within the availability of existing publications.

5. Analysis of the Similar and Dissimilar Vulnerable Sectors to Climate Change among the Five Research Sites: The five research sites' analyses were conducted by extracting the similar and dissimilar sectors that are impacted by climate change. The similar vulnerable sectors refer to the commonality among the research sites, and the dissimilar vulnerable sectors refer to the distinctiveness of each research site.

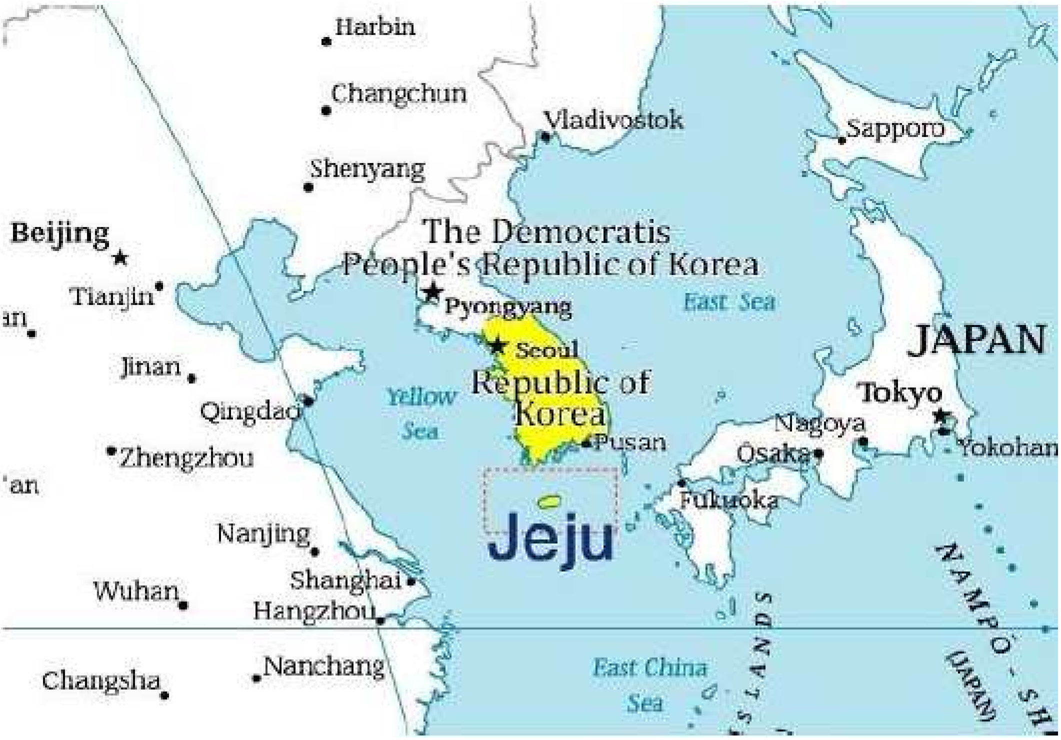
The extraction of similar and dissimilar vulnerable sectors was based on the findings from the analysis of climate change impacts that occurred in each research site. After the extraction, the following two additional detailed analyses were done on both similar and dissimilar vulnerable sectors. One was the analysis of the differences in the state of climate change impact among the similar and dissimilar vulnerable sectors, respectively. The other was the analysis of factors causing the differences among the similar and dissimilar vulnerable sectors, respectively.

The two detailed additional analyses were completed on the basis of three approaches diagramed in <Figure 1>. The first analysis was from the differences in the socioeconomic structure as the source of human-induced greenhouse gases emission in each research site. The second analysis was from the differences in the sensitivity to climate change. The third analysis was from the differences in existing strategies and/or policies responding to climate change.

Chapter 3
Introduction of the Research Sites

1. Jeju Island

South Korea is composed of nine provinces and six metropolitan cities. Jeju Island is a special self-governing province located in the southernmost part of the Korean peninsula (<Map 1>. It is 73km from east to west, 41km from south to north, and its total area is 1,847km^2, which is about 1.83% of South Korea.



<Map 1> Geographic Location of Jeju Island

In 2002, a total of 830.94km^2, which is about 45% of the island, was designated as a Biosphere Reserve site (<Map2). Jeju Island BR is composed of three areas; the core area covers 151.58km^2, the buffer zone, covers 146.01km^2 , and the transition area covers 533.358km^2 (JSSGP, 2012: 45).

<Map 2> Geographic Location of Jeju Island Biosphere Reserve

Conservation

With the participation of Jeju residents and community organizations, Below are the major acts being applied for the conservation of Jeju Island BR (JSSGP, 2005, 137-166).

o Core area:

- Designated as National Park by Natural Parks Act
- Designated as Seogwipo Provincial Marine Park
- Application of Cultural Heritage Protection Act

o Buffer zone:

- Designated as Conservative Mountainous District
- Management of Mountainous Districts Act
- Designated as Seogwipo Provincial Marine Park

o Transition area

- Zonation of Relative/Absolute Conservation in Land-use
- Management Plan of Environment Resources as a Whole

Sustainable Use

Using the designated 6 tracking paths in Mt. Hallasan National Park, hiking, visiting, rest area, and academic monitoring and research, etc., are permitted in the core area. Shiitake mushrooms are cultivated in some areas.

The buffer zone is used as pasture, mountains and forests, and miscellaneous area, etc. Tourism activities in the buffer zone are done mostly in public tourism resorts, such as Natural Forest Resorts, Roe Deer Eco-Park, Saryeoni Forest Trail, and Seogwipo Provincial Marine Park, etc.

The majority of Jeju BR's economic activities are located in the transition area. There are 21 golf courses, 31 public and private facilities that are related to tourism, 26 accommodations, and 15 schools, etc. A brand new logo that symbolizes Jeju BR's designation by UNESCO has been designed. The following five products that are produced in the BR are using this new logo on their products to promote Jeju BR; shiitake mushroom, green tea, Sasa quelpaertensis, wood-cultivated ginseng, and pork.

Land-Use Based on Geographic Information System, Prior Location Review of Urban Management Plan, and research and monitoring on a periodic base, etc. are the management systems being employed for Jeju BR sustainability (JSSGP, 2005, 137-166).

1. 1: Socioeconomic Characteristics

Before the 1970s, Jeju was engaged primarily in agriculture. With the launch of the South Korean government's first 5 year economic development plan in 1970 to promote Jeju's tourism development, Jeju has transformed into an industrial society.

As shown in <Table 1>, Jeju Island has experienced a remarkable socioeconomic structural transformation from 1998 to 2013. Jeju's population increased by 11.2%, a 160.0% increase of gross regional domestic product (GRDP), and a 229.76% increase of tourists during that period. In terms of the industrial origin of GRDP, the implementation of a highly industrialized economic structure took place. This is proved by the facts that the contribution of the first and secondary industry to GRDP decreased remarkably, while the occupation of the tertiary industry in GRDP increased from 59.6% in 1998 to 80.1% in 2013.

Considering the fact that as is shown in <Figure 1>, the major source that emits greenhouse gas is the secondary industry. It is maintained that the socio-economy of Jeju Island is structured significantly as environmentally friendly.

<Table 1> Changing Socioeconomic Structure on Jeju Island

Sector \ Year		1998	2003	2008	2013
Population		543,715	553,864	543,200	604,670
Tourists (million)		3.291	4.913	5.822	10.851
GRDP (million USD)		4,608	6,786	8,833	11,978
Industry Origin of GRDP	Primary Industry	24.2%	16.1%	17.6%	16.2%
	Secondary Industry	16.2%	18.0%	12.1%	3.7%
	Tertiary Industry	59.6%	65.9%	70.3%	80.1%
	Total	100.0%	100.0%	100.0%	100.0%
GRDP per Capita		8,617	12,252	16,261	19,809

Source: *Jeju Statistical Yearbook* published by Jeju Special Self-Governing Province

1. 2: Geological Characteristics

Jeju Island is a volcanic island, formed approximately two million years ago until historic times, by a volcanic eruption and shows the following characteristics (JSSGP, 2012: 10-15).

Jeju is a typical shield volcanic island that has a gentle topography with an oval shape that stretches in an east-northeast direction. The lavas including the quality of trachyte as basalt are distributed widely in Jeju Island. The lavas form a wide range of volcanic topographies and about 360 small volcanoes called Oreum, including Mt. Hallasan (1,950m above sea level) is located in the center of Jeju Island. In relation to the conditions and time of the volcano, the mountain system, the water system, and the coastal topography show various characteristics.

The mountain system shows a gentle slope on the east-west side (3-5 ^{o}C) and relatively a steeper slope on the south-north side (5-10 ^{o}C). Except for the southern coastal area of Jeju Island, approximately 120 small and large lava caves are distributed on the entire island. The representative cave is Geomunoreum lava tubes which were registered as a World Natural Heritage site in 2007. The lava caves are distributed largely in east and west. Such a geographic distribution of lava caves are related to the characteristics that the east and west regions form a more gentle slope and more wide in the area of land.

Jeju Island has a radial water system with Mt. Hallasan as apex. A wide lava plateau is developed in the east-west side of Mt. Hallasan which has a gentle slope. This results in poor development of water system, forming mainly two streams towards north and south from the summit of Mt. Hallasan as the center of Jeju Island, but mostly are dry streams.

The total length of Jeju's coastline is 419.95km. Most of it is exposed to volcanic rocks. Small-scale pocket beaches and coastal sand dunes are developed along the coastline.

Most soils are of typical volcanic ash soil. The major parent material of the soil is basalt even though some ingredient includes tuff. Jeju Island was formed by numerous volcanic activities for about 1.8 million years, which resulted in the parent materials of volcanic ash soil crumbling in different forms at different times.

1. 3: Ecological Characteristics

Jeju Island BR holds various types of land cover that maintains biological diversity, and its ecological profiles of Jeju Island BR are characterized in terms of the geographic distribution of habitats and characteristic species (JSSGP, 2012: 15-27), habitats of special interest (JSSGP, 2012: 27-33), and endangered or threatened species (JSSGP, 2012: 33-38).

Geographic Distribution of Habitats and Characteristic Species

The geographic distribution of habitats and characteristic species are divided into seven zones; Alpine Coniferous Forest, Shrubbery Zone, Temperate Deciduous Broadleaf Forest, Warm Temperate Evergreen Lucidophyll Forest, Wetland Vegetation, Mid-mountain Pasture Zone, and Coastal Habitat with Reculiar Landscape.

o Alpine Coniferous Forest: The forests of *Abies koreana* E.H.Wilson, which is an evergreen needle leaf tree, are distributed in the flatland or valley located at the altitude of 1,400-1,950m. The soil in this location is relatively rich.

o Shrubbery Zone: The communities of *Rhododendron yedonense* f. *poukhanense* (H.Lév.) M.Sugim. ex T.Yamaz. and *Rhododendron mucronulatum* var. *ciliatum* are the representative shrub forest in Jeju Island BR. Except for the area of *Abies koreana* E.H.Wilson forest, they are formed at the altitude of 1,400m and higher.

o Temperate Deciduous Broadleaf Forest: The forests of *Quercus mongolica* are distributed at the slope of Mt. Hallasan at an altitude of approximately 1,200-1,400m. The woody plants that live in this area together with *Quercus mongolica* are *Acer pseudosieboldianum*, *Carpinus laxiflora*, and *Viburnum furcatum*, etc.

The forests of *Carpinus laxiflora* and of *Quercus serrata* as another Temperate Deciduous Broadleaf Forests are distributed at the slope of Mt. Hallasan at the altitude of approximately 800-1,200m, and also in the dry slope and ridge located at the altitude of approximately 600-1,000m, respectively.

o Warm Temperate Evergreen Lucidophyll Forest: Evergreen lucidophyll forests are developed in both banks of Hyodoncheon Stream and Yeongcheon Valley. The banks run from the altitude of about 400m in the southeast slope of Mt. Hallasan to Seogwipo coast. The major species that appear in the tree layer are *Castanopsis sieboldii*.

A total of 251 tracheophyta are distributed in three islands; Supseom Island, Munseom Island, and Beomseom Island. Among ~~them~~ these trees, 47 species are evergreen trees.

o Wetland Vegetation: Crater lakes are formed on the summit of each monogenetic volcano and various wetland plants are distributed around the crater lake. Unique vegetation appears from monogenetic volcanos. Overall, the majority of species are *Scirpus triangulatus, Scirpus tabernaemontani,* and *Isachne globosa,* etc.

o Mid-mountain Pasture Zone: Jeju Island BR's grass areas are distributed in the transition area. Most of the grass areas are the communities formed by continuing setting fire and mowing grass in the past for securing pasture and/or farmland, and are wider than other plant zones.

o Coastal Habitat with Reculiar Landscape: The communities of soft coral being composed mostly of the corals belonged to Gorgonacea and Lobophyton schoedei Moser are distributed over a wide area around Munseom Island, Beomseom Island, and Supseom Island located in the south of Jeju Island. A total of 15 coral species including three stony corals and one thorny coral are designated and preserved as protected species by the Natural Environment Conservation Act.

Habitats of Special Interest

o Gotjawal (Lava Stony Forest); Gotjawal was formed when lava with high viscosity gushed out from Mt. Hallasan and split into large and small rocky masses. The masses piled up and formed a rough and lumpy topography, which is called Gotjawal. Gotjawal contributes to the recharging of underground water, and causes warm and moist effects. There's a coexistence of tropical plants of the northern limit and polar plants of the southern limit in Gotjawal. In this sense, it can be said that Gotjawal is a rare and unique forest that exists in the world.

Gotjawal's soil is poorly developed, with thick layers of small and large rocky masses. No matter how much it rains, rainwater runs into the underground due to the poor soil condition, and recharges clean and clear underground water, Jeju islanders depend as their main water source. Thus, Gotjawal functions as a sponge. Due to

Gotjawal's vulnerability to the exposure of polluted underground water from pollutants flowing into rainwater, great attention in conserving and managing Gotjawal is needed.

There are rare plant species inhabiting in Gotjawa; *Mankyua chejuense,* a pteridophyte that was discovered in Jeju Island for the first time, *Microsorum buergerianum* and *Diplazium nipponicum,* which are unrecorded species in Korea, *Quercus gilva,* a protected wild plant designated by the Ministry of Environment, *Maesa japonica,* a woody plant, and *Illicium anisatum,* a rare plant, etc.

o Oreum (Monogenic Volcano): Oreum is a monogenic volcano formed by volcanic ejects and is distributed throughout the whole area of Jeju Island. Oreums are distributed mainly in the east and west mid-mountain zone of Mt. Hallasan, and is considered as an important element that forms Jeju Island's unique landscape. There are about 360 Oreums in total; 79.7% are located at the altitude of less than 600m. Oreums are composed of grassland, natural forest, artificial forest, and wetland, etc., and is biologically diverse and scarce, has natural characteristics, and inhibits a diversity of species.

o Inland Wetland: There are a total of 253 inland wetlands in Jeju Island; 40 wetlands are in Jeju BR. Four wetlands are registered with Ramsar Wetland. Three Ramsar Wetlands are in Jeju BR. These four Ramsar Wetlands are designated as wetland protection areas by the Ministry of Environment and protected and managed by law.

Endangered wild plants and animals inhabit in the inland wetlands. Vegetation shows a different distribution structure according to geography. According to geography, vegetation shows a different distribution structure. The dominant species are *Isachne globosa*, *Eleocharis tetraquetra*, and *Dimeria ornithopoda,* etc. Collected insects around the wetlands are 11 Orders, 56 Families, and 149 Species. Jeju Island's endemic insects inhabiting in the wetlands are: 3 Orders, 5 Families, and 6 Species.

o The Community of Soft Coral: There are many rare and precious biological organisms in Jeju's sea that are not common in other seas in Korea. Seogwipo's soft coral communities (corals that do not produce calcium carbonate skeletons) form a beautiful underwater landscape. A variety of unique biological organisms inhabit in the many islands around Seogwipo.

The beautiful underwater landscape connotes a rich biological diversity. Soft coral communities exist in areas where many encrust animals (biota that cling unto rock surfaces, mostly compound animals) inhabit. Many species belonging to the Ostreidae Family inhabit together as ~~a~~ cluster of lumps. Tangled lumps of oysters with curvy shells occupy many small spaces. This is the reason why a community of soft corals has a richer biological diversity than a sea that has a shallow underground or a low and smooth slope.

Stony corals such as *Alveopora japonica*, *Tubastraea coccinea*, and *Rhizopsammia minuta mutsuensis*, etc. form a community as a result of a unique geographical distribution that is in between a subtropical and temperate zone.

Endangered or Threatened Species

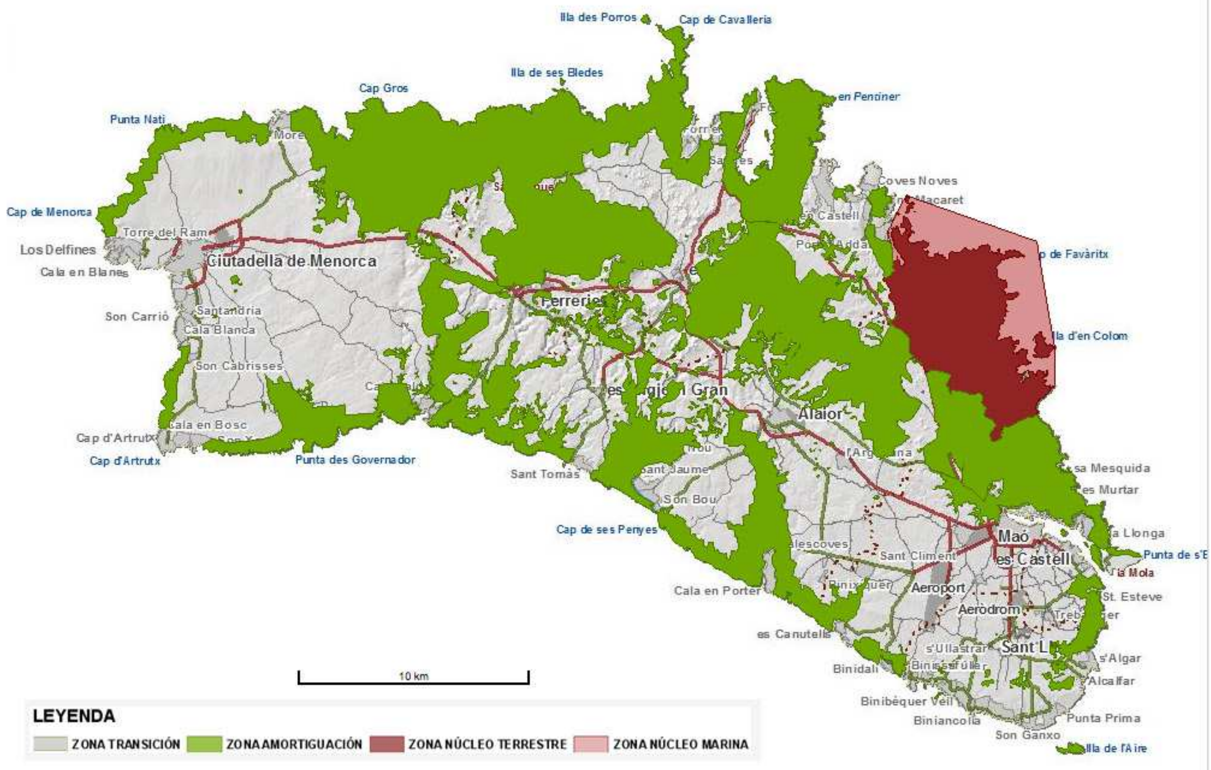
According to *Research on Red list of Wild Plants in Jeju Island for Construction of Ecological Geographic Information System*, a total of 536 taxonomic groups were evaluated at a regional level. The groups are: Extinct (1 species), Extinct in the Wild (2 species), Regional Extinct (2 species), Critically Endangered (61 taxonomic groups), Endangered (13 taxonomic groups), Vulnerable (83 taxonomic groups), and Least Concern (374 taxonomic groups). Meanwhile, a total of 157 taxonomic groups were evaluated at a district level. The groups are: Critically Endangered (19), Extinct (4), Vulnerable (1), and Least Concern (133).

Among the animals listed in the IUCN Red List, a total of 103 species inhabit in Jeju Island. They are 1 Pisces, 6 Amphibia, 5 Reptilia, 86 Aves, and 5 Mammalia by taxonomic group. On the other hand, 133 species are listed in Korea Red Data, and is composed of 3 Pisces, 6 Amphibia, 13 Reptilia, 86 Aves, and 5 Mamalia. Among them, Leopard Cat (*Prionailurus bengalensis*) lives in the wild, but is extinct in Jeju Island.

In South Korea, endangered wild plants and animals are protected and monitored by the Wild Animal and Plant Protection Law. South Korea's criteria for classifying endangered wild animals and plants for the Wild Animal and Plant Protect law is different from IUCN's criteria. There are 31 species in Jeju Island (the first grade endangered wild plant: 6 species, the second grade endangered wild plant: 25 species) from the total 77 endangered wild plants that are classified under this law. There are 87 endangered wild animals in Jeju Island among the total of 165 species that are designated by this law.

2. Menorca Island

Menorca belongs to the autonomous community of the Balearic Islands (Spain) (<Map 3>) and is the easternmost island in the archipelago of the islands. Menorca is located in the western basin of the Mediterranean Sea, between parallels 39º 47 '55" N and 40º 05' 17" N, and meridians 10º 08 '05" E and 10º 41' 28" E (<Map 3> and <Map 4>).

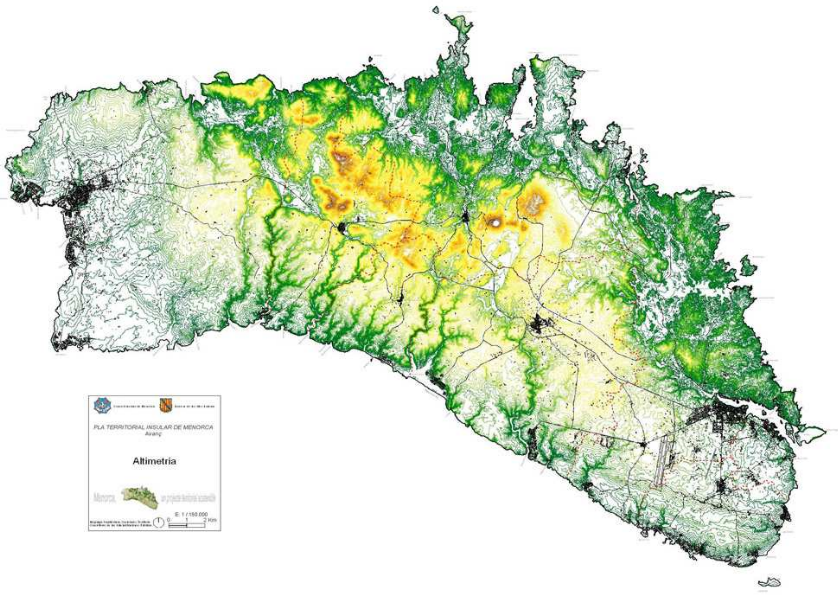


<Map 3> Map of Menorca, with Towns and Main Roads. In green Core Area of

the Biosphere Reserve (Source: Consell Insular de Menorca)

<Map 4> Situation of Menorca in the Mediterranean Sea

Menorca has a total area of about 702 km^2. The island is roughly rectangular in shape; the greater distance from end to end is 48km; the maximum width of 22km., and the coastal perimeter is about 216km. The maximum height of the island is Monte Toro 358m, other small mountains of the island do not exceed 300m. However, the northern part of the island is quite rugged, with a succession of hills and valleys. The southern part is more uniform, it is a more or less flat platform but crossed by small ravines that end up in the sea (<Map 5>). Its climate is typically Mediterranean, with a long, hot and dry summer, but with a strong maritime influence.



<Map 5> Relief Map of Menorca

2. 1: Socioeconomic Characteristics

<Table 2> is the changing socioeconomic structure on Menorca Island for 37 years during the period of 1975 to 2012. The changing process by sector shows a rapid transformation towards an industrial and open society.

<Table 2> Changing Socioeconomic Structure on Menorca Island

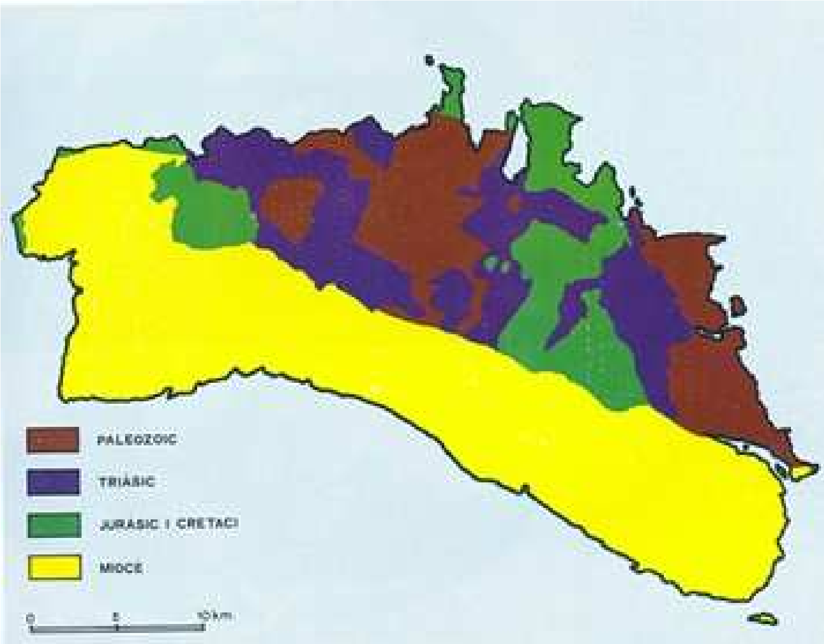
Sector		1975	1987	1997	2002	2007	2012
Population		53,012 (3)	64,201 (1991)(3)	69,071 (7)	78,796 (7)	90,235 (7)	95,178 (7)
Number of Tourists				850,000 (2)	1,119,193 (2003) (8)	1,141,403 (8)	1,117,612 (7)
GRDP at Current Prices (€)				1,005,494 (4) (1998)	1,218,277 (4)	1,514,016 (2004) (5)	
Industry Origin of GRDP	Primary Industry	14% (1)	1.5% (1)	2.7%			
	Secondary Industry	51% (1)	36% (1)	29.0%	27.9 (6)	28.5 (6)	24.5 (2011) (6)
	Tertiary Industry	35% (1)	62.5% (1)	68.3%	72.1 (6)	71.5 (6)	75.8 (2011)(6)
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
GRDP per Capita at Current Prices (USD)				14,557 €	15,461 €	18,269€ (2004)	

(1) Marí (1992)
(2) Cortès (2002)
(3) Fullana (2009)
(4) CES (2003).
(5) IBESTAT. Accessed on line (April 2014) http://ibestat.caib.es
(6) Centre de Reserva Económica (UIB-SA Nostra)
(7) IBESTAT, Accessed on line (Abril 2014). http://ibestat.caib.es
(8) Murray (2010)

The secondary sector is currently (2012) less than 25% of the economy of the island, which is divided between 15.7% in construction and 8.5% in the industry. Ten years ago, in 2002, the secondary sector accounted for nearly 30% of the economy, construction accounted for 12.3% while industry was the 15.6% of the economy. In the 1970s, the secondary sector was more than 50% of the economy, mostly because of the industry. The primary sector was very important in the past, but in the early 70s of the twentieth century, it represented less than 15% of GDP. Currently the primary sector is residual, represents less than 2% of the GDP of the economy, and it was excluded of the economic calculations by the methodological difficulty of accurately calculating so low values. The main productions of agrarian system of Menorca are milk and cheese.

2. 2: Geological Characteristics

Menorca is formed by a large number of different types of geological materials. The majority of the geological materials are of marine origin, except for a few small outcrops of volcanic rocks that are sedimentary rocks. Carbonate rocks are the majority but, unlike the rest of the islands of the archipelago, there is a significant part of the territory formed by siliceous materials.



<Map 6> Geological Map of Menorca. Source: OBSAM (http://www.obsam.cat)

Geologically the island of Menorca is divided into two nearly symmetrical parts (<Map 6>). The northern part is known as Tramuntana and the southern as Migjorn. A line that runs diagonally from one end to the other of the island clearly separates the two parts.

Tramuntana, which is located in the northern part of the island, is in fact a mosaic of materials from Paleozoic (Devonian and Carboniferous periods) and Mesozoic (Lower Triassic period) eras, so it is an area with a very heterogeneous landscape structure. Most of these materials are siliceous and generate acids and impermeable soils. The southern and western parts of the island are constituted by a fairly homogenous platform formed by limestone and calcareous rocks that formed in the Miocene period (Tertiary Era). These materials, quite recent in comparison to those of the north, have not suffered important tectonic folds and fractures, therefore the relief is not very rugged. However, because the carbonate composition of the rock, karstic phenomena have been very important. Distributed throughout the territory of the island there are geologically recent materials (Quaternary Era), for example there are numerous remains of ancient dunes and beaches that appear both in the coast and in the inland.

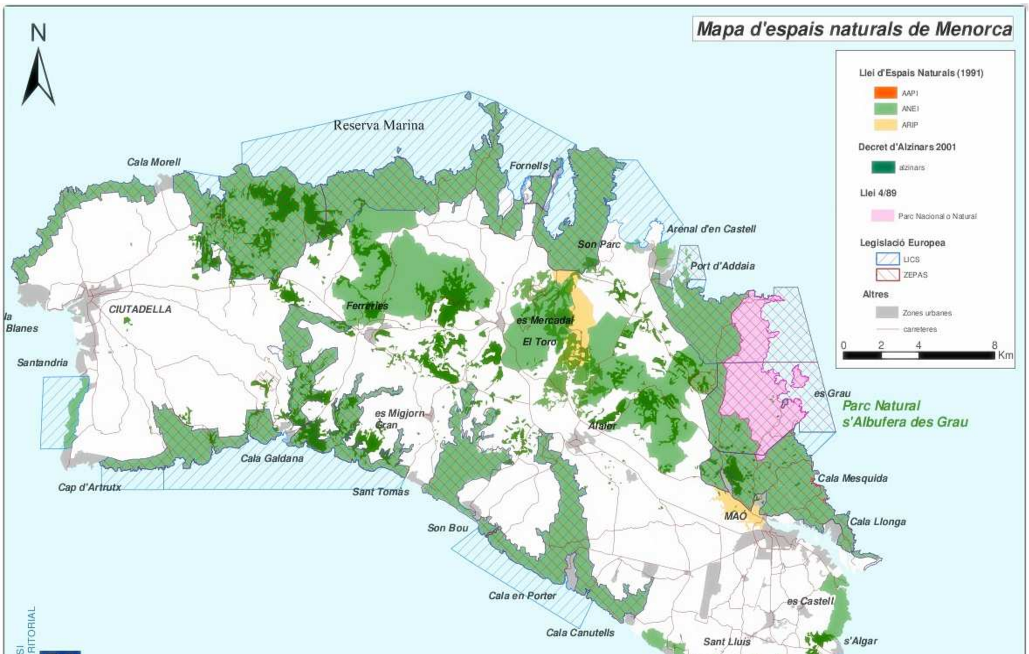
2. 3: Ecological Characteristics

Flora and Fauna

The vascular flora of Menorca is composed of 1,072 native species, of which 60 are endemic (5.6%) (Rita & Palleras, 2006). 31 species are legally protected, 10 of them at an international level, 7 at a national level, and 23 at a regional level. One of these species is extinct in the wild but is preserved in botanical gardens. The vertebrate fauna of Menorca is composed of 3 amphibians, 12 reptiles (including a sea turtle), 218 birds and 27 mammals (including 15 species of bats and without cetaceans) in addition to 324 species of fish living in the continental shelf (excluding pelagic and wandering species) (source: de Pablos, 2009). Ten endangered or vulnerable species have a high legal protection status.

Protected Areas

Menorca has 40,660ha (including 8,664 marine ha) integrated in the European Natura 2000 network with a protected area status as LIC and/or SPAs. These terrestrial areas protected at a European level represent approximately 45.7% of the total surface of the island (<Map 7>).



<Map 7> Map of Protected Areas in Menorca (Source: GAAT, http://www.gaat.es)

Albufera des Grau NP is a unique natural park on the island. Its land area is 3331.5ha and marine area is 1735.5ha. This natural park is the core area of the Biosphere Reserve. The north coast of the island was established as a marine reserve that covers an area of 5085.6 ha.

Additionally, among regional and territorial planning laws about 60% of the island (often overlapping with the areas discussed in the previous paragraphs) has been urbanistically protected.

Main Natural Environments

The territorial area that is actually used for agricultural purposes represents about half of the surface of the island. The proportion of land for agricultural usage has dropped significantly in the past 60 years (<Table 3>), while the natural usage has increased, probably due to an increase in forest area and natural pastures. It has also increased in urban usage (which includes communication ways, industrial uses, tourist resorts, etc.).

<Table 3> Evolution of Land Use from 1956 to 2007 in Menorca Island

Land Uses	**1956 (1)**	**1973 (1)**	**2000 (1)**	**2007 (2)**
Urban uses %	0.8	2.3	5.2	06:08

Agricultural uses %	61.5	60.3	57.7	49.7
Natural uses %	37.7	37.4	37.1	43.5

1. Bauzà (2006) =3. Menorca…"is different". VIII Coloquio y Jornadas de Campo de Geografía. Islas Baleares.
2. OBSAM (2012). Cartografia Digital de l'ocupació del Territori de Menorca. Actualització 2007. On line (Abril 2014) http:www.obsam.cat

Approximately 28% (19.881ha) (OBSAM, 2012) of the island's surface is covered by forest vegetation. The main trees that form the forest or maquis are *Quercus ilex, Pinus halepensis* and *Olea europea*. These three species of trees can appear in monospecific forest or in mixed communities. Two important areas of the environment are the wetlands and salt marshes. There are two major areas occupied by these ecosystems, one in the northeast part of the island (Albufera des Grau) and one in the south (Son Bou). In many cases the salt marshes and coastal wetlands are associated with dune systems and beaches, forming ecologically inseparable units.

These beaches and dunes are populated by a particular psammophyte vegetation, it represents the largest tourist resource on the island. On the other hand, from a botanical point of view, Menorca's rocky coastline is highly considered for its biodiversity, because there are many endemic plants in the coastal belt.

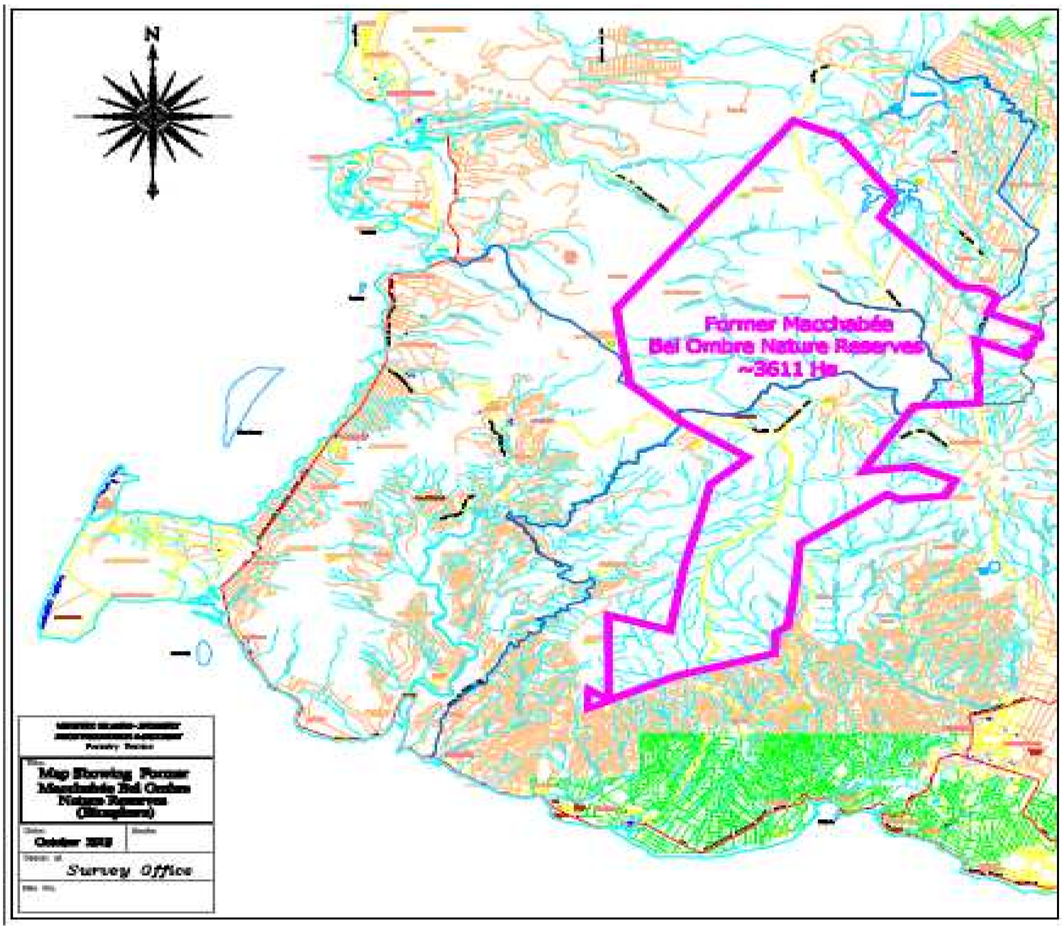
Rock walls and cliffs, both coastal and inland areas, have a very high rate of endemic plants. These ravine walls and sea cliffs are also important places for breeding bird species. Many birds of prey, such as Egyptian vulture, falcon, owl, etc. use these walls for nest building. Similarly, the coastal cliffs are used as nesting areas for threatened birds, such as the osprey and the Balearic shearwater.

The island has a unique permanent water course, but there are numerous seasonal streams throughout the island that are dry during the summer.

3. Mauritius Island

The Republic of Mauritius is located in the Indian Ocean, 800km southeast of Madagascar. It consists of two main islands, Mauritius (1865 km^2) and Rodrigues (109 km^2) and three groups of outer islands; St Brandon Archipelago, Agalega, and the Chagos Archipelago. The total land area of the Republic of Mauritius is 2,040 km^2 with an Exclusive Economic Zone (EEZ) that extends over more than 2 million square kilometers (<Map 8>). <Map 9> shows the zonation of Mauritius BR.

< Map 8> Showing the Location of Mauritius Which Forms Part of the Mascarene Islands in the Indian Ocean



<Map 9> Zonation of Mauritius Biosphere Reserve

3. 1: Socioeconomic Characteristics

<Table 4> shows the changing socioeconomic structure on Mauritius Island. In 1997, the population increased to 1,293,542 from 1,155,344 in 2012 with a mean growth rate of about 0.8% per year. Over the next twenty years, population growth is expected to stabilise at replacement levels or less. Since population density in Mauritius is already high, presently at 657 people per km^2, the predicted modest population growth (of 50,000 by 2032) will increase pressures on land use.

Mauritius received its status as a state with high human development from on its economic strength. Mauritius has a diversified economy with a stable secondary and tertiary sector. Sugar production has been the backbone of the country’s economy and is still an important pillar. The textile industry, finance and tourism sectors have become more significant and are now the three pillars of Mauritius’s economy.

Mauritius has embarked on an ambitious strategy to find new drivers for economic growth.

<Table 4> Changing Socioeconomic Structure on Mauritius Island

Year / Sector		1997	2002	2007	2012
Population		1,155,344	1,216,492	1,264,574	1,293,542
Tourists (million)		536.0	682.0	907.0	965.4
GRDP (million USD)		2,590.8	4,266.5	7,181.6	11,470.6
Industry Origin of GRDP	Primary Industry	9.3%	6.0%	4.5%	3.7%
	Secondary Industry	29.7%	29.3%	26.5%	24.8%
	Tertiary Industry	61.0%	64.7%	69.0%	71.5%
	Total	100.0%	100.0%	100.0%	100.0%
GRDP per Capita		2,557	3,525	6,227	8,881

Source: Central Statistics Office, Mauritius

The Government is putting a lot more emphasis on the development of the ICT sector and the promotion of Mauritius as a seafood hub in the region.

Gross tourism receipts grew from USD 475 million in 2000 to USD 1.48 billion in 2012. The tourism industry has been one of the most dynamic sectors of the Mauritian economy, which contributed a GDP increase from 4.2 % in 2000 to 13.2 % in 2012. The number of tourists has reached almost one million (965,400) in 2012. More than 50% of tourists are from Europe, but the biggest growth was from Asia, mainly China and India.

3. 2: Geological Characteristics

Mauritius has no proper continental shelf and the sea reaches a depth of 3,000m within a few kilometres off its coastline (Saddul, 2002). Mauritius' geology is of volcanic origin and encircled by fringing coral reefs that enclose lagoons of various widths (Saddul, 2002).

Geological studies of McDougall *et al.* (1965) and McDougall and Chamalaun (1969), describe Mauritius as being 7.8 million years old. The BR includes the largest remaining tract of native forest on Mauritius and most of the areas are important for mainland Mauritius' wildlife (Jones and Hartley, 1995).

The BR is entirely of volcanic origin. The old and the young volcanic series were separated by a long period of erosion and subsistence. The oldest rocks are believed to be of 5.5 to 8 million years old, described as olivine basalt, and are believed to be the remains of an immense shield volcano which was built up from the floor of the ocean (Saddul, 2002).

The early lavas of the young volcanic series appear to be confined to the south-west of the island where they can be seen in the mouth of the Black River Gorges. They also extend in a narrow strip through Plaine Champagne to a point just west of the Gorges View Point. They are not as hard as the old series (Saddul, 2002).

The rocks are mainly volcanic, basically consisting of olivine basalt. The rock of the steep jagged peaks is older, extremely hard, and dark in colour, while the rock of the interspersing plains is younger, not as hard and varies in colour, from very dark to light grey (Saddul, 2002).

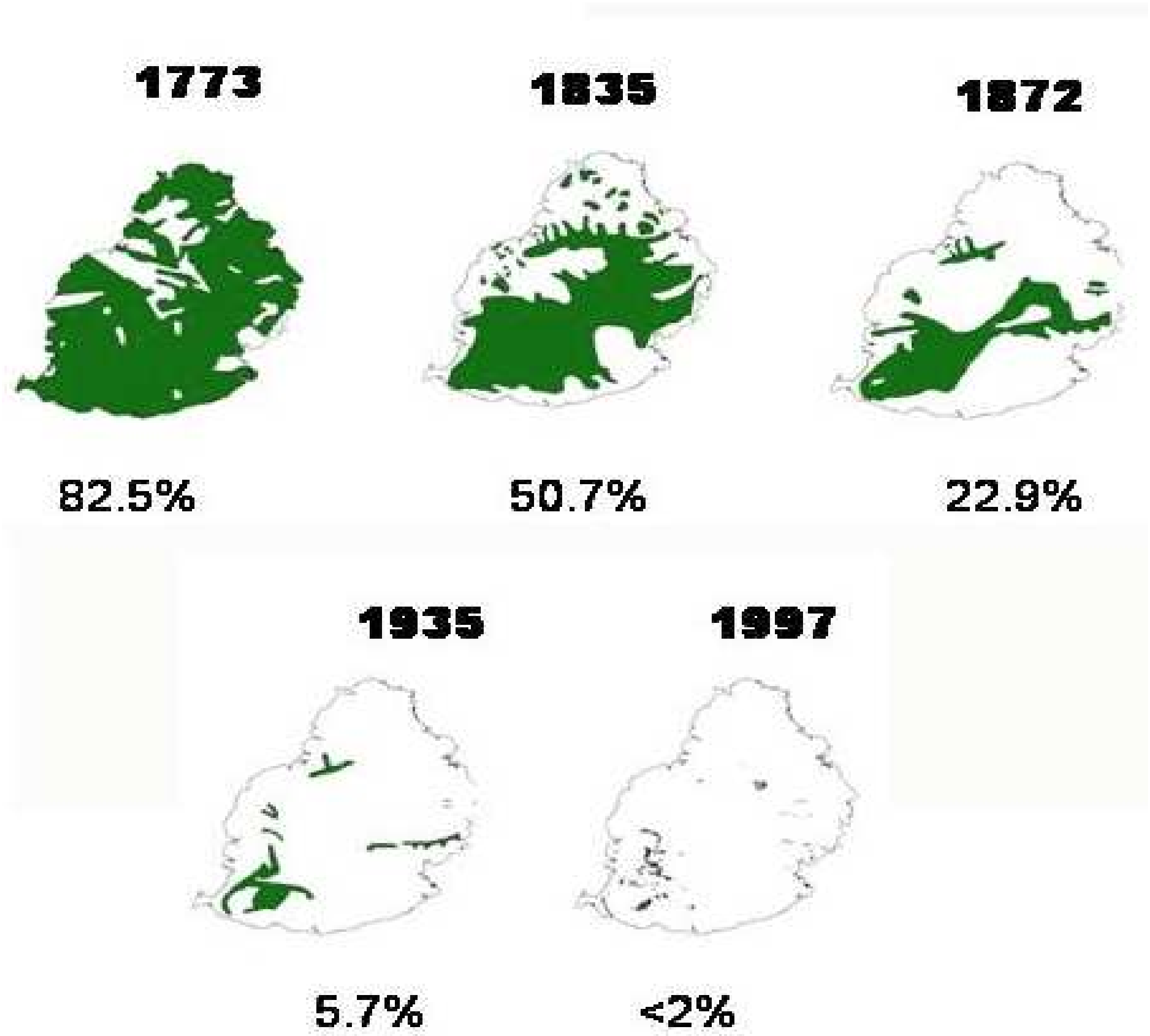
The soils of BR can be described as a complex of mountain soils ranging from moderately deep brown silty clay loam to very shallow lithosols. Within the BR, the only areas which do not fall within this category are Plaine Champagne and the region around Mare Longue. These plains are rolling to moderately sloping and soil is humic ferruginous latosol. Boulders of basalt appear on the surface on eroded slopes.

3. 3: Ecological Characteristics

Before its discovery by the Portuguese in 1507, except for two small birds of prey, man or predatory animals did not inhabit the island. After the Portuguese, the Dutch were to visit the island and resulted in the exploitation of the island by the Dutch East India Company. They cut the forests to exploit the ebony and the palms in the lowland regions and the plains. The forest cutting process was later accelerated markedly during the French and the British administrators to make room for agriculture and also infrastructure, like roads and settlements (Brouard, 1963). Thus, the evolution of endemic forest from early settlement to present time showed a considerable decrease in area as per <Map 10>.

Mauritius, which used to support a rich biogenetic diversity of wildlife, is now sadly famous as the home of the extinct flightless Dodo (*Raphus cucullatus*), the very symbol of extinction (Cheke, 1987). It was also quoted as the third country in the world to have the most threatened plant species (Jones, 1987; Swinnerton, 2004). Furthermore, it has been included together with Madagascar as one of the biodiversity hotspot in the world (Myers et al, 2000).

The need to conserve the remnants endemic forests lead to the creation of two reserved areas at Macchabee and Bel Ombre in the late 1950's. Due to the uniqueness of these two reserves, they were later in 1977 proclaimed as UNESCO Man and Biosphere Reserve. This was an important step for the conservation of the last remnants of the islands' endemic vegetation. It should be noted that about 40% of Mauritius flora and fauna is endemic to the island, but with the invasion of alien species this indigenous nature is at high risk.



<Map 10> State of the Native Forest since Colonization of Mauritius
Source: National Park and Conservation Services, 2006

This 3,964 ha of MAB reserve was later in 1994 with the adjoining forest proclaimed as the first national park of Mauritius. The Black River Gorges National Park of an area of 6,574 ha was to foster in situ conservation through human intervention (e.g. weeding of exotic species, trapping introduced macaques) and ex situ conservation such as plant propagation and captive breeding of endemic birds.

The Macchabee/Bel Ombre Biosphere Reserve of Mauritius displays not only impressive geological features that has created breathtaking sceneries and landscape but also its unique biological diversity. The BR includes the largest remaining tract of native forest on Mauritius and most of the areas important for wildlife on mainland

Mauritius (Jones and Hartley, 1995).

Studies on the vegetation communities of Mauritius were carried out by Vaughan and Wiehe (1937, 1941, 1947), Strahm (1994) and Page and D'Argent (1997). The indigenous vegetation has developed into distinctive communities with respect to rainfall, altitude and temperature. These communities can be grouped into two main categories: the upland association and the lowland association.

Lowland Plant Communities

Dry Evergreen Thickets and Forest: This type of forest is subjected to a dry period between May and November with the driest months occurring in October and November. The forests' physiognomy is markedly different from the Upland forests and includes characteristic heterophily in juvenile stages of numerous trees and shrubs, along with numerous species becoming deciduous throughout the driest months. Dominant canopy trees may reach up to 18 m in height.

Upland Plant Communities

Marshland and Pandanetum: These vegetation types occurs in the base of volcanic craters and are characterised by poorly drained shallow soils with numerous streams and often with areas of standing waters. This vegetation type is generally characterised by canopy height which may only reach 1 or 2 m. Several species are now confined to these remaining marshlands regions in the BR.

Heath Formation/Sideroxylon Thicket Transition: The heath formation is restricted and occurs on the outskirts of the *Croton/Stilingia* sp. marsh at Le Petrin and a few isolated areas at Plaine Champagne in the BR. This vegetation type gradually gives way to a *Sideroxylon* sp. dominant community prior to the upland forest communities.

This vegetation occurs on areas of groundwater laterite and is often exposed to drying winds. This community supports a diversity of small epiphytic species which generally grow on the bases and stems of the shrubs and other species which occasionally occur within this type of forest.

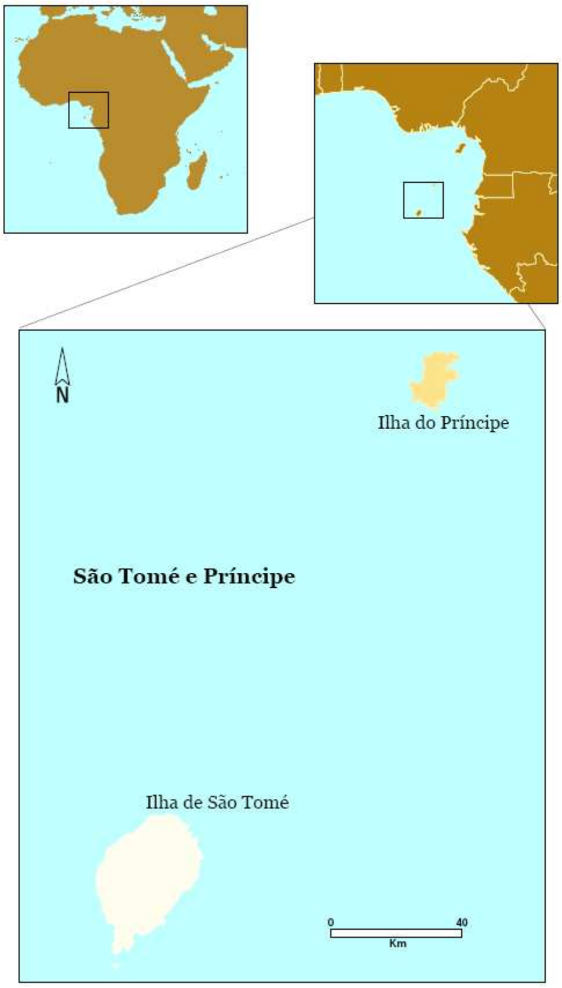
Sideroxylon Formation: This vegetation type is typically very diverse in its floristic composition and consists of a relatively open canopy of *Sideroxylon puberulum* and *Sideroxylon cinereum* with a closed and dense stratum layer of smaller woody shrubs. This vegetation type varies greatly in its floristic composition depending upon location. In the very wet uplands, there is a greater diversity of epiphytes and water-loving plants including several species of *Pandanus* sp. Canopy height depends on location and can be from 6 to 12 m in height.

Wet Evergreen Climax Forest: This type of forest is located on the upland plateau and lower elevations of Bel Ombre to the South. Remnants of this type of forest occur in region receiving 2000 to 5000mm of rainfall and occur between 400 and 700m altitude. The lower elevation forests of Bel Ombre are considered an intermediate transitional forest which has species from both the upland and lowland forest communities. Its structure is very similar to the true upland climax forest.

Endemic avifauna forms an important component of the biodiversity of Mauritius, which is known to have harbored a rich diversity of bird species. During the past 400 years, habitat destruction has been cited as the major cause of the decline of over 50% of avian species (Johnson and Stattersfield, 1990). Cheke (1987) reported that since the late fifteenth century the Mascarene Islands (Mauritius, Rodrigues and Reunion) have lost over 50% of their endemic land avifauna. Presently there are nine remaining endemic forest living birds in the BR and all of them are reliant to a greater or lesser extent to the BR for their persistence.

4. Príncipe Island

With a terrestrial area of 142 Km^2 and a maximum altitude of 948m, Príncipe Island is the smaller of the two islands that make up the archipelago and country of the Democratic Republic of São Tomé e Príncipe (<Map 11>). Príncipe Island is an autonomous region (political and administrative autonomy) with a local government and parliament.



<Map 11> Location of Príncipe Island

Príncipe Island Biosphere Reserve (PIBR) corresponds to the whole island of Príncipe including a vast surrounding marine area and islets (<Map 12>).

<Map 12> Biosphere Reserve Zonation of Príncipe Island

4. 1: Socioeconomic Characteristics

In 2012 (last census) Príncipe had a total of 7,324 of which 3,579 were women and 3,745 men (INESTP, 2012)., sustained in the increase in the number of live births and reduced infant mortality, as well as increased life expectancy. All communities and socioeconomic activities occur in the transition zone of the BR.

The Regional Government is the most important employer with recent private investors playing also an important role as employer in the sectors of tourism, agriculture and other services.

Príncipe is essentially an island where fishing and agriculture dominate besides a small tourist development, mainly composed of residential tourism in the capital of Santo António and a small island resort in the area of Bom Bom Islet, well integrated into the landscape that recently was the first African Hotel obtaining the Biosphere Responsible Tourism certification.

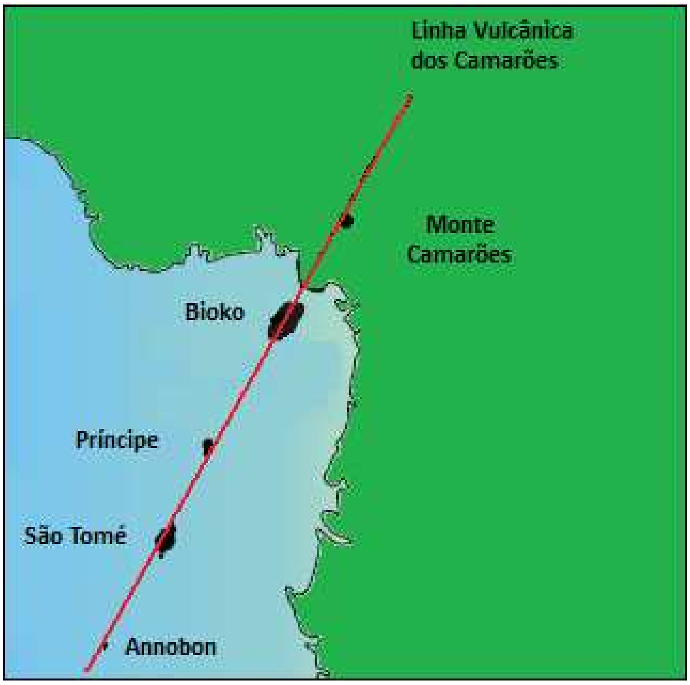
Agriculture and fisheries are mainly subsistence activities, particularly for consumption and trade in the local market. Agriculture and fish products are mainly consumed in its primary form, but there are some processed products such as dried fish, fried bananas, the “cacharamba” (local sugar cane rum) and palm tree wine.

Ethnically, the population of Príncipe is the result of miscegenation of various ethnic groups of African, European and also Asian origins. The influences are mostly native populations of the West African coast, where the kingdom of Portugal made the slave trade, from Senegal to Angola, but mainly from the Benin kingdom located in present Nigeria, Gabon and Congo. Later, around the nineteenth century, due to agricultural policies adopted in the cultivation of cocoa and coffee, many contract workers came from Angola, Mozambique and Cape Verde, the latter being the largest group of servants who came to the island of Príncipe and logically the biggest contributors to the genetic heritage of the island.

4. 2: Geological Characteristics

The genesis of the Gulf of the Guinea islands is related with the separation of the African and South American continents that began about 145 million years ago during the Cretaceous period (<Map 12>). During the process, which was about 80 million years, the movement of the African continent ~~has~~ opened a line of magmatic conduits, allowing the formation of the Cameroon volcanic line that extends in the continental plate, from Lake Chad to the southwest to Mount Cameroon and the island of Bioko (formerly Fernando Pó) in the Gulf of Guinea and on the ocean floor, including the islands of Príncipe, São Tomé and Annobon (former Good Year island).

The island of Príncipe is the oldest of the group of the three oceanic islands, with an estimated age of 31 million years. The island of Sao Tomé is estimated to be 14 million years old and the island of Annobon is the most recent formed island, with an approximate age of 5 million years.



<Map 13> The Cameroon Volcanic Line Originated the Islands of the Gulf of Guinea

The topography of Príncipe Island shows a geomorphology divergence between the southern and northern portion of the island. The northern and central areas of the island consist of plains and hills that have a relatively gentle relief. On the other hand, the southernmost area has a more abrupt terrain, with a small mountain range where the peak of Príncipe is located. Peak Príncipe is the highest point of the island and rises to an elevation of 948 meters.

The northern part of the island has a platform of smooth topography with an average elevation of 150 meters above sea level, probably due to episodes of volcanic fissure type. In the eastern part of the island there are several sandy carbonated beaches such as Praia Macaco, Praia Banana, Praia Boi, among others, including Praia Grande, the largest sandy beach of Príncipe. In sections where there are no sandy or rock beaches, the coastline has small basaltic cliffs.

The southern part of the island is geomorphologically more rugged and is characterized by having a small mountain range of east-west orientation. The range extends from the Morro do Este and peak Mencorne on the east coast to the Carriote and peak Mesa and on the west coast, converging in its northern limit with peaks João Dias, João Dias Filho and peak Papagaio.

The highest peak is the Pico de Príncipe with 948 meters of altitude, located in a central position of the southern half of the island followed of Pico Mencorne with 921 meters of altitude. The western coastline, the result of increased exposure to oceanic currents, is mostly rocky in nature, while the eastern coast, less exposed, allows the accumulation of coastal and marine sediments, allowing the existence of many sandy beaches, ranging its tone in the proportion of carbonated coral and volcanic basalt constituents.

The lithology of Príncipe Islands includes two main units. The northern part is mainly composed of effusive melanocratic rocks in basaltic terms, mostly with aphanophyric texture with phenocrysts of olivine and augite, and even some trachytes. With a lesser expression there are pyroclastic rocks typically resulting from explosive volcanic activity.

The southern part of the island is dominated by feldspar phenocrysts with phonolite, another type of aphanophyric volcanic rocks poor in quartz. Sedimentary rocks are restricted to a few outcrops of Miocene limestone and crystalline limestone, predominantly in the eastern part of the island.

The soils of the island of Príncipe are characterized by red, yellow, brown and yellow humic ferrasols with its genesis in aphanitic volcanic rocks, brown and yellow fersiallitic soils born by aphanitic volcanic rocks, lithic brown and humic brown soils originating from melanocratic aphanitic volcanic rocks, psammitic non calcareous regosols, luvisols, complex soils and laterite soils, characteristic of the humid tropics. The eruptive aphanitic rock types that gave rise to these soils are mostly basalt, phonolite and in lower expression trachytes. In general, the yellow ferrasols are present throughout the island, sometimes there are presence of associated lateritic materials and complex soils, which covers most of the southern half of the island due to mixed fractions of lithic brown humic soils and ferrasols both yellow and brown. The soil types less common are luvisols, limited to the mouth of Rio Banzú, the psammitic non-calcareous regosols confined to the coastal area of Praia Salgada and Praia Abade and lithic brown soils, circumscribed to the Abade plantation.

4. 3: Ecological Characteristics

The island of Príncipe is part of the biodiversity hotspot of tropical forests of West Africa, having ~~in~~ the terrestrial component a wide range of plant communities and habitats of high international importance such as primary tropical forests, shadow forests, palm trees and lowland riparian habitats. As an oceanic island, the native biological richness of Príncipe is accentuated by its geographic isolation, including several *taxa* of endemic flora and fauna.

The lush vegetation of the Island of Príncipe, typical of tropical areas, includes a high number of endemic species to some of the Afrotropical ecosystems representative of the equatorial zone.

The southwest coastal zones have a high level of protection (Natural Park and core zone of Biosphere Reserve) due to its extraordinary values in primary and secondary forests, landscape, geological and human values. Also the marine part of the south of the island is classified in terms of protection, integrating the Príncipe Natural Park. These areas correspond to the main core zone of the proposed Biosphere Reserve.

The forest of Príncipe Island, together with the island of São Tomé and Annobon, was considered as Africa's second most important forests in terms of conservation and thus classified by the World Wide Fund for Nature (WWF) as one of the 200 most important ecoregions in terms of biodiversity.

Of the 450 species of flora present on the island of Príncipe, 44 are endemic to the archipelago and of these 24 *taxa* are endemic to the island of Príncipe.

The indigenous terrestrial fauna of Príncipe Island, accounts for seven mammals, twenty-eight birds, thirteen reptiles and three amphibians. The invertebrate fauna, although less studied, includes forty-two species of Lepidoptera, thirty-two species of terrestrial molluscs and eight neuroptera species. Recent data collection and research work conducted by the California Academy of Sciences (CAS) shows a great variety of beetles including several endemic species, especially among the Carabidae and Cerambycidae, suggesting that the vast and rich biodiversity of the island still has many secrets to be discovered.

Príncipe Island is classified as an IBA by Birdlife International due to the occurrence of several endemic species such as the Dohrn's Thrush-babbler (also known as the Príncipe Flycatcher-babbler) *Horizorhinus Dohrn*, the Velvet-mantled Drongo, *Dicrurus modestus*, the Príncipe Glossy Starling *Lamprothornis ornatus*, the Príncipe sunbird *Nectarinia hartlaubii*, the Príncipe Speirops *Speirops leucophaeus*, the Príncipe Seedeater *Serinus rufobrunneus* and the Príncipe Golden Weaver *Ploceus princeps*.

The wealth of wildlife that inhabits the forest of Principe also extends to the herpetofauna, home to thirteen species of reptiles and three amphibians, which the Many-Scaled Feylinia (blind snake) *Feylinia polylepis*, the Yellow Banded Blind Snake *Typholps elegans*, the Príncipe Snake *Gastropyxis principis* and the biggest of Africa's treefrog, *Leptopelis palmatus* locally known as rennet (Palm Forest Frog), are endemic to the island.

With regard to mammals, the island of Príncipe houses four species of bats, *Rousettus aegyptiacus princeps* and *Eidolon helvum*, two frugivorous megachiroptera *Hipposideros ruber* and *Pipistrellus sp.*, two insectivores microchiroptera and one endemic subspecies of shrews *Crocidura poensis*. Of the known species of bats, *Rousettus aegyptiacus princeps* megachiroptera and the microchiroptera *Pipistrellus sp* are endemic to the island of Príncipe.

Due to its geographical location at the point of convergence between the subequatorial Benguela current and the Gulf of Guinea’s warm current, the marine ecosystems of Príncipe Island displays an enormous wealth and diversity, accounting for now, including pelagic species, three hundred and fifty-five fish species, eleven species of cetaceans, five species of sea turtles, twenty-eight species of marine molluscs and several species of other marine invertebrates such as corals, crustaceans and echinoderms.

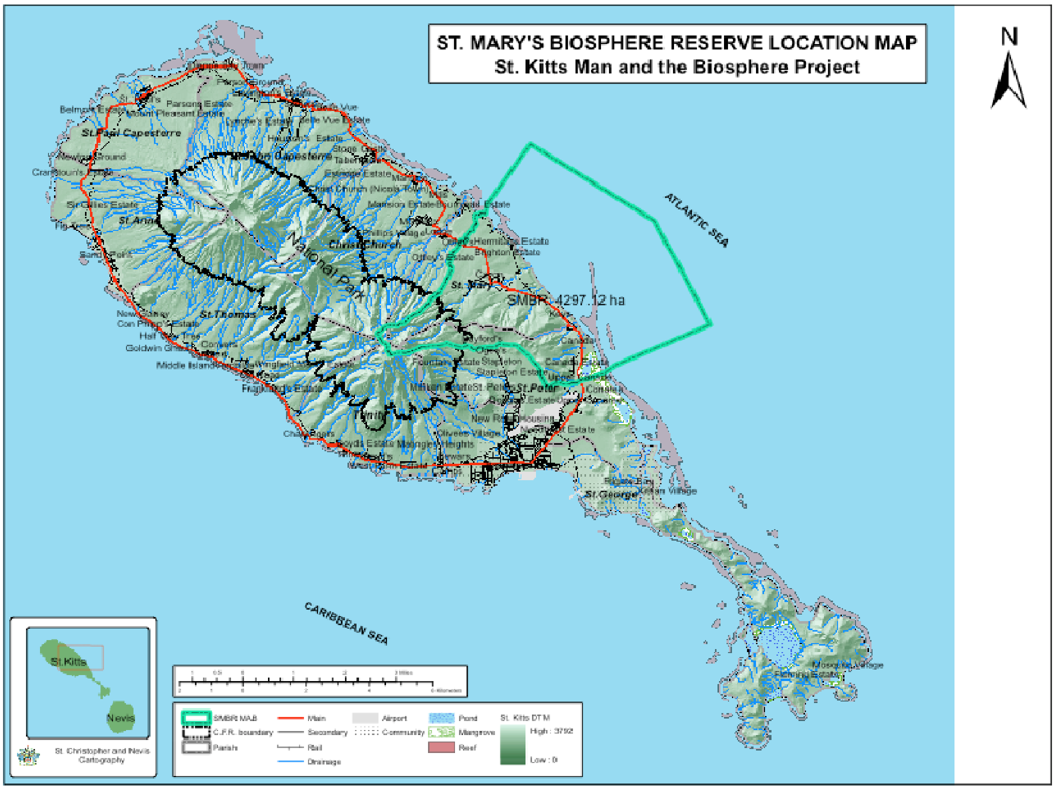
In relation with the sea birds, the Tinhosas Islets, located twenty-two kilometres off the island of Príncipe are the more important IBA in the country. Composed of two rocky islands, the Tinhosa Grande with 20 hectares and 56 m of altitude and the Tinhosa Pequena with 3 hectares and 65 m high, the two islets are home to the largest colonies of several species of marine birds in the Gulf of Guinea, justifying the classification as IBAs by BirdLife International, indicating its global importance for conservation of these species. The species that breed in greater numbers are the Sooty Tern *Sterna fuscata* with an estimated 100.000 breeding pairs, the Black noddy *Anous minutus* with 20.000 couples, the Brown-common noddy *Anous stolidus* with 8.000 couples and the Bworn Booby *Sula leucogaster* with around 3.000 couples. Also nests in small numbers the White-tailed tropic bird *Phaethon lepturus*, but there is doubt about the nesting of the Madeiran Storm-petrel *Oceanodroma castro* and the Bridled Tern *Sterna anaethetus*.

In addition to the breeding species, common visitors of these islets are the Red-billed tropic bird *Phaethon aethereus*, the Masked Booby *Sula dactylatra*, the Red-footed Booby *Sula sula* and the Ascension frigatebird *Fregata aquila*.

The fishing stocks exploited by the inhabitants of the Príncipe, have high importance in their livelihood and nutrition, as well as the increase in their income. Some of the most exploited species are the Atlantic flying fish *Cheilopogon melanurus*, the Bennet’s Flyingfish *Cheilopogon pinnatibarbatus*, the Atlantic Agujon needlefish *Tylosurus acus*, the Balao halfbeak *Hemiramphus balao* and the Ballyhoo halfbeak *Hemiramphus brasiliensis*.

5. St. Kitts Island

The St. Mary's Biosphere Reserve (SMBR) belongs to the St. Kitts Island, and with Nevis Island, form the Federation of St. Kitts & Nevis, which is located in the northern part of the Lesser Antilles chain of Islands in the Eastern Caribbean (<Map 14>).

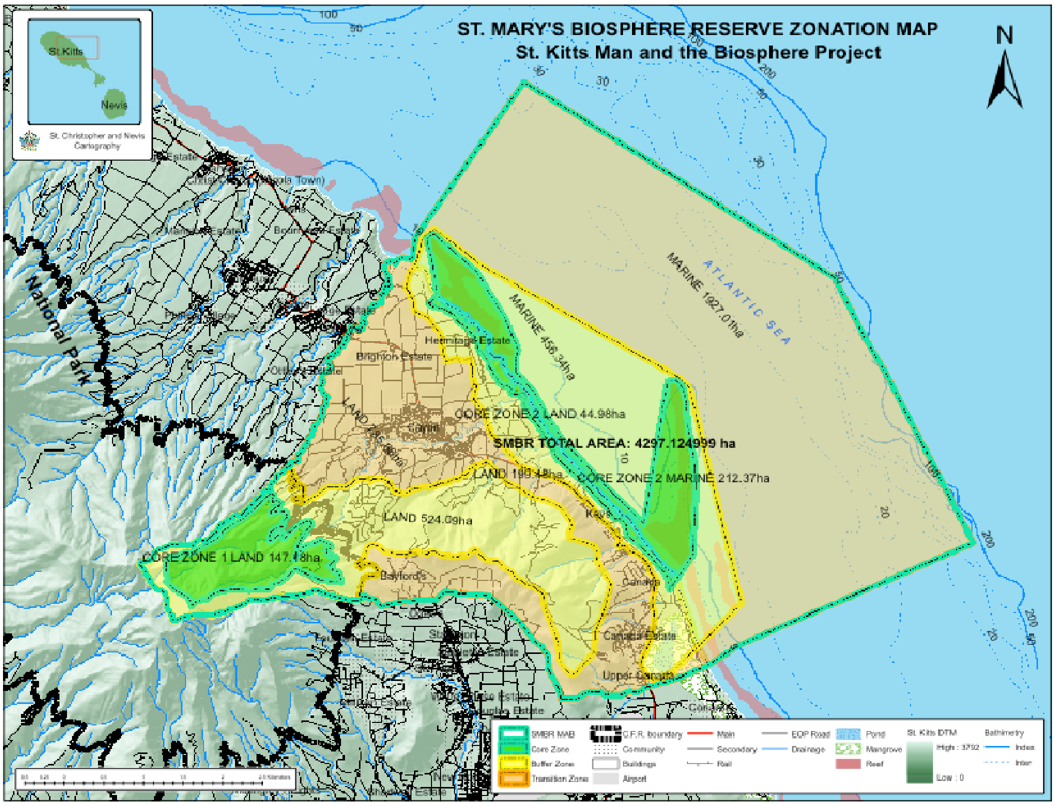


<Map 14> Location of St. Mary's Biosphere Reserve

The Federation of St. Kitts & Nevis has a total land area of 269km^2. The larger of the two islands, St. Kitts is 176km^2 in area with approximately 36.8km long and is roughly oval in shape with a narrow neck of land extending like a handle from the south-eastern end. Nevis has an area of 93km^2, with a length of 12.3km and with a width of 9.6km at its widest point.

The SMBR consists of 4,297.125ha. The overall zonation of the reserve directly relates to the two Core Zones contained within: a terrestrial area of 192.16ha that is a part of a larger forest reserve national park; and a 212.37ha of marine area that contains sandy beaches, a steep rocky shoreline, and coral reef as well as fisheries (<Map 15>).

According to Udvardy's MAB publication entitled "A Classification of the Biogeographical Provinces of the World" (1975), the SMBR corresponds to the Lesser Antillean Biogeographical Province, itself a subset of the Neotropical Realm according to floristic and faunal characterizations.



<Map 15> Zonation of St. Mary's Biosphere Reserve

5. 1: Socioeconomic Characteristics

Current St. Kitts & Nevis total population is 50,726 (est. 2012). St Mary's Parish, which includes the main towns and smaller settlements in the biosphere reserve, contained a population of 3,541 with 1,171 households, which is approximately 10% of the island's population. The principal villages of Cayon and Keys had populations of 2,081 and 395, respectfully, in 2001. Approximately one-third of the population of Keys Village resides on the east side of the main island road and within the SMBR Buffer Zone. The remainder of the village is located in the Transition Zone. The villages of Canada, Canada Estate, and Upper Canada are located at the edge of St. Peter's Parish and did not contain more than 500 individuals in 2001. Established in 2008, Windsor University School of Medicine located at Brighton's Estate in the Transition Zone has an annual population of 750 non-resident university students.

The ethnic composition of St. Kitts is predominantly Black, British, Portuguese, and Lebanese (GoSKN, 2006). The local communities within or near the SMBR are made up of a Creole population of primarily West African descent. Although there are no large enclaves of ethnic minorities within the SMBR, the urban population in Cayon Village contains a small number of people of non-Kittitian West Indian and Guyanese origin that are integrated into the community. Ethnicity does not appear to be a determining factor in occupational selection. Windsor University School of Medicine is a largely self-contained community made up of approximately 750 non-Kittitian students.

St. Kitts and Nevis was the last sugar monoculture in the Eastern Caribbean until the government decided to close the sugar industry in 2005, after decades of losses at the state-run sugar company. To compensate for the loss of the sugar industry, the Government of St. Kitts and Nevis has begun exploring alternative energy uses for sugar cane. Tourism has shown the greatest growth and is now a major foreign exchange earner for St. Kitts and Nevis, as evidenced by an 83% increase in foreign direct investment in a range of tourism-related projects.

Like other tourist destinations in the Caribbean, St. Kitts and Nevis is vulnerable to damage caused by natural disasters and shifts in tourism demand. The government has made significant progress on reducing its public debt - from 154% of GDP in 2011 to 83% in 2013 - although it still faces one of the highest public debt levels in the world, largely attributable to public enterprise losses.

St. Mary's Parish employs more people in non-farm positions, such as sales, construction, and fishing than through farming. Many of the informal sector jobs (sales, construction, etc.) are located in the nearby capital, Basseterre, with only a few sales and construction jobs in Cayon and Keys. In Cayon and Keys, locals are also employed by businesses of snackettes, restaurants, and bars. Tourism opportunities are increasingly common; however, many of these require a short commute to Basseterre. Fishing occurs off the shore of Cayon and Keys, and among other bays and deep sea locations around the island. This largely takes place in the marine Transition Zone and beyond. Small-scale traditional coastal resource harvesting occurs along the shoreline of St. Kitts.

Agricultural and subsistence horticulture occurs in the Buffer Zone of Canada Hills and in the Transition Zone surrounding Cayon and Keys. Several sections of the Transition Zone and a few small areas in the Buffer Zone near Cayon are recommended for agricultural expansion. Small-scale non-timber forest gathering and subsistence horticulture is practiced by a small number of Rastafarian farmers in the upper reaches of the SMBR Buffer Zone above Cayon (Caesar, 2009).

5. 2: Geological Characteristics

St. Mary's Biosphere Reserve has a ridge-to-reef topography: the mountain ridges of the cloud forest in the Central Forest Reserve National Park (Core Zone 1) to near shore coral reefs in Keys and Cayon (Core Zone 2). Other physical features include long and narrow forested ridges with deep valley ghauts (seasonal streams) that are surrounded by rolling forested and agricultural hills. Many of the larger ghauts lead to sandy beaches and the Atlantic Ocean. There are a few remnant sand dunes abutting Keys Beach. The northern coast of the proposed reserve has rocky bays and steep, black rock cliffs. The only named river in St. Kitts is located in Cayon, and has many unnamed tributaries flowing to it. Greatheeds Salt Pond is a 35-acre salt pond with an associated mangrove marsh.

The highest elevation above sea level reaches 812m above sea level and the lowest elevation above sea level corresponds to the 0. The maximum depth below sea level is approximately 200 feet for the coastal/marine areas.

<Map 16> General Location of St. Kitts Island

<Map 17> Political Map of St. Kitts Island

The island, which remains seismically active, is composed almost exclusively of volcanic rocks of andesite or dacite mineralogy. Newer volcanics rest on a basement of older rocks, now only exposed where the newer deposits have been denuded. Evidence of older (Eocene) volcanic basement rocks can be seen on the face of the SEP and its extension to the Morne, Conaree and Canada Hills. There are three younger volcanic centres along the island's central spine, which were active during the Pleistocene period when they yielded andesitic pyroclastics. The latter are retained as ash, reworked sands and gravels, cobbles and boulders. Some alluvial outwash deposits can be found in ghaut floors by the coast (GoSKN, 2006).

The regional geologic formations include Older Basement Volcanoes located in the general vicinity of Bayford's and Canada; Late Tufts of Mt. Misery in Cayon; Basseterre Tufts near Canada and Keys; and Sandy Point Hill Dome (Greatheed Pond) in Upper Canada. Most soil types on the island are a product of weathered volcanic parent material. The physical qualities and chemical properties on St. Kitts have developed mineral rich soils. Land and Carroll (1966) grouped the soils into seven broad groups based on weathering and clay development (GoSKN, 2006). Local soil types are Allophanoid Latosolics at the highest elevations and the crater; Kandoid, just below the crater; Protosols, found throughout the proposed biosphere; Young Soils, above Cayon; Saline Soils at Greatheed Pond (GoSKN, 2006). <Table 5> is a chart of the soil groups labelled by Lang and Carroll (1966).

<Table 5> Soil Types in St. Kitts Island

Group	State Development	Weathering Stage
Protosol	Without clay development	0
Young Soils	Without marked clay development	1
Smectoid Clay Soils	Marked clay development	0-3
Allophanoid Latosolics	Marked clay development	2-5
Kandoid Latosolics	Marked clay development	2-5
“Mixed Clay” Latosolics	Marked clay development	2-5
Kandoid Latosols	Marked clay development	6-7

5. 3: Ecological Characteristics

There are six main habitats or land cover types, and one combined anthropomorphic cover type. As indicated in the text and shown on the map above, there are some land cover types that have been combined with land habitat type.

The Dry Evergreen Forest Habitat

This habitat is a secondary forest found regionally on St. Kitts. It occurs in different successional stages on several land cover types throughout the SMBR including: Evergreen Forest, which includes Sierra Palm Forest; Seasonal Evergreen Forest; and Semi-deciduous/Semi-evergreen Forest (Helmer et.al., 2008).

Beard (1949) identified this type as being a secondary forest that occupies lands below the rainforest, usually on lands thrown out of cultivation. He enumerated 21 species including many intolerant pioneer species. The flora differs from that found in the rainforest. Constant interference by man has resulted in every stage of transition including open pasture. Present are native carpet grass (*Axonopus compressus*) or induced guinea grass (*Panicum maximum)* through guava-miconia thickets, to closed forests dominated by Spanish oak (*Inga laurina*) or Locust (*Hymenaea courbaril*), in the damp protected areas the Sierra palm (*Aerista monticola)*. Pure stands of the common tree fern (*Cyathea arborea)* can also be found.

This vegetation is characterized by *Olea europea* subsp. *africana, Juniperus procera, Celtis kraussiana, Euphorbia amplipylla, Dracaena spp. Carissa edulis, Rosa abyssinca, Mimusops kummel, Ekebergia capensis*, etc. There is also bamboo (*Arundinaria alpina*) and extensive areas of grassland rich in species including many legumes. The most important genera are *Hyparhenia, Eragrotis, Panicum, Sporoblus, and Pennisetum* for the grasses and *Triflium, Eriosema, Crotalaria* for the legumes. Smaller trees include *Allophyllus abyssinicus, Euphorbia abovalifolia, Rapanea simensis, Olinia aequipetala,* etc. Epiphytes including orchids, mosses and lichens (especially *Usnea)* are common. The shrub layer's usual constituents are *Discopodium penninervium, Myrsine africana, calpurina aurea, Dovyalis Abyssinica,* etc. Climbers including *Smilax sp., Rubia cordifolia, Urera hypselodendron, Embelia schimperi, Jasminum floribundum* and various species in the Cucurbitaceae (vines and lianas), etc usually join the strata of vegetation. The ground is covered with grasses, various other herbs including ferns and mosses. Characteristic fauna species include ground lizard, hermit crab, Caribbean elania, and mockingbird.

Elfin and Sierra Palm Cloud Forest and Evergreen Cloud Forest

These are regionally distributed; however, they occur only on the peaks and ridges above 2,000 feet. Within the SMBR this habitat type is distributed locally. This is a zone above the rainforest of constant atmospheric saturation. The vegetation is a low gnarled tangled growth, usually about 12 ft in height and loaded with mosses and epiphytes and matted with lianas.

The dominant vegetative types found here are *Freziera undulata, Weinmannia pinnata, Charianthus spp., Clusia sp.* and the Sierra palm (*Acrista* sp.). In the high elevation cloud forest you will find frogs, river crab, red-necked pigeon, mountain whistler and the Purple-throated Carib (Barlow 1993).

Dry Scrub Woodland

This is a combination of the Drought Deciduous Open Woodland and Deciduous Forest and Scrubland land cover types of St. Kitts (Helmer et.al., 2008). Beard (1949) suggested that this was principally isolated to the hills of the southeast peninsula, which were probably forested at one time with presumably deciduous seasonal forest. There are, however, small, localized patches of Dry Scrub Woodland in the Canada Hills and Bayford's of the biosphere reserve.

The following species were observed in Semi-Deciduous Woodland/Shrubland and Semi-Deciduous Forest with succulents, both of which have xeric conditions: leucana (*Leucaena leucocephala),* gilriccidia *(Gliricidia sepium),* balsam *(Croton flavens),* acacia *(Acacia farnesiana),* fiddlewood *(Citharexylum spinosum),* gumbo limbo (*Bursera simaruba),* calotropsi *(Calotropsi procera),* frangipani *(Plumeria alba),* organ pipe cactus *(Cephalocereus royenii),* blacktorch *(Erithalis fruticosa),* clammy cherry *(Cordia oblicua),* buttonwood *(Conocarpus erectus),* Guadeloupe marlberry *(*Ardisia obovata*), white indigoberry (Randia aculeate), and sea grape (Coccoloba uvifera)* (GoSKN, 2006).

Forested Wetland-Mangrove

This is an area of special concern in St. Kitts because of the encroachment of coastal development and industrial activities. This habitat is unique because it is limited in its size and distribution. The Greatheeds Pond is a former freshwater SMBR biosphere reserve. The pond is threatened on all sides by encroachment and pollution; it is now more saline than the sea.

In this habitat the plant community is dominated by a few mangrove species and one species of fern. The characteristic species found in the mangrove swamps in the SMBR are: black mangrove (*Avicennia germinans*), buttonwood (*Conocarpus erectus*), white mangrove (*Laguncularia racemosa*), swamp bloodwood (*Pterocarpus officinalis*), red mangrove (*Rhizophora mangle*), manchineel (*Hippomane mancinella)*, and mangrove apple (*Sonneratia alba)*. There are a number of heron that you may find in a mangrove swamp such as Great blue, Little Blue, and Green-backed heron, other bird species include Mangrove cuckoo, and the Belted Kingfisher. Underwater you may find Mangrove oyster, Mangrove upside-down jelly, White mullet, Queen conch and West Indian sea egg.

Littoral Vegetation Complex/Littoral Woodlands

This is regionally distributed. The littoral zone begins at the high water mark and extends in this case to the permanent line of vegetation just beyond the beach vegetation.

The most common species are: White cedar (*Tabebuia pallida*), Galba, (*Callophylum calaba*), Sea grape (*Coccoloba uvifera*), Indian Almond (*Terminalia cattapa*), Zicaque or Coco-plum (*Chrysobalarrus icaco*), beach morning glory (*Ipompea pescaprae*), bay bean (*Canavalia roseus*), manchineel (*Hippomane mancinella*), and Madagascar periwinkle (*Catharanthus roseus*).

Barrier/Coral Reef and Rubble bottom/Sea Grass Beds

These are combined because of the overlap in marine species and similar management practices. The Barrier/Coral Reef is distributed regionally and the Rubble bottom/Sea Grass habitat is local to the SMBR.

Many species inhabit the Caribbean coral reefs. The following are representative of the many species found in the Barrier/Coral Reef and Rubble Bottom/Sea Grass: parrotfish, damselfish, surgeonfish, lizardfish, trumpetfish, goatfish, nightfeeding fish, wrasse, porcupinefish, angelfish, conch, sponges, swiss cheese algae, sea pearl algae, elkhorn coral, sheet coral, black coral, tube coral, and sea fan to name a few (Barlow, 1993; Wilkins, 2009).

Anthropogenic Land Cover.

This includes heavily modified land cover categories: sugar cane and minor crops, quarries, and urban development (Helmer et.al., 2008). These lands have been highly impacted by human use and occur regionally. Remnant sugar cane fields from former plantations are found throughout the countryside of the SMBR. An existing quarry mines rock from the hillside to be used for construction materials lies at the southern end of the SMBR. Urban development is associated within the larger communities of the biosphere reserve, such as the village of Cayon. Existing urban development consists of residential, commercial, and mixed use facilities in the centre of Cayon, Keys, and Canada villages. In the hills above Cayon, GoSKN has recommended lands for agricultural expansion. There is also proposed land use zone expansion of industrial, commercial, residential, mixed use, community facilities, buildings, and possibly a landfill in the vicinity.

In addition to the numerous plants of house gardens, characteristic species of anthropogenic land cover include such plants as sugarcane (*Saccharus officinarum*), casha (*Acacia* spp.), sea island cotton (*Gossypium barbadense*), wild tamarind (*Leucaena leucocephala*), coralita (*Antigonon leptopus*), sensitive plant (*Mimosa pudica*), West Indian creeper (Wedelia triobata), leaf of life (Bryophyllum pinnatum), quick stick (*Gliricidia sepium*), tamarind (*Tamarindus indica*), lantana (*Lantana camara*), castor bean (*Ricinus communis*), lion’s tail (*Leonotis nepetifolia*), and guava (*Psidium guajava*).

Chapter 4
Current State of Climate Change

1. Jeju Island

1. 1: Greenhouse Gas Emission

In 2005, the Jeju government estimated Jeju Island's greenhouse gas emission for the first time. Jeju Island's greenhouse emission had never been estimated. <Table 6> shows Jeju Island's greenhouse gas emission in 2005, and using 2005 as the base year (JSSGP, 2010: 136), BAU (Business As Usual) estimated Jeju Island's emission for 2015, 2020, and 2013.

<Table 6> Greenhouse Gas Emission in Jeju Island

Year / Source	2005	2015	2020	2030
Industry	31.9%	27.8%	26.8%	23.5%
Transportation	29.7%	29.8%	30.0%	32.9%
Home/Public/Others	38.4%	42.4%	43.2%	43.6%
Total (ton: CO_2-equivalent)	4,070,146	4,593,386	4,944,539	5,881,791

As shown in <Table 6>, greenhouse gases emitted in 2005 was 4,070,146 ton as CO_2-equivalent. The quantity of emission is estimated as 4,593,386 ton in 2015, 4,944,539 ton in 2020 and 5,881,791 ton in 2030. In 2005, the emission from home/public/others was 38.4%, 31.9% from industry and 29.7% from transportation. The proportion of emission from transportation and home/public/others is forecasted to increase in the future, while the proportion of emission from industry is forecasted to decrease. It is anticipated that the increase rate of emission from home/public/others will be significantly higher than the emission from transportation.

Three significant characteristics of greenhouse gas emission were found from the 2005 data (Jeong, 2008). Firstly, 92% are from direct emissions and 8% are from indirect emissions. Secondly, in 2005, Jeju Island's greenhouse gas emission occupies 0.88% of the total quantity emitted from South Korea. Thirdly, 86.6% are emitted from energy in Jeju Island, while 84% are from the total energy in South Korea.

1. 2: The State of Climate Change

The state of climate change can be examined from a wide range of sectors. However, data for all sectors aren't available. Below are Jeju Island's data on the state of climate change (JSSGP, 2010: 44-50).

Temperature in Atmosphere: In comparison to 1930, Jeju Island's annual average temperature rose by 1.5℃ in the 1990s. There was an increase of 2.0℃ in spring, 1.0℃ in summer, 1.50℃ in autumn, and 1.8℃ in winter. The increase in minimum temperature was the main cause of temperature rise rather than the increase in maximum temperature. The main cause of the rise of temperature was the increase of the minimum temperature, rather than the increase of the maximum temperature. The temperature rise in Jeju Island is significantly higher when compared to the global temperature increase during the last 100 years (0.74℃) and the Korean peninsula (1.50℃).

Precipitation: Annual precipitation is significantly different by region in Jeju Island. From 1961 to 2007, Seogwipo City had the highest increase of annual precipitation; approximately 800mm. On average, the annual precipitation amounted to 1,360mm in 1961, but 1,500mm in 2007. However, there have been less rainy days during the recent 20 years. This means that there has been a remarkable intensity in precipitation.

Meteorological State: In comparison to the 1930s, Jeju Island's winter was shortened by 36 days and autumn by 4 days in the 1990s. Meanwhile, summer was lengthened by 30 days, and spring by 10 days. A rise in temperature during summer increased tropical nights and the usage of air conditioning during the day. Average tropical nights were 16.2 days/year, but increased to 29.3 days/year in Seogwipo City and 22.5 days/year in Jeju City since the 2000s. However, days using heating systems decreased. Meanwhile, the freezing and frosty days decreased.

Typhoon: Since 1959, there were 123 typhoons in Jeju Island and caused USD 420 million of property damage. There was an average annual number of 1.2 typhoons before 2000, but increased to 2.2 after the year 2000. Central pressure and daily maximum precipitation has also increased. Particularly, instantaneous wind velocity has increased by 10m/s during the past 57 years. Recent typhoons accompany stronger wind and heavy rain, meaning that the fluctuation of typhoon intensity is now more variable due to climate change.

Sea Surface Temperature: Sea surface temperature rises differently by costal area in Jeju Island. However, during the past 86 years, from 1924 to 2009, its annual average was 16.59℃ and increased by 1.94℃. Low temperature occurred in 1928-1942, 1965-1970, and 1983-1989. Meanwhile, during 1958-1965, high temperature occurred. The sea surface temperature increased by 0.26℃ in summer and 4.75℃ in winter during the 86 year period. This proves that winter temperature rise is four times higher than summer.

Sea Level: During 1985 to 2007, the average annual sea level rise was 6.01mm/year in Jeju City and 6.10mm/year in Seogwipo City. From 1970 to 2007, the sea level rose 225.7mm during a 38 year period.

2. Menorca Island

2.1: Greenhouse Gas Emission

The majority of Menorca's energy is derived from fossil fuels The entire island's energy consumption involves greenhouse gas emissions due to its limited renewable energy; a wind farm and two solar parks. Menorca's direct emissions of CO_2 (fuel +

electricity production) have been estimated by the *Observatori Socio-Ambiental de Menorca* (OBSAM) (Tables 7 and 8).

<Table 7> Emissions of CO_2 and Greenhouse Gas in Menorca Island

Source	2000 (%)	2005 (%)	2010 (%)	2012 (%)
Burning gas and fuel	47.03	44.02	37.76	37.34
Generation of electricity	52.97	55.98	62.25	62.64
TOTAL	100	100	100	100
Emissions	2000	2005	2010	2012
Total Tons CO_2	587,731.5	717,518.8	667,349.0	616,942.7
Total Tons CO_2 equivalents	637,452.8	778,220.0	723,805.9	669,135.2
Tons CO_2/capita *di jure*	8.1	8.3	7.1	6.5
Tons CO_2/capita *di facto*	5.7	7.4	6.3	5.5
Tons CO_2 eq./cap. *di jure*	8.8	9.0	7,7	7.0
Tons CO_2 eq./capita *di facto*	6.2	8.0	6.8	6.0

Source: OBSAM (2014)

<Table 8> Sources of CO2 Emission in Menorca Island

CO_2 emission source (2012)	**%**
Electricity generation	62
Car fuels	21
Aviation fuels	8
Heating fuels	6
Primary sector fuels	3
TOTAL	100

Source: OBSAM (2013)

In 2008, Menorca issued 737,066.3 tonnes of CO_2, or 8.0 tons per inhabitant *di jure* (7.1 tons/person *di facto*), while in Spain (2007), emissions were 7.7 tonnes CO_2/person, in Germany 9.7 and 19.1 in the U.S. (source: IAE, International Energy Agency, Rita, 2010). The economic crisis led to a significant reduction of these emissions (reduction of energy consumption, reduction of car and air traffic) from this year. Yet, these values were the highest ever reached. As a result, the total CO_2 emissions in 2012 amounted 616,942.7 tons, representing an overall reduction of 16.3%. The emissions per capita in 2012 were 7 tons/inhabitant *di jure*, representing a reduction of 21.7% from 2005's maximum value.

According to the Office of Climate Change in Balearics, CO_2 emissions represent 92.2% of the total GHG (Source: OBSAM, 2013).

2. 2: The State of Climate Change

Throughout the twentieth and early twenty-first century, marine and atmospheric changes were complex in the Mediterranean basin, where Menorca is located. Most of the parameters that were studied did not behave linearly, due to the fact that in addition to global climate change, other factors were intervened at a regional level Although the data were collected during the first half of the twentieth century, the research duration is not long enough, plus, the data from the last decade can change the observed trends. In any case, all studies conclude that there is a trend towards an increase in air temperature. This increase is also observed in sea temperature even in its deeper layers, and is producing a rise in sea level. Also some authors report an increase in extreme events. There is not a uniform opinion about rainfall behavior. Although the trend seems to decline, the variability of this parameter does not allow confirming this trend.

Temperature in Atmosphere: There has been an increase in the average daily temperature of 0.13°C/decade from 1901 to 2005 (1.35ºC for all period) in the Iberian Peninsula. It has not been a linear increase; the increase were at rates of 0.48°C/decade (Brunet et al., 2006, Bladé & Castro-Díez, 2010) during the latter part of this period (1973-2005). This increase was 50% higher than what was anticipated for the Northern Hemisphere. This temperature increase occurred especially during spring and summer (Bladé & Castro-Díez, 2010, AEMA et al., 2008). Menorca presented somewhat higher results (OCLIB, 2007), with increased daily maximum temperatures of 0.5°C/decade and a daily minimum of 0.61°C/decade from 1976-2006. Also Menorca's temperature has been increasing especially in spring and summer, while winters have been fairly stable. This situation has resulted in a shorter duration of spring due to an increasing temperature for the months of May and June. Thus, the summer season has extended (Jansà, 2012).

Precipitation: The trends in rainfall are uncertainty (AEMA et al., 2008). According to OCLIB (2007), for the period 1950-2006, there has been a decline in rainfall of 30% (190mm by 100 years), mainly concentrated in the autumn and winter months, with an increase of less intense rain and a reduction of moderate rain.

However, the data analysis during 1950-2011 from Menorca's weather stations are inconclusive. The 1950-1980 period is extremely variable, but the linear trend during these thirty years shows a decline in precipitation. The next period, 1980-2011, had very intense dry periods, including the minimum of these 61 years, but the linear trend was slightly positive. This variability is a characteristic of the Mediterranean climate, which makes the trends calculation very sensitive for the considered periods (Bladé &

Castro-Díez, 2010, Jansà, pers. Com.), therefore unsuitable for forecasting. Reports available (Bladé & Castro-Díez, 2010) on a larger scale (Iberian Peninsula) offer similar conclusions, however the reports note that the reduction in rainfall by the end of winter (February and March) is rather conclusive.

Extreme events: Changes in the occurrence, persistence and intensity of extreme, high-impact events have already been observed in the past few decades in the Mediterranean (Xoplaki, et al., 2012). According to Della-Marta et al. (2007) and the European Environment Agency (EEA et al., 2008), the frequency of hot days in Europe tripled between 1880 and 2005, and the duration of heat waves doubled over the same period. According to EEA, extremely high temperatures, tropical nights and heat waves are becoming more frequent. Also the EEA (2008) notes that the extremely low temperatures are increasingly scarce and heavy rains have increased in the past 30 years in the Mediterranean region.

However, this same Agency did not find clear trends over the duration of droughts in Europe or in the frequency of storms. In the same sense, other authors have found that there are no evidence of changes in the intensity or the number of extreme atmospheric phenomena during the last decades of the twentieth century (Vargas-Yánez, 2010b).

The Menorca and Balearic Islands have not found any concrete data on this subject, although the island's meteorologists have discussed about an increase in extreme weather events as a manifestation of climate change on the islands (Jansà, 2007).

Sea Surface Temperature: According to Vargas-Yánez et al. (2010 a y b), it is indisputable that the deep waters of the Western Mediterranean has an increase of temperature and salinity throughout the twentieth century. These changes have accelerated in the last decades of the twentieth century.

Following the same authors, the surface waters of the Western Mediterranean, where Menorca is located, have had two very different stages since 1948. The first period of temperature decrease, which lasted until the mid to late 70's, was followed by a second period of rapid rise in water temperatures. During the entire period of 1948-2007, the Western Mediterranean's average increase in the surface temperature was between 0ºC and 0.5ºC (the maximum corresponds to an increase of 0.083°C/decade). The temperature increased between 0.05°C and 0.2°C (period 1948-2000) in the middle layers, although the increase in this level is not confirmed (Vargas-Yánez et al. (2010b). And in the deep layers, the temperature increase was between 0.03°C and 0.1°C. Salinity increased between 0.05 and 0.06 ups in these deep layers.

By 2100, models developed with current data predict the Mediterranean Sea's surface temperature to increase by 3.5°C (Gomis, 2014).

Sea Level: The Western Mediterranean sea level fell from early 60's to mid-90's due to the atmospheric pressure being higher than normal; meaning that the Western Mediterranean sea behaved differently from the rest of the oceans due to regional atmospheric conditions. During this period, oceans levels rised at rates of 1 to 2 mm/year (Gomis, 2006 and 2008). But from the 90's the Mediterranean sea level rose rapidly at rates between 2.4 and 8.7 mm/year, although with a high variability according years and observation stations (Vargas-Yánez, 2010a). According to Gomis (2014) models predict a sea level rise of 35-40cm by 2100 only by the effect of temperature increase, regardless of the increase produced by the melting of the poles. Level changes produced by atmospheric pressure and increased salinity will not be relevant. Nor is change in wave height expected, so flood levels will be determined by the average sea level.

3. Mauritius Island

3.1: Greenhouse Gas Emission

Supported by the US Country Studies Program for Climate Change in 1990, Mauritius' preparation of national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHG) was launched in 1995. Since the year 2000, the National Inventory of GHGs compiles an annual report by the Central

Statistics Office. They published in the Digest of Environment Statistics using a different methodology than the one used in 1995. <Table 9> shows the greenhouse gas emission in Mauritius.

< Table 9> Greenhouse Gas Emission (Carbon Dioxide) in Mauritius Island

Year / Source	2000 (%)	2005 (%)	2010 (%)	2012 (%)
Industry	62.8	65.4	70.2	69.8
Transportation	29.9	27.8	24.9	25.5
Home/Public/ Others	7.3	6.6	4.9	4.7
Total (ton)	100.0 (2,456,800)	100.0 (2,996,000)	100.0 (3,665,500)	100.0 (3,743,400)

Source: Central Statistical Office, Mauritius

As shown in <Table 9>, the greenhouse gases emitted in 2012 was 3,743,400 ton as CO_2-equivalent compared to 2,456.800 tons in 2000. This indicates an increase of 52.3 % emission of CO_2 in the past 12 years with an average annual increase of 4.36%. Industry emission which also included energy generation emission had increased significantly from 2000 to 2010 and had shown a slight decrease in 2012. Transportation emission decreased from 29.9% in 2000 to 24.9% in 2010 but showed an increasing trend in 2012 (25.5%).

The projected greenhouse gas emission (Ton CO_2 equivalent) under business as usual (BAU) is shown in <Table 10>.

<Table 10> Projected Greenhouse Gas Emission in Mauritius Island under BAU

BAU Emission (Ton CO_2 equivalent)			
Source \ Year	2020	2030	2040
Industry	2,750,000	3,164,000	3,885,000
Transportation	1,213,000	1,614,000	2,136,000
Home/Public/Others	1,599,000	1,664,000	1,816.000
Total	5,562,000	6,442,000	7,837,000

Source: Mauritius Meteorological Service, 2010

It is estimated that the total quantity of emission will be 5,562,000 ton in 2020, 6,442,000 ton in 2030 and 7,837,000 ton in 2040. The proportion of industry, transportation and home/public/others emission are forecasted to increase in the future.

3. 2: The State of Climate Change

Mauritius enjoys a mild tropical maritime climate throughout the year, with a warm and humid summer extending from November to. Between June and September is a relatively dry cool winter. October and May are the transitional months.

South-East trade winds, emanating from subtropical anticyclones that travel Eastward over the South of the Indian Ocean, blows over the island predominantly throughout the winter. These anticyclones, often preceded by cold fronts, inject relatively cold air and give light rain over the country, mainly over the East, South and Central Plateau. In between the anticyclones, the weather is generally pleasant with a gentle breeze.

During summer, the subtropical anticyclones become weaker and migrate toward the pole. The weather in Mauritius is then mainly influenced by weather systems of tropical origin. The most significant ones are the tropical depressions that may evolve into cyclones. Approximately nine of these develop into named cyclones each year in the South West Indian Ocean and are associated with very strong winds and heavy rains, leading to local flash floods during their passage over or near the islands.

Temperature in Atmosphere: During 1950-2007, temperature data analysis from several stations in Mauritius and over the Outer Islands showed that the mean temperature was rising by about 0.16 °C per decade. On average, temperatures have increased over the region by 0.74 °C to 1.2 °C since 1950. The warming effect has not been uniform. The minimum temperature has increased by a larger magnitude. Most of the warming started ~~as~~ from the mid-seventies (Boodhoo, 2009).

Regression analysis revealed that the mean temperature has increased by 0.18 ^{o}C per decade at a national level, while the increase in minimum temperature has been higher than the increase in maximum temperature (Mauritius Meteorological Service, 2010). Furthermore, it has been observed that summer temperatures have been increasing more rapidly than winter, ~~ones~~ and the number of days with maximum temperatures above the threshold value of 30 ^{o}C is on the rise.

Analysis of temperatures at Vacoas during 1950-2008 shows an increase in the annual number of hot days and warm nights. During the last ten years, summer maximum temperatures (therefore daytime temperatures) became warmer by an average of 1.0 °C. By all comparisons of temperatures, the summer of 2008 –2009 has been a unique one: day time maxima have stayed between 33 – 34 ºC almost continuously for weeks (Boodhoo, 2009).

Precipitation: Annual rainfall over Mauritius has decreased by about 63mm per decade over the past century (1905-2007). Moreover, a change in the rainfall pattern was noticeable with a delay in the onset of summer rains resulting in a lengthening of the dry season. Over the last 50 years, rainfall variability has increased significantly over the western and northern districts, thus exacerbating the situation in these already water-stressed regions.

The amount of rainfall has decreased by at least 400 mm between 1931-1960 and 1971-2000. Thus, the main recharge zone has witnessed a decrease from 4,400 mm per year to 4,000 mm per year and an area of less than 800 mm has appeared along the western coast. In addition, rainfall variability has risen together with an increased occurrence of high-intensity rainfall events (Mauritius Meteorological Service, 2010). This condition favoured the occurrence of flash floods and corresponds to the damage of run-offs from recharging of aquifers.

The duration of the intermediate dry months; the transition period between winter and summer, is becoming longer. Summer rains used to start by November in the 60's and 70's, however, they now occur only in late December. Since the most recent four summer seasons, rains started only in January of the following year. In addition, and as if it's trying to catch up with the delay, it really pours with recurrent flash floods in February and March when it begins to rain. This shift in the onset of summer rain is highly significant. It translates into an increasing pressure on the water sector to increase storage capacity to cater for longer periods of dry spells and to meet equally increasing demands of the agricultural, tourism, industrial and domestic sectors.

The temporal distribution of rain is no longer what it used to be. The number of rainy days has decreased but the frequency of heavy rainfall events has increased (Boodhoo, 2009). In the past, most of the summer rains were the results from cyclones. However, since the past five or so years, summer rains have been harvested outside cyclones (Boodhoo, 2009).

Extreme Weather Event: Though no change has been observed over the last 30 years in the number of tropical storm formations in the SWIO, the frequency of intense tropical cyclones (wind gusts between 234 and 299 km/h) has increased. The number of rainy days and the amount of precipitation has decreased. However, the number of heavy rainfall events has increased in recent years. Consequently, flash floods and temporary disruption of various socio-economic activities have become more frequent.

A survey conducted in 2006 identified 326 flood-prone areas out of which half are highly vulnerable areas. More river banks have burst in recent years. The number of these sites has increased by more than half in the past decade as a result of more frequent and intense episodes of natural disasters and where new infrastructural developments were not designed to cater for events of such magnitudes. Recently, these flood-prone areas have often led to substantial damages to agriculture and other properties and even to loss of human lives.

Sea Level: Based on the reconstructed tide gauge data and complementary Topex/Poseidon altimeter data during 1950-200, the cumulative sea level in the South West Indian Ocean has risen on an average of 7.8cm at Port Louis. Analysis of datasets from the tide gauge sited at Port Louis indicates an average rise of 3.2cm during 1988-2007. Thus, this increase during 20 years exceeds the data that was observed since 1950. A study based on a sea level datum calculated in 1968 by HMS Owen, estimated that sea level has risen at a rate of 1.2mm/yr (comparable to global mean sea level increase of 1.0-2.0mm per year during this century) (Ragoonaden, 1997).

Sea Surface Temperature: The summer of 2008-2009 experienced abnormally high sea surface temperatures in the South West Indian Ocean. Ship observations and high–tech drifting buoys confirmed that on certain days, SST between Mauritius and Madagascar reached 31 degrees celcius, which is greater by 3 degrees above the long term mean temperature for the region around Mauritius (Boodhoo, 2009).

Projection of impacts of climate change in Mauritius Island

- Decreasing trend of 8% in annual rainfall. Utilizable water resources will decrease by up to 13% by 2050.
- Increase in heavy precipitation events with an increased risk of flash floods.
- More frequent heat waves in summer.
- Increasing frequency of heat spells, giving rise to cardiovascular and pulmonary complications.
- Increase in the number of intense tropical cyclones

- Increase in duration of dry spell
- Increase events of high energy waves (tidal surge) impacting the shores of Mauritius.
- Heat stress will impact on productivity in the poultry and livestock sector
- Propagation of vector-borne and infectious diseases as a result of higher temperature and recurrent floods.
- Lengthening of the transmission period of important vector-borne diseases due to rise in temperature.
- Live corals to be reduced by 80-100% in the event of 3.28°C rise in temperature by the year 2100.
- Migratory shifts in tuna aggregations, thereby disrupting the local seafood hub activities and other fish based industries and may result in conflict over the stock both at a national and international level.
- Changes in fish stock distribution and fluctuations in abundance of conventionally fished and “new” species may disrupt existing allocation arrangements.

4. Príncipe Island

4. 1: Greenhouse Gas Emission

There is no specific estimation of greenhouse gas emissions for the Island of Príncipe. Instead, São Tomé & Príncipe Government estimated the two Island's greenhouse gas emissions in 1998 and 2005. <Table 11> shows the greenhouse gas emissions in 1998 and 2005.

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<Table 11> Greenhouse Gas Emissions in São Tomé & Príncipe Island

Sectors	**1998 (Gg E-CO_2)**	**2005 (Gg E-CO_2)**
Energy	79,077	101,4763
Industry and Waste	34,085	13,96
Forests and land use (excluding sinking)	73,775	73,775
Agriculture and Farming	43,152	7,425
Total emissions	**230,089**	**196,63**
Estimate CO_2 depletion Agriculture, Forest & other land and soil uses	-704,55	-727,57

From <Table 11>, we concluded that São Tomé & Príncipe should not be considered as a greenhouse gas emission source. Instead, the country should be considered as a CO_2 depletion role model, due to the vast and well preserved forest areas, especially in Príncipe Island.

An increase of installations for the energy sector as domestic electric power in different communities within the country is anticipated. Industry and transportation have a very low contribution.

4. 2: The State of Climate Change

According to Penhor et al [1], during 2040-2060, São Tomé and Príncipe will have a loss of precipitation, combined with an increase of mean temperatures.

1. Avaliação da Evolução Climática de S.Tomé e Príncipe - Penhor, M.; Vaz, B.; Neves, M. (2001).

Temperature in Atmosphere: There has been no significant change in the minimum, maximum and mean temperatures recorded between 1951 and 1977. During this period, the recorded values were, respectively, 21.3ºC, 29.3ºC and 25.3ºC.

After 1977, increase of 0.032ºC in the maximum temperature was recorded. On the other hand, smaller increase (0.021ºC) in the minimum temperature was also registered. For 2050, the mean temperature is expected to increase 1ºC to 2ºC.

Precipitation: The meteorological data collected by the Meteorological National Institute (INM), shows an average precipitation of 913mm between 1951 and 1976. During 1977-2000, the mean precipitation was lower, reaching the value of 816mm per year. The projection for 2040-2060 indicates the possibility of a precipitation loss that can reach 12 to 14mm (worst scenario) and 8 to 10mm (best scenario).

Sea Surface Temperature: There are no data available for sea water temperature.

Sea Level: There are no data available for the sea level variation.

5. St. Kitts Island

5.1: Greenhouse Gas Emission

The Initial National Greenhouse Gas Inventory of Anthropogenic Emissions for the Federation of St. Kitts & Nevis was provided in the First National Communication (<Table 12>).

<Table 12> Initial National Greenhouse Gas Inventories of Anthropogenic Emissions for St. Kitts & Nevis Island

Greenhouse Gas Sources and Sink Categories	CO_2	CH_4	N_2O	NMVOC	CO
Total (Net) National Emission (Gigagrams per Year)	(18.9)	2.83	0.11	1.19	0.07
1. All Energy	70.89		0.01	0.01	0.07
Fuel Combustion	*70.89*		*0.01*	*0.01*	*0.07*
Energy and transformation industries	6.45				
Industry	0.16				
Transport (Road, Rail and Navigation)	26.27				
Residential	7.35				
Agriculture, Forestry, Fishing	28.19				
Biomass burned for energy	2.41				
Fugitive Fuel Emission					
Oil and natural gas system	NA				
Coal mining	NA				
2. Industrial Processes				1.18	
Road paving asphalt				*0.89*	
Alcoholic beverages				*0.03*	
Food production		*0.69*		*0.26*	
3. Agriculture		0.65	0.09		
Enteric fermentation					
Leaching of agricultural fields			*0.02*		
Cultivation of histosols			*0.03*		
Manure management		*0.04*			
Indirect Atmospheric Deposition			*0.04*		
4. Land Use Change and Forestry		0.0002	0.001		
Changes in Forestry and other woody biomass Stock	(85.62)				
Forestry and Glassland Conservation	2.93	0.002			
Abandonment of Managed Lands	(7.10)				
Carbon release from agriculturally Impacted soils					
5. Other Sources as Appropriate and to Extent Possible		2.1423	0.01		
Solid Waste disposal on land		2.14			
Sewage		0.0023	0.01		

NA: not applicable

CO_2 emissions derive mainly from the combustion of fuels that are used in power-generation, transports, manufacturing industry, construction and international bunkers (aviation).

St. Kitts & Nevis has a much reduced manufacturing and industrial sector, thus resulting in a small contribution to CO_2 emissions. The only perceptible greenhouse gases are methane (CH_4) and nitrous oxide (N_2O) for agriculture and farming sectors.

Forest and water sectors are also minor contributors to the greenhouse gas emissions.

5. 2: The State of Climate Change

Climate change scenarios for 2030, 2050 and 2100 were developed, covering temperature, precipitation, sea level and atmospheric CO_2 concentrations.

Temperature in Atmosphere: An increase of 0.9ºC for 2030, 1.5 ºC for 2050, and a maximum of 3.0ºC for 2100 is expected.

Precipitation: The precipitation scenario indicates an increment in annual mean precipitation values, respectively, 12.9% for 2030; 20.6% in 20150 and up to 42.3% in 2100.

Sea Surface Temperature: There are no data available for sea water temperature.

Sea Level: Sea level variation data is not available but based on global scenarios, an increase is expected.

Chapter 5
Implementation of Climate Change Policies

1. Jeju Island

In 2007, the South Korean Ministry of Environment designated Jeju as a model province that is responsive to climate change. However, before 2007, the Jeju Government did not launch any in earnest climate change policies except for environmental policies that were related to climate change. Since 2008, Jeju Government developed and launched full-scaled climate change policies that are composed of 75 individual projects, establishing vision, goal, three strategies, and 15 policies.

Vision is a cognitive map that an organization perceives as a desirable future to realize. Goal is defined as the result or achievement toward which effect to realize vision is directed. Strategy is a method or plan chosen to bring about a desired future such as achievement of vision through goal. Policy is a principle of action adopted to guide decisions and achieve strategies. Project is a concrete to achieve policy. In this regard, vision, goal, strategy, policy, and individual project are an integrated framework within a hierarchical umbrella; from vision to individual project through strategy and policy.

1. 1: Vision, Goal, Strategy, and Policy

<Figure 2> shows Jeju Island's vision, goal, and three strategies (JSSGP, 2010: 166). In <Figure 2>, MIDAS stands for “Mitigative”, “Decreasing”, “Adaptable”, and “Standard”. In other words, Jeju Island's vision is to mitigate climate change, decrease the impact caused by climate change, and adapt to climate change. The global standard established as the goal implies that Jeju Island aims to become a world-class model in responding to climate change through this strategy.

Vision: Opportunity to Transform Climate Change To Green Growth (MIDAS)

↓

Goal: Global Standard Responding to Climate Change

↓

3 Strategies and 15 Policies

1. Realization of Low-Carbon Green City
   - ① Completion of Leading Model Responding to Climate Change
   - ② Institutional Improvement for Responding to Climate Change
   - ③ Expansion of Carbon Sink
   - ④ Creation of Low-Carbon Green City
   - ⑤ Establishment of Energy-Saved Social System
2. Promotion of Green Growth Industry
   - ⑥ Promotion of Low-Carbon Green Tourism
   - ⑦ Establishment of Production System of Environmentally Friendly Agricultural, Fishery, and Livestock Product
   - ⑧ Expansion of R&D for Green Industry
   - ⑨ Expansion of New and Renewable Energy
   - ⑩ Transformation to Low-Carbon Industrial Structure
3. Precautionary Prevention and Utilization of Opportunity
   - ⑪ Establishment of Disaster Prevention System
   - ⑫ Maintenance and Expansion of Biodiversity
   - ⑬ Development of Fish Species and Crops as New Income Sources
   - ⑭ Efficient Management of Water Resource
   - ⑮ Climate Change Education and Publicity

<Figure 2> Vision, Goal, Strategy, and Policy of Climate Change in Jeju Island

1. 2: The Projects Being Launched by Strategy

Below are the 75 projects that are implemented to achieve Jeju Island's vision, goal, and three strategies..

Strategy 1: Realization of Low-Carbon Green City: 35 projects

①Completion of Leading Model Responding to Climate Change: 9 projects

- o Establishing Domestic and International Cooperative System Responding to Climate Change
- o Operating Demonstration Projects of Carbon Emission Trading by Public Institution
- o Promoting Energy Goal Management by Public Institution
- o Reducing Greenhouse Gas Emission from Vehicle
- o Establishing Test Road for On-line Electric Car
- o Supplying Electric Car
- o Expanding Supply of Green Car
- o Expanding Supply of CNG Bus
- o Conducting Research on Climate Change Adaptation

②Institutional Improvement for Responding to Climate Change: 1 project

- o Enacting Ordinances Related to Climate Change

③Expansion of Carbon Sink: 5 Projects

- o Planting Five Million Trees
- o Cultivating Green Forest
- o Preventing Forest Disaster and Restoring Damaged Forest
- o Conserving Gotjawal(Lava Stony Forest) through Purchase of Private-Owned Ones
- o Afforesting Marine Forest in Coastal Belt

④Creation of Low-Carbon Green City: 8 Projects

- o Establishing Space Planning for Low-Carbon Green City
- o Expanding Certification Program on Environmentally Friendly Building

o Establishing Energy-Saved Urban Sign Board

o Implementing Housing Development in Farming and Fishing Village

o Implementing Model City on Roundabout

o Establishing Metropolitan Intelligent Transport System (ITS)

o Utilizing Bicycle Use

o Introducing New Concept Mode of Public Transportation

⑤Establishment of Energy-Saved Social System: 12 Projects

o Establishing Green Campus

o Establishing Smartgrid Test Complex

o Inviting Lodgement Base of Smartgrid to Jeju

o Substituting Streetlights with Light Emitting Diode (LED)

o Substituting Traffic Lights with Light Emitting Diode (LED)

o Expanding Carbon-Point Institution for Reducing Greenhouse Gas Emission

o Practicing Green Life at Home

o Expanding Supply of Clean Energy (Urban Gas)

o Practicing Green Building

o Supporting Fishing Boats with High Efficiency Equipment

o Promoting Consumption Movement of Local Foods

o Operating Early Education School of Energy-Saving

Strategy 2: Promotion of Green Growth Industry: 23 projects

⑥Promotion of Low-Carbon Green Tourism: 3 Projects

o Developing Marine Eco-Tourism

o Introducing Low-Carbon Green Tourism and Developing Tourism Products

o Establishing Low-Carbon Model Tourism Complex

⑦Establishment of Production System of Environmentally Friendly Agricultural, Fishery, and Livestock Product: 8 Projects

o Establishing the Base of Green Organic Agriculture

o Continuing Expansion of Environmentally Friendly Agriculture

o Establishing the Base of Environmentally Friendly Agriculture

o Operating Model Farming Using New and Renewable Energy

- o Promoting Tangerine Industry Responding to Climate Change
- o Establishing Information System on Disease and Insect Pest Control
- o Conducting Researches on Production Technology of Agriculture Responding to Climate Change
- o Supplying Decomposable Fishing Equipments

⑧Expansion of R&D for Green Industry: 2 Projects

- o Conducting Researches on Technology of Sub-Tropical Biotic Resources
- o Creating *Sasa quelpaertensis* as a New Industry

⑨Expansion of New and Renewable Energy: 8 Projects

- o Expanding Supply of New and Renewable Energy
- o Launching Swine Manure Bio-Gas Plant
- o Promoting Carbon-Neutral Environmental Treatment Facilities
- o Supplying Green Home
- o Establishing Offshore Wind Power Generation
- o Establishing Electric Service System as a Transportation Facility Based on New and Renewable Energy Source
- o Establishing Terrestrial Electric Facility at Jeju Harbor
- o Establishing Comprehensive Environmental Energy Town

⑩Transformation to Low-Carbon Industrial Structure: 2 Projects

- o Promoting Voluntary Agreement with Industries Emitting Bulk Quantity of Carbon
- o Supporting Green Growth Industries with Small and Medium Industry Promotion Fund

Strategy 3: Precautionary Prevention and Utilization of Opportunity: 17 projects

⑪Establishment of Disaster Prevention System: 2 Projects

- o Repairing Creeks and Managing Vulnerable Districts to Disaster
- o Promoting Precautionary Measures on Vulnerable Districts to Disaster Responding to Unusual Weather

⑫Maintenance and Expansion of Biodiversity: 2 Projects

- o Conducting Long-Term Researches on Mt. Hallasan Ecology Responding to Climate Change
- o Monitoring Fisheries Ecological Environment and Conducting Researches on Restoration

⑬Development of Fish Species and Crops as New Income Sources: 4 Projects

- o Surveying Environment of Jeju Coastal Fisheries
- o Promoting Green Lavers Sedimented in Coast as Industrial Resources
- o Promoting Sub-Tropical Fruit Industries Responding to Climate Change
- o Introducing and Selecting Sub-Tropical Crops Responding to Climate Change

⑭Efficient Management of Water Resource: 3 Projects

- o Conducting Researches on Water Resources Caused by Change in Precipitation Pattern
- o Developing Alternative Agricultural Water
- o Reusing Treated Sewage

⑮Climate Change Education and Publicity: 6 Projects

- o Establishing and Operating Asia Climate Change Education Center
- o Promoting Landmark Industry Responding to Climate Change
- o Promoting Zero Movement of Leftover Food
- o Promoting Education of Eco-Driving
- o Supplying Small Cars and Encouraging to Use Them
- o Introducing Green Roof System

1. 3: Reduction Target of Greenhouse Gas Emission

These 75 projects have different periods of completion. For example, some projects are promoted for two years, and others for five years. By implementing these 75 projects, Jeju Government has aimed to reduce greenhouse gas emissions by 10% in 2015, 15% in 2020, and 14% in 2030. <Table 13> shows the greenhouse gas emission reduction target by source in detail (JSSG, 2010: 210-211).

<Table 13> Reduction Target by Source of Greenhouse Gas Emission in Jeju Island

Source of Emission	Emission Estimated by BAU (ton: CO2-equivalent)			Reduction Target (ton: CO2-equivalent)		
	2015	2020	2030	2015	2020	2030
Home	694,129	697,693	601,115	135,091 (19%)	188,255 (27%)	194,478 (32%)
Commercial and Public	1,252,810	1,438,299	1,963,801	142,771 (11%)	240,939 (17%)	268,985 (14%)
Transportation	1,365,127	1,481,559	1,935,453	41,145 (3%)	60,693 (4%)	60,455 (3%)
Industry	775,722	815,902	847,054	60,142 (8%)	99,427 (12%)	94,873 (11%)
Industrial Processing	77,208	75,642	70,851	-	-	-
Agriculture and Livestock	324,123	341,055	374,921	74,368 (23%)	129,665 (38%)	225,407 (60%)
Waste	104,267	94,398	88,596	7,032 (7%)	7,032 (7%)	7,032 (8%)
Total	4,593,386	4,944,539	5,881,791	460,549 (10%)	726,011 (15%)	851,239 (14%)

Note: The figures in parenthesis refer to the rate of reduction.

The following are found to be significant from <Table 13>. Firstly, the Jeju Government did not target the reduction of greenhouse gas emission from Industrial Processing which is the source of producing goods. As shown in <Table 1>, secondary industry which is the main source of greenhouse gas emission, is a minor industry in Jeju Island. Meanwhile, the target reduction is 8% in 2015, 12% in 2020, and 11% in 2030 for Industry's greenhouse gas emission, which is based on energy usage.

Agriculture and Livestock is the main sector for Jeju Island's reduction target, setting its reduction goal to 23% in 2015, 38% in 2020, and 60% in 2030, followed by Home and Commercial/Public sector. Transportation and Waste are minor reduction targets.

2. Menorca Island

Menorca's policies to fight against climate change (mitigation and adaptation) should be analyzed in the geographical and political context where the island is located. Menorca is under four levels of political decision: the European Union (EU), the Government of Spain, the Government of the autonomous region of Balearic islands, and the insular government of Menorca. Effective action to reduce emissions, necessarily requires coordination of these four levels of political decision. An analysis of emission reduction policies with special emphasis on the regional and island levels are made in this chapter.

2. 1: European Union

Spain, a member of the EU, introduced a legislation and the EU showed a very decided position regarding this matter. The most important decision the EU agreed upon is grouped into a strategic document known as "The Climate and Energy Package" (2009) (http://ec.europa.eu/clima/policies/package/index_en.htm), this is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy goals for 2020. These targets, known as the "20-20-20" targets, set three key objectives for 2020:

o A 20% reduction in EU greenhouse gas emissions from 1990 levels (For Spain the Kyoto agreement admitted of an increase of 15% from 1990, later flexibility mechanisms (carbon trading) has set an intermediate goal for our country + 35% compared to 1990 emissions);

o Raising the share of EU energy consumption produced from renewable resources to 20%;

o A 20% improvement in the EU's energy efficiency.

The Climate and Energy Package comprises four pieces of complementary legislation which are intended to deliver on the 20-20-20 targets:

o Reform of the EU Emissions Trading System (EU ETS)

o National targets for non-EU ETS emissions o National renewable energy targets

o Carbone capture and storage

2.2: Government of Spain

Among Spain's most important documents for planning and strategizing to reduce GHG emissions and to adapt to climate change can be emphasized below (Ministry of Agriculture, Food and Environment, http://www.magrama.gob.ex/ex/cambio-climatico/temas/mitigacion-politicas-y-medidas).

o Spanish Strategy on Climate Change and Clean Energy 2007-2012-2020 (EECCEL 2007-2012-2020).

o National Action Plan for Renewable Energy in Spain 2011-2020 (PANER 2011-2020).

o National Action Plan for Energy Efficiency in Spain 2011-2020 (PAEE 2011-2020)

o Strategy for Sustainable Mobility (EEMS)

o National Plan for Adaptation to Climate Change (NAPCC)

Various topics such as, Energy, Emissions Trading, Transportation, Waste, Building Standards, Forestry, Agriculture and Livestock, Taxation, etc. emerged from these planning documents. Thus, for example, it has been regulated emissions from large industries, energy efficient design of buildings, solar thermal energy requirement to install in new or renovate buildings, waste reduction policies and GHG emission control, progressive vehicle taxation in relation to emissions, etc.

2.3: Autonomous Government of Balearic Islands

In 2005, the Government of the Balearic Islands created an Interdepartmental Committee on Climate Change (CICC) and a Technical Committee on Climate Change (CTCC). These committees drafted an "Action Plan to Combat Climate

Change 2008-2012", which was approved in 2008. This plan has been completed, and an assessment of the fulfillment of its objectives has been made.

In 2013, the CICC approved the Balearic Climate Change Strategy 2013-2020. Until now, the main result of this document has been the adoption (2014) of a "Plan to Mitigate Climate Change in the Balearic Islands from 2013 to 2020" (Govern de les Illes Balears,

http:///www.caib.es/govern/sac/fitxa.do?estua=3185&lang=ca&codi=1474210&coduo=3185) which currently is the main regional document to address the problem of climate change.

A very detailed analysis regarding source emissions, a proposal of possible pathways that can reduce emissions, and possible outcomes under different future scenarios are written in this document. This plan, because its regional level, does not segregate the data by islands, except for a few specific action, so that the values of reducing emissions refer to the archipelago.

The plan proposes a target of reducing 20% of GHG emissions by 2020 in comparison to emissions from 2005. In 2011, for the very first time, Balearic Islands' emission levels fell under the emission levels of 2005; about 10,000kt CO_2e. So a reduction target of 20% represents about 2000 Kt CO_2e for the whole archipelago.

The PMCCIB proposes 50 actions to reduce GHG emissions, however, the majority of the proposed actions are for demonstration purposes and has minimal or zero impact. The majority of the reduction is related to the Mainland's new electric transport connection and also the increased use of gas for the production of electricity. Both measures would significantly reduce emissions per unit of electricity produced, and would make an important impact on the total amount of emissions. On the other hand, the Plan barely proposes any measures to promote clean energy and substantial changes in transport policies or to reduce electricity consumption.

Only 11 plans from the 50 proposed measures will contribute more than 1,000t CO_2 /year of reduction of emissions as follows.

o New electrical interconnection Peninsula-Mallorca. It could be operational by 2017 or 2018, are estimated 900,000t CO_2/year of emissions savings. It is the best investment that can be made to mitigate climate change in the Balearic Islands.

o To get in 2020 an emission rate associated with electricity production of 0.5t CO_2/MWh (linked to the new electric cable with the Peninsula, and the promotion of renewable energy). This figure, with a demand of 6,500GWh, represent emissions of 3,250,000t of CO_2 in 2020, which is a 33% less compared to 2005 (when the archipelago produced approximately 4.9 million tons of CO_2 in the production of electricity).

o Creating a network of 2000 charging points for electric vehicles. Objective: CO_2 saving of 1,200t /year by 2020 compared to 2005.

o Promotion of biomass. Objective: saving 21,720t of CO_2 in 2020 compared to 2005.

o Renewal of agricultural machinery. Objective: 5,881t of CO_2 saving/year.

o Agri-environmental subsidies to organic farming. Objective: 229 beneficiaries, 12,884ha; reduction of 12,884t CO_2e/year.

o Agri-environmental subsidies to integrated production. Objective: 209 beneficiaries 3812.52ha; reduction of 1,900t CO_2e/year.

o Promote afforestation of agricultural land: 70 beneficiaries, 888.67ha; Fixing 1,140 t CO_2/year.

o Promoting the use of forest biomass. Objective: saving 21,720t of CO_2/year by 2020 compared to 2005.

o Application of island waste minimization plans. Reduction of about 23,506t CO_2e/year in 2020 compared 2010.

o Implementation of plans and programs for waste management to achieve a reduction of 50% by weight. Objective: reduction of about 327,982.5t of CO_2e in 2020 compared to 2010.

2.4: Insular Government of Menorca

The Insular Government of Menorca has not yet developed strategies or planning documents on climate change. However, there is quite detailed information on the evolution of emissions and are developing interesting performances of evaluation, monitoring, reporting, pilot projects, etc. Below is a summary of the most important plans.

o Reduction in emissions in recent years: Menorca is included in the PMCCIB. However, the proposed 2020 objectives are much easier to achieve than on other islands of the archipelago due to a significant reduction in emissions recently.

In 2013, Menorca generated 17.2% less CO_2 than in 2005, which implies that CO_2 emissions have been reduced by 123.2Kt compared to the reference year. The island is very close to achieving the EU objectives five or six years ahead of schedule. To achieve this target, Menorca should reduce only 20.3Kt of CO_2 in seven years. In addition, the emissions per capita of de jure inhabitants have reduced from 8.3t in 2005 to 6.2t CO_2/inhabitant.year in 2013 - 25.3% less- (when measured per de facto inhabitants has actually decreased from 7.4t to 5.2t CO_2 inhabitant.year - 29.7% less-). Data compiled from OBSAM, 2014.

Reducing GHG emissions in recent years is partly due to the economic crisis that has continued since 2008. The economic crisis has reduced economic activity, which has resulted in a reduction in electricity consumption.

o Renewable energy: Since 2004, there has been a park with four turbines that produces a total of 3.2MW (800 KW each). Each household currently consumes in average potencies d'1-2KW; so, the maximum output can reach four mills supply nearly 3,200 families or street lighting throughout Menorca. In 2013, the production of wind energy was 6,035MW.h, it accounted for 1.25% of the electricity consumed on the island. It has been estimated that the park could reduce the emission of 6,000t of CO_2 a year. However, the contribution to emissions reduction target is neutral because in 2005, the reference year, they were already operating.

In 2008, two solar parks that generated 1MW and 3MW respectively, were installed. These installations, plus a few small producers of solar energy, generated 9,359.3MW.h in 2013, representing 1.93% of the electricity consumed in Menorca.

Both wind and solar power provide 3.2% of the island's electricity consumption.

o Energy efficiency Plan: Since 2002, campaigns were conducted to improve the energy efficiency of public lighting, lights bulbs were replaced with more efficient bulbs, lamps were redesigned to reduce light pollution, astronomical clocks for automatic light control were installed. The result has reduced consumption by 1,000MWh/year.

o FERME Project: Promotion of renewable energy and sustainability in rural areas in Menorca Biosphere Reserve.

FERME Project. (http://www.biosferamenorca.org/Contingut.aspx?IdPub=485). This project has launched a series of actions to improve the energy efficiency of farms as below.

- Course of Renewable Energy and energy consumption for installers.
- Course of Energy Efficiency and Renewable Energy on farms.
- Study the potential for improvement in energy efficiency of agricultural and livestock farms in the Menorca Biosphere Reserve.
- Energy Audit or agricultural and livestock holdings
- Energy Audit and Agricultural Cooperatives.
- Awareness Day on renewable energy in rural areas of Menorca.
- Good practice guide to saving energy in agriculture

The expected result after the completion of the project is that it can achieve a reduction of between 5 and 15% water consumption and energy on farms.

o Reduction of urban solid waste: Urban waste is a major source of GHG emissions. Baleares accounted for 3.2% of total GHG, so its reduction contributes to the reduction of emissions. Waste production in Menorca peaked in 2003 with 65,689.7t, since then it has been reduced to 56,970.6t in 2011, which implies a reduction of 13.3%. Meanwhile, the recovered waste has progressively increased: in 2003, 16.4% were recovered while in 2012 a 20.6% of recovery was achieved. So the total reduction of waste not recovered was 17.6% from its 2003 peak. The reduction of waste production per capita was better (since in this period has also been an increase in the population). In 2003, every inhabitant de jure produced 1.9kg/year, while in 2012 it fell to 1.3kg/year representing reduction of 34.0% (when calculated per population de facto, values are 1.6 kg/year in 2003 to 1.1kg/year in 2012 representing a reduction of 32.7%). Data based OBSAM 2014.

o Adaptation of forests to climate change: The *Consell Insular de Menorca* is developing the EU LIFE + project "Sustainable Forest Management in Menorca in the context of climate change." (LIFE+07ENV/I/000824) (http://lifeboscos.cime.es/). The project started in January 2009 and has a planned duration of five years with a total budget of 1,444,385 Euros, financed 50% by the LIFE + Programme of the European Union.

The main objective of the project is to contribute to the adaptation of the Mediterranean forest ecosystems to the negative impacts of climate change through sustainable forest management.

o Environmental education and training operates some courses. The major courses are the following two.

- Congress on Renewable Energy and Sustainability Island Territories, 2013: The Menorca Biosphere Reserve Agency organized the first Congressional Renewable Energy and Sustainability in Island Territories, as part of the events celebrating the 20th anniversary of the declaration of Menorca Biosphere Reserve.

- International Summer University Menorca - Illa del Rei opened the following two courses.

· Course: Energy first Century (2011)

· Course: The climate of the twenty-first century (2014)

3. Mauritius Island

The impacts of climate change are already apparent through an accelerating rise of sea level, a decreasing trend in annual rainfall, an increasing trend in temperature, an increase in frequency and intensity of extreme weather events, as well as recurrent floods and droughts.

From 2000 to 2006, the net greenhouse gas (GHG) emissions rose by 16.8% in the energy sector, which is the highest contributor to national emissions, with an annual average increase of 2.7%. The land use change and forestry (LULUCF) sector represented a net removal of CO_2 from the atmosphere during 2000–2006. Due to the conversion of some 300ha of forest land for a dam, this net removal was much lower in the year 2000. Mitigation measures noted in the SNC include renewable energy; reducing traffic congestion which is one of the main causes of high level of CO_2 emissions in the transport sector; managing landfills to reduce emissions, possibly through direct conversion to electricity or through methane produced during composting or gasification; programmes in the agricultural sector to reduce burning of residues and promote their conversion to composts, to be used in lieu of inorganic fertilisers; and enhancing sink capacity through better management of existing forests while reducing timber exploitation.

The main mitigation measures implemented since 2000 include:

Shift to energy-efficient appliances and buildings;

Promotion of solar water heaters through financial incentives;

Installation of four wind turbines in Rodrigues;

Flaring of landfill gas;

Partial replacement of sodium vapour lamps for street lighting with energy saving lamps;

Setting-up of endemic gardens in schools to enhance sink capacity and promote awareness;

Planting of mangroves as sinks to CO_2 and initiation of an afforestation and tree planting campaign;

Phasing out of HFCs and PFCs;

Replacement of household incandescent bulbs with energy saving lamps; and

Increasing the energy conversion efficiency of bagasse.

3. 1: Measures Being Undertaken to Address Climate Change

In 2010, the following duties were imposed to a newly created Climate Change Division in the Ministry of Environment and Sustainable Development.

- Develop a climate change mitigation and adaptation framework;

- Coordinate national, regional and international projects in relation to climate change and sea level rise;
- Conduct and report greenhouse gas (GHG) emission inventories;
- Devise and coordinate the implementation of an inter-sectoral climate change monitoring programme and its reporting;
- Identify and coordinate Research & Development priorities associated with climate change and sea level rise;
- Follow up on matters pertaining to climate change in national, regional and international fora;
- Contribution in Public Outreach Programme.

The Africa Adaptation Programme (AAP) is one of the major climate Change adaptation programme. Implementation started in January 2010 and was successfully completed in February 2013. The main objective of the AAP was to integrate and mainstream climate change adaptation into the institutional framework and into core development policies, strategies and plans of Mauritius. The key sectors that are considered under the AAP are Disaster Risk reduction (DRR), Environment, Fisheries, Agriculture, Education, Health, Tourism and Infrastructure. The projects comprise the development of climate-resilient policies, strategies, legislations, action plans, as well as capacity building, research and raising awareness 31 activities have been completed under the programme. Below are some of the key achievements from the AAP:

Long-term Dynamic Modeling: Disaster Risk Reduction Strategy and Action Plan, including Risk Maps in relation to inland flooding, landslide and coastal inundation for the Republic of Mauritius.

Policy Reports/Documents Produced

o A National Climate Change Adaptation Policy Framework

o Policy Recommendations to mainstream climate change adaptation in the Environmental Impact Assessment and Integrated Coastal Zone Management process and guidelines

o Climate Change Adaptation Strategies and Action Plans in the Agricultural, Fisheries, Tourism for both Mauritius and Rodrigues and Water Sector for Rodrigues.

o A draft Climate Change Bill has been prepared.

Institutional Strengthening through training of some 2600 professionals and other stakeholders for building resilience against climate change (Agriculture, Construction, Climate Modeling and Analysis, Disaster Risk Reduction, Education, Environment, Fisheries, Finance, Gender, Health, Tourism and Water)

o African Mayoral Consultation Forum in Port Louis, July 2011. 75 participants from local authorities attended.

o Training for the Review and Development of Climate Resilient Policies in Mauritius and Rodrigues, August and October 2011.

o Training of Trainers and Capacity Development on Mainstreaming Gender in Climate Change and Community-Based Adaptation, April 2012.

o Development of pedagogical materials and teachers' guide on Climate Change Education and Training for Primary/Secondary School Teachers, Inspectors and Head Masters/Rectors, April 2012.

o Training of Health Professionals on climate-related health impacts, May 2012.

o Training workshops for Architects and Engineers on Climate Change Adaptation in the Building Sector and training of Engineers on Climate Change Adaptation for Road Infrastructure, August 2012.

o Regional workshop on Climate Financing - leveraging public finance to catalyze private sector engagement for climate resilient development, August 2012.

o Training of onion planters on use of salinity meter, salinity management and mangrove plantation, August 2012.

o Workshop on Climate Change Knowledge Management, September 2012.

o Workshop for Media group and Communication Managers, October 2012.

o Workshops on climate change for strategic level stakeholders including MID

Steering Committee Members, Gender and Youth Associations, October 2011 and October 2012.

o Workshop on presentation of research findings for studies on climate change, December 2012.

o Workshop for Village Council Leaders on enhancing climate change resilience at village council level including distribution of plants and bins to local authorities, January 2013.

Sensitisation of some 25,000 people on Climate Change across the Republic of Mauritius

o Awareness Campaigns. Awareness Week on Climate Change, Symposium and Exhibition, University of Mauritius, July 2011. A Mobile Graphic Exhibition (bus) on climate change was put on display at primary schools, secondary schools, Municipal Councils, District Councils, Social Centers and Commercial Centers around Mauritius, April 2012.

o Exhibition on climate change at Rajiv Gandhi Science Centre, June 2012.

o Climate Change Knowledge Fair in Mauritius, October 2012.

o Climate Change Knowledge Fair in Rodrigues, January 2013.

Demonstration Projects Undertaken

o Coral farming activities at Albion, Pointe aux Sables and Trou aux Biches in Mauritius and at Graviers and Hermitage in Rodrigues, 2011 and 2012.

o Installation of seawater temperature sensors at 5 stations in Rodrigues (Riviere Banane, Anse aux Anglais, Grand Baie, Plaine Corail and Pointe L'herbe), April – June 2012.

o Provision of salinity meters and training of onion planters on the South East Coast of Mauritius and the plantation of mangroves at Petit Sables, Grand Sables and Bamboux Virieux, October 2012.

o Setting up of an Endemic Garden and an Information Centre at Panchavati, December 2012.

o Raising awareness to enhance resilience of vulnerable communities including equipment donations, December 2012 and January 2013.

o Setting up of 7 Agro-meteorological Stations as part of an Agricultural Decision Support System in different regions namely at; Wooton, Richelieu, Flacq, Plaisance, Plaine Sophie, Reduit, and Barkly to provide timely and vital information to planters for a sustainable agriculture, January 2013.

Promotion of Research on Climate Change Adaptation

o Evaluation of the vulnerability of coastal communities to climate change in the island economies - The case of the Republic of Mauritius by Prof. S. K. Sobhee, University of Mauritius.

o Energy futures of Mauritius in a carbon constrained world by Mr X. Koenig, Ecological Living In Action Ltd.

o Use of compost by farmers as an adaptation strategy for climate change: Land application and simulation studies by Dr (Mrs.) G Somaroo, University of Mauritius.

o Climate Change and agriculture in Mauritius - impacts and vulnerability assessment by Mr R. Sultan, University of Mauritius.

o Assessing the impacts of climate change on the Phenology of Native Mauritian Plants by Mrs. P. Tatayah, Mauritius Wildlife Foundation.

o The use of system dynamics approach to identify integrated coastal zone planning and management indicators for Mauritius: A performance evaluation model by Dr C. Bokhoree, University of Technology, Mauritius.

o Modeling the Influence of Large Scale Circulation Patterns on Precipitation and a Multivariate Drought Analysis for Mauritius by Mr. A. K. Sohun,Scinova Consulting Ltd.

o Development of Offshore Wind Maps for Mauritius by Mr. K. Kathapermall, Mauritius Research Council.

o Safe and Sustainable Utilisation of Coal/Bagasse Ash in Agro-ecosystems as Soil Amendment for Crop Protection by Prof. V. Lalljee, University of Mauritius.

o Assessing the Potential Use of Coal Ash and Bagasse Ash as Inorganic

Amendment in the Composting Process of Municipal Solid Wastes: Improvements in Compost Quality for Agronomic Applications by Prof. (Mrs.) R. Mohee, University of Mauritius.

o Encapsulated Use of Bottom Ash in Concrete by Prof. Ramjeawon & Mr. A. Cadersa, University of Mauritius.

o Setting up of a Climate Change Information Centre at the Ministry of Environment and Sustainable Development to provide up-to-date information on climate change and for informed decision making.

o Installation of a High Performance Data Server at the University of Mauritius for climate modeling and for research purposes.

Technology Needs Assessment (TNA): The Technology Needs Assessment project has also been completed in March 2013. A technology action plan to implement technologies to reduce greenhouse gas emissions in the energy industries sector has been developed. In addition, technologies that support adaptation in the agricultural, water and coastal zone sectors to climate change which are consistent with national development priorities has been developed.

3. 2: Initiatives in Other Key Sectors

Agriculture Sector: Food Security Fund has been established to increase the resilience of Mauritius towards food self-sufficiency by increasing production of local foodstuff and by partnering with neighboring countries at the regional level.

Water Sector

o Preparation of an integrated water resource plan to harness additional water resources, along with water network maintenance to conduct hydrological studies, boosting efficiency of water usage, and amending water-related legislations.

o Mini-Hydro power plants have been set up at La Nicoliere Feeder Canal and

Midlands Dam

o Construction of additional storage dams ~~is~~ are being explored at Bagatelle

Coastal Zone

o Setback policies: increased setback from 15m to 30m of the high-water mark;

o Appropriate frameworks for the sustainable management of sensitive coastal zones and environmentally sensitive areas have been elaborated and the recommendations are under implementation;

o An Inter Coastal Zone Management Framework has been developed.

o A capacity development for Mauritius' coastal protection and rehabilitation is in progress.

Fisheries

o Marine Ranching to enhance and sustain marine resources and to ultimately sustain livelihoods.

o In 2012, a total of 100,000 fingerlings of ‘cordonnier’ released at the Blue Bay Marine Park – La Cambuse, the Fishing Reserves of Poste Lafayette, Trou d’Eau Douce and Riviere Noire.

o Coral Farming in ocean based nurseries in view to restore the degraded coral reefs around the island.

o Mangrove propagation to restore mangroves with a view to rehabilitate and reforest denuded areas and sensitise the younger generation and the general public on the concept of coastal environment protection.

3. 3: Reduction Target of Greenhouse Gas Emission

<Table 14> shows the projected cumulative reduction of GHG emission in Mauritius.

<Table 14> Projected Cumulative Reduction of Greenhouse Gas Emission in Mauritius Island

	Potential Mitigation (Gton CO_2 eq)			Potential Mitigation (%)		
Year	2020	2030	2040	2020	2030	2040
Energy Industries	379	1055	1971	14	33	49
Transport	252	400	534	21	25	25
Agriculture	29	31	31	12	12	12
LULUCF	-78	-132	-183	43	85	159
Solid Waste	622	616	622	81	74	62
Wastewater Handling	324	347	334	56	61	61
Total	1528	2317	3309	28	37	42

Source: Mauritius Meteorological Services, 2010)

Note: The negative figures for Land Use, Land Use Change and Forestry means that CO_2 is being absorbed and not emitted.

4. Príncipe Island

The Democratic Republic São Tomé e Príncipe National Climate Change Adaptation Strategy and the second national communication (2011) to the Climate Change Convention provides a comprehensive description of the climate change scenarios for the entire country (Island of São Tomé and Island of Príncipe), as well as the policies and actions that are related with adaptation and mitigation. Despite being an integrated national strategy covering both Islands as a whole, there are some specific recommendations for Príncipe Island.

4.1: Mitigation

Mitigation measures are established for the most relevant sectors, covering energy and transportation, land use, forests, agriculture and farming, waste, industry and building.

Although São Tomé e Príncipe's greenhouse gas emission level is extremely low when compared with the Annex I countries, it is extremely committed in regards to the implementation of mitigation measures. Particular interest is shown in increasing the renewable component of energy production through hydroelectric, wind and solar sources. Changes in legislation and price policies are expected for the energy sector, as well as for the prevention of pollution and land use. Agro-forestry techniques will be improved with land planning and urban development rules.

4.2: The Projects/Actions Being Launched by Strategy

One of the major priorities for São Tomé e Príncipe lies on the need of solid and technically sounding information on the meteorological and climate change variables. Thus, enhancing technical and institutional capacity ensuring the collection of liable data is one of the main priorities.

Through bilateral and multilateral cooperation projects, São Tomé e Príncipe will implement all over the country mini-hydric dams for electric power production as well as land fill units for urban solid waste.

Specific interventions for Príncipe Island include financial support through the national budget and Inclusion of Príncipe Island on the national networks for data collection.

Replication of ongoing and planned national projects, which are currently restricted to the Island of São Tomé, such as:

- o Mini-hydric damns and electric power production units
- o Reutilisation of rain water for irrigation and domestic use
- o Introduction of improved stoves allowing the reduction of charcoal consumption and consequently decreasing the use of forest
- o Massive reforestation with indigenous and endemic species
- o Introduction of environmental issues in the national school curricula

o Resettlement of particular fishing communities by installing social facilities and infrastructures away from the shore line

o Introduction of climatic alert systems for preventing natural disasters

5. St. Kitts Island

The vision for the sustainable development of the Federation of St. Kitts & Nevis calls for the integration of sustainability and environmental considerations within all sectors. In view of ensuring the country's state of readiness for adaptation to climate change, detailed and measurable sectoral objectives and targets have been established. The measures for responding to climate challenge are based on two major aspects:

o Reduction in emission of greenhouse gases

o Adaptation to the identified sources of vulnerability

5.1: Objectives and Targets

The following five are set up as the objectives.

o Protection of natural systems maintaining the genetic diversity of species and preserving resilience and productivity of natural systems

o To provide long term prosperity with lasting and secure livelihoods minimising resource depletion, environmental degradation, cultural disruption and protecting human health

o Reduction of country's dependence on non-renewable energies through conservation and efficiency

o Development of information systems and analytical techniques, facilitating environmental management

o Improvement of land planning and land use enhancing a balanced development among districts, and efficient system of settlements, optimum use of natural resources and conservation of the dominant scale and character of the natural environment.

As for the targets:

o Reduction of chemical and particulate air pollution by 50% by the year 2020

o Reversal of deforestation, desertification and other land degradation by the year 2020

o Achievement of sustainable exploitation of forest resources as well as their protection

o Increase in the use of renewable energy sources

o Decrease in the use of chemical fertilisers

o Improvements in the quality of potable water and air

5.2: Strategies and Actions

Several actions strategically aligned with the objectives and targets are adopted, including:

o Building and strengthening human and institutional capacity

o Establishment of adequate legal and institutional frameworks and mechanisms facilitating the integration between the economy and the environment

o Revision and harmonisation of national planning and environmental legislation

o Encouraging the adoption of more effective environmental management practices and technologies

o Ensure compliance with all environmental, planning and infrastructure guidelines, standards and regulations

o Application of the polluter-payer principle

o Promote regional and international cooperation in environmental matters

Mitigation

Specific mitigation and adaptation measures are established for ~~the~~ different sectors. The residential sector has given priority to creating and promoting an enabling financial and fiscal environment to adopt an efficient energy, which includes the introduction of renewable technologies. On the transport sector, mitigation of greenhouse gases will be approached through planning and improvement on the traffic management. The energy sector will pay attention to the optimization of existing power plants for more efficient use of fuel. Switching from liquid fossil fuels to natural gas combined with the retro-fitting of existing plants with modern efficient technologies will also be implemented. Incentives for investment in renewable energy and removal of policies that hinder the application and use of new technologies are expected.

Mitigation options have not been developed for the industrial, agricultural and waste sectors based on the insignificant levels of greenhouse gas emissions.

Adaptation

Adaptation measures will cover several sectors such as water resources management, agriculture, tourism and human health.

For the water sector the following measures are included: Rational use of water enforced by the national water authority; Controlled rate of water pumping from aquifers; Conservation of protective forests allowing higher rates of infiltration of rainfall to aquifers; Protection of contamination of underground water from pollution sources.

For agriculture, the potential adverse impacts of climate change require that research and analysis be initiated into the potential for developing and introducing cultivars to the expected climatic conditions.

For tourism, the following adaptation options have been identified: Developing and enforcing environmental policies and regulations for tourism activities that take in account the issues of sea level rise and other climatic variables; Redirecting tourism from activities that adversely impact on natural ecosystems toward more societal activities of historical, traditional and cultural nature, not associated with climate change issues; Encouraging tourism resorts to make greater use of locally-produced goods so as to reduce costs.

For human health, the adaptation measures include the following: Developing a healthcare forecast system for acute respiratory, cardiovascular and other diseases, for which weather and climate conditions constitute the triggering mechanism; Strengthening of data collection and reporting systems; Vaccination campaigns for all possible diseases; Sustained and improved disease vector control; Educational and promotional health related public campaigns; Promoting a healthy life style.

Chapter 6
The Impacts of Climate Change

In this chapter, the climate change impact analyses were confined not to the entire island where the five research BRs are located, but within the boundary of the five BR zones. In cases where the entire island is designated as a BR, the entire island was the target to collect the data on the impact of climate change. The following five sectors were examined on BR zones' impact of climate change.

First: The ecological, geographical, and geological impacts occurred from rising temperatures, drought, flood, landslide, soil loss, and forest fires.

Second: Changes in agricultural activities, such as production output, product being cultivated, production district, and increase or decrease in agricultural production areas where agricultural products are cultivated in terrestrial BRs.

Third: For BRs where tourism resorts run in terrestrial BR, the change in tourism revenue, number of tourists, and increase or decrease in number of days tourism resorts are closed.

Fourth: For BRs where marine is included, the change in marine ecological system, fish species disappeared, fish species being endangered, and new fish species appeared.

Fifth: For BRs where other climate change impacts, except for the above four sectors appeared, the unique ones.

The above five sectors are based on a desk research which goal is to collect data from existing publications. Thus, the sectors for which there is no published data available are excluded in this chapter.

Another important reminder in this chapter is that change of a reality between two periods of time is a result caused by multi-factors. Due to such a characteristic change of profile, it is almost impossible in empirical analysis to extract the net influence of a factor impacting on the determination of the change of ~~a~~ reality. This methodological limitation is inherent in this chapter in analyzing the impact of climate change on island and coastal biosphere reserves.

1. Jeju Island BR

1.1: The Impacts on Terrestrial Ecology

There are biodiversity changes in vertical and horizontal distribution areas due to the change in plant species' growing areas. The vegetation belt is also changing from changes in the composition of species. Nonetheless, there are no comprehensive empirical research on the change in biodiversity except for the extinction and the reduction of population of endemic species (Kim, 2013).

However, three existing research publications about climate change impact on plants in Jeju BR are available (JSSPG, 2010: 49; Kim, et al. 2012, Kim, 2013). Two existing research publications about climate change impact on animals are also available (JSSPG, 2009: 103-109. JSSPG, 2010: 49). The former focuses on changes in the vegetation belt, and the latter on insects and birds.

Flora and Vegetation

Overall, temperate and arctic plants in the vegetation belt moved 200-1,200m northwards. The area of alpine plants was reduced by plants located in the lower part to move upland. Their blooming, fruiting and fertility of seeds changed.

The area of the vegetation belt changed remarkably by forest for 42 years from 1967 to 2009 as below (JSSPG, 2010: 49; Kim, et al. 2012, Kim, 2013).

Abies koreana **E.H.Wilson Forest:** The total distribution area of *Abies koreana* E.H.Wilson forest was reduced by 34%. Particularly, their distribution area which is located higher than 1,000m from sea level was reduced to 19.9% in 2009 from 30.2% in 1967. The vegetation belt is moving northward. In addition, the species composition of *Abies koreana* E.H.Wilson is changing. In accordance with this change, subalpine bush is formed in areas where *Abies koreana* E.H.Wilson forest were formed.

The Forests of Other Plants: In order to identify the change in forest areas, in a field survey was conducted in three sites in 2009 – Sajebi Hill, Gaemidung, and Donnaeko, covering pine tree forest, shrub forest, and other plant forest.

o Pine Tree Forest: The total area of pine tree forest is 1,320ha which occupies 8.6% of Jeju Island BR. Its elevation ranges between 630m and 1,500m. More than 80% of pine tree forest distributes between 1,000m and 1,400m from sea level. Pine tree forest in Sajebi Hill increased by 8.3ha, showing 11.57ha in 1967 and 19.87ha in 2009. Pine tree forest in Gaemidung increased by 34.02hs for 42 years from 1967 to 2009. However, pine tree forest in Donnaeko increased by 27.07ha.

o Shrub Forest: The area of shrub forest in Sajebi Hill decreased by 4.51ha, showing 26.72ha in 1967 and 22.20ha in 2009. the total area in Gaemidung decreased by 5.74ha. However, the total area in Donnaeko increased by 28.42ha.

o Other Forests: In Sajebi Hill, areas of other forest being composed of trees, except *Abies koreana* E.H.Wilson, pine tree and shrub decreased by 2.86ha, showing 107.32ha in 1967 and 104.86ha in 2009. The area in Gaemidung also decreased by 5.74ha, while the area in Donnaeko increased by 1.35ha. However, the mixed stand forest in the three survey sites being mixed mainly with need leaf tree and evergreen lucidophyll tree increased by 99ha, showing 725.1ha in 1967 and 923.4ha in 2009.

Pine Wilt Disease: Wilt disease is any number of diseases that affect the vascular system of plants. Attacks by fungi, bacteria, and nematodes can rapidly kill plants, large tree branches or even entire trees. Wilt diseases in woody plants tend to fall into two major categories, those that start with the branches and those that start with the roots.

Commonly known as pine wood nematode or pine wilt nematode is a species of nematode that infects pine trees and causes the disease pine to wilt. It is probably native to North America, where it was first described from a longleaf pine in Louisiana. It occurs in much of the United States, Canada, and Mexico. It also occurs in Japan, China, Taiwan, Korea, and Portugal.

The occurrence and state of pine wilt disease (hereafter PWD) in Jeju Island including BR sites are summarized as below (JSSGP, 2014; Lee, et al., 2014).

The main cause of PWD is that trees get water stress and result in weakness against the 2nd insect plague. In addition, high temperature causes a rapid diffusion of pine wood nematode. Long-term drought causes moisture deficiency. Weak control activity within an appropriate time (such as not removing the dead pine trees) causes ~~a~~ rapid damage to the tree. Pine trees form a forest with less other trees, and result in the absence of a natural enemy near the village such as woodpeckers.

The first occurrence of PWD in Jeju Island was September, 2004. It was lulled since 2006. However, in 2013, 40% of the entire pine forest (16,284ha) was infected with pine wood nematode and the number of dead pine trees were 287,000. In 2013, the average temperature in Jeju Island in July and August was 27.5~29.1℃. This is 1.5~2.1℃ higher than the average temperature during the past three years. The average precipitation days were 2.3~4.0 days, which is 0.7~3.5 days fewer than the average during the past three year. Such an abnormal climate provided a fittest environment to the diffusion of pine wood nematode

In 2014, Jeju Island's climate including temperature, precipitation, precipitation day, and drought was not extreme. However, 324,000 pine trees close to dead trees being infected by PWD were removed.

Others: Some rain forests emerge in coastal areas, valleys, waterfalls, cave terrain , and lava fields. For warm temperate evergreen lucidophyll forests, the number of population decreased at high latitude, but increased at low latitude.

The distribution of *Miscanthus sinensis* Andersson is expanded to upland. For example, about 200 populations are discovered between 1,383-1,607m from sea level. However, they inhabit intensively between 1,400-1,500m from sea level, competing fiercely with *Empetrum nigrum* var. *japomicum* K.Koch, *Rhododendron yedonense* f. *poukhanense* (H.Lév.) M.Sugim. ex T.Yamaz., *Juniperus chinensis* var. *sargentii* A.Henry, *Thymus quinquecostatus* Celak, *Primula modesta* var. *hannasanensis* T.Yamaz., and *Sasa palmata* (Bean) E.G.Camus, etc. The competition results in the decrease in or extinction of population of alpine plants such as, in particular, *Empetrum nigrum* var. *japomicum* K,Koch, *Juniperus chinensis* var. *sargentii* A.Henry, *Thymus quinquecostatus* Celak, and *Primula modesta* var. *hannasanensis*

T.Yamaz. etc.

Floral weather being defined as the time of germination, blossoming, and leaf unfolding is a sensitive indicator of how plants react to climate environment and climate change by region. This is because the floral weather in spring is advanced when temperature rises. As such, many plant species in Jeju Island BR begin to bloom earlier. For example, cherry blossom blooms six days earlier compared to several decades ago.

Fauna

Insect: It is a general trend that for most insects, their development day decreases and their outbreak gets earlier as temperature rises. A wide range of insect species inhabit in Jeju Island including Jeju Island BR (See page 14 in Chapter 1). However, no research has been conducted yet on the change in development day and outbreak of for insects. Significant changes due to climate change in Jeju Island BR has decreased in population of *Aphantopus hyperantus* (Linnaeus) and *Eumenis autonoe* (Esper) which are rare insects inhabiting in subalpine zone, and increase in appearance ratio of subtropical insects such as *Reticulitermes speratus* (Kolbe) (JSSPG, 2010: 49).

Bird: Two remarkable changes in bird ecology caused by climate change occur (JSSPG, 2010: 49). One is the emergence of subtropical birds. The other is that some migrating birds in winter become the resident birds in Jeju Island, while some migrating birds in winter moved their destination to the southernmost region of the Korean peninsula.

For the former, it was observed that subtropical birds such as *Hydrophasianus chirurgus* (Scopoli), *Sturnus sericeus* (Gmelin), and *Phyacornis fuliginosus* are reproduced. For the latter, cormorant (*Phalacrocorax* capillatus) and *Tachybaptus* ruficollis are the representative migrating birds to become the resident birds in Jeju Island, while *Platalea* minor is a representative migrating bird which does not come to Jeju Island from Siberia in winter

Others: No empirical data are available on other animals being impacted from climate change. However, it is assumed that bird hatching time, amphibians, reptiles, and insects becomes earlier. Another assumption is that for mammals (deer, weasel, and rabbit, etc.), ecological changes such as time of childbirth and/or hibernation emerge.

1. 2: The Impacts on Geology and Geography

Only one empirical research on the geological change in Jeju Island BR is available (Sohn, et. al. 2009). Sohn et al. discovered the naked lands and caved valleys formed by rainwater here and there in the grass area are distributed in the subalpine zone close to the top of Mt. Hallasan. Slope collapse, soil erosion, and sedimentation are progressed rapidly in the vicinity of Baengnokdam which is the crater located on the top of Mt. Hallasan. However, it is not sure that to what extent these are caused by climate change.

An empirical research on the change in Jeju geography is available (JSSPG, 2009: 144-157). This research is based not on Jeju Island BR, but on the entire Jeju Island. The coastal areas are eroded due to sea level rise. The erosion is progressed mainly in pocket beach, tuff cone which is a volcanic sedimentary layer, and tertiary marine sediments. These erosions result in loss of facilities and damage on the villages in coastal areas.

1.3: The Impacts on Agriculture

As explained in Chapter 3 on Jeju Island BR, five agricultural products are produced in the BR, using the new BR logo on their products to promote Jeju BR; shiitake mushroom, green tea, *Sasa palmata* (Bean) E.G.Camus, wood-cultivated ginseng, and pork.

However, no existing empirical research is available on the change in their cultivation mode, arable land, production output, and profit which might be caused by climate change.

On the other hand, two comprehensive researches on the impact of climate change on agriculture in the entire Jeju Island are available (JSSPG, 2009: 193-224, JSSPG, 2010: 49-50). They conclude that climate change impacts on the following six agricultural sectors.

Firstly, the arable land of tangerine (Citrus unshiu S.Marcov.) and subtropical fruits, all of which are the major agricultural products in Jeju Island, moves northward due to rise in temperature. The sugar content of tangerine is changing.

Secondly, subtropical or tropical crops such as pineapple, and mango, etc. can be cultivated in the naked land.

Thirdly, agricultural products are damaged by the invasion and settlement of exotic diseases and insect pests. For example, *Liriomyza trifolii*, *Frankliniella occidentalisi* Pergande, and *Thrips palmi* Karny settle down in Jeju Island.

Fourthly, exotic plants invade new sites where there are no pathogenic fungus and insects in the mechanism of food-chain. This results in a natural selection of original plants due to the lack of their adaptation to the exotic plants which are new neighborhoods.

Fifthly, exotic weeds such as *Solanum viarum* Dunal, *Amaranthus spinosus* L., and *Hypochaeris radicata* L. invaded and settled down in Jeju Island. They have a high possibility to weed out the indigenous species and derive them to extinction.

Sixthly, an earlier seeding period for barleys and leafy vegetables, and their production output is decreasing.

1. 4: The Impacts on Tourist Resort

As explained in Chapter 3 on Jeju Island BR, tourism activities in the buffer zone are conducted mostly in public tourist resorts, such as Natural Forest Resorts, Roe Deer Eco-Park, Saryeoni Forest Trail, and Seogwipo Provincial Marine Park, etc.

The majority of Jeju Island BR's economic activities are located in the transition area. There are 21 golf courses, 31 public and private facilities that are related to tourism, 26 accommodations, and 15 schools, etc.

Jeju Special Self-Governing Province publishes tourism statistics annually, covering a wide range of sectors such as number of tourists, tourism revenue, length of stay, and transportation used, etc. on the basis of entire Jeju Island.

However, no data on the individual tourism sights that are located in Jeju Island BR buffer zone are available.

1.5: The Impacts on Marine Ecology

As is shown in <Map 2>, three islands and the marine around them are designated as a site of Jeju Island BR. No existing publications are available for the impact of climate change on terrestrial ecosystem of the three islands and their neighboring marine.

However, two publications are available for the impact of climate change on the entire Jeju marine (JSSPG, 2009; 2010). They cover the change in sea algae and marine ecology, as below.

Sea Algae (JSSPG, 2009: 126-127): Sea lettuce is reproduced throughout the year and restrains the reproduction of other sea algae. Crustose coralline algae increase rapidly. Especially, crustose coralline algae is known as a major dominant species informing the decrease in the biodiversity of sea algae.

Marine Ecology (JSSPG, 2009: 255-257, JSSPG, 2010: 48): Marine ecology consists of physical environment and the species inhabiting in the area. The former includes depth of water, seawater temperature, ocean current, salinity, and sea-floor topography, etc. The latter includes plankton, nekton, and benthic organism, etc. The change in physical environment influences the organisms living in the marine ecosystem in terms of their reproduction, growth, and breath, etc.

In this context, the spreading whitening (efflorescence marine), which is caused by the change in marine ecosystem due to the increase in carbon dioxide in atmosphere and seawater temperature rise, is a major indicator informing a significant change in marine ecology across the coast of Jeju Island.

Physalia physalis, which is observed mainly in Philippines and Okinawa, appears in the coastal area during the summer. The sea algae being discovered in subtropical ocean is reproduced. The rapid increase in reproduction of both crustose coralline algae and articulate coralline algae promotes spreading whitening (efflorescence marine). *Martensia denticulate* which is a subtropical sea algae is reproduced rapidly from May to July, and reduces the implantation of beneficial sea algae. *Herdmania momus*, *Heteractis aurora*, and *Alveopora japonica* disturb the early implantation of sea algae.

Enteromorpha prolifera, which is a green algae that reproduces vigorously in the coast of eutrophication, flowed into the coast of Jeju Island in July and August, 2008, moving along with the ocean current from Qingdao, China, and impacted on sandy beach and fishing ground.

A new fishing ground of cutlassfish was formed. Cold current fish species are disappearing, while tropical species, such as tuna are appearing.

2. Menorca BR

2.1: The Impacts on Ecology and Biodiversity

General Changes in the Structure of the Ecosystems

The effects of Spain's climate change on ecosystems and biodiversity was published by Fernández-González (coor.) in 2005. This work assumes two climate change scenarios - an optimistic and pessimistic scenario. For Menorca, the aridity of the climate will increase, from “dry” to “semi-arid”, while the climate would change from “Mesomediterranean” to “Termomediterranean” or even “Inframediterranean” in both scenarios (according the Rivas-Martínez & Loidi’s bioclimes stages classification, 1999). Generically this indicates that mesophilic plant communities will suffer water stress and may be more affected by pathogens and pests, mainly in the hottest and driest borders of their distribution area. Therefore, more xeric communities could move to these zones that now are too wet or cold (Fernández-González et al., 2005b). These vegetation changes, plus the change in the climate itself, could increase the risk of forest fires. Menorca is going through this process - substitution of holm oak forests (*Quercus ilex*) by other woody communities dominated by *Olea europea* or *Pinus halepensis*, as explained in the next section.

It is also expected that wetlands ecosystems (ponds included) that are dependent on rainfall may undergo major changes (desiccation, increased salinity) due to the reduction of freshwater input. These changes have been taking place in the Natural Park of Albufera des Grau for years, which is the core area of the Biosphere Reserve. However, it is very difficult to distinguish the reduction of freshwater input arising from water withdrawals from human consumption or from agriculture.

In the long term, the extension and complexity of the beaches and dunes' ecosystems are likely to reduce significantly due to increased sea level. This process is accelerated by the mass tourism of beaches, lacking appropriate management systems.

It is also likely that there will be reduced populations and a possible extinction of plants and animal species that are deeply affected by the island's habitat change. Likewise, some invasive alien species can be favored. Several particular cases were documented along with some cases of marine environment in the following sections.

Changes on Forest Systems due to Weakening of the Trees and Increased Pests and Pathogens

Holm oaks (*Quercus ilex*) form one of the main forests in Menorca. However, during the last few decades, they are declining and dying-back.Holm oaks that are in areas that suffer from water shortage from shallow soils or sloping areas with sunny exposures are particularly affected. An estimated mortality rate is between 2 to 4.6% and almost 30% of average defoliation (Moralejo, 2010). These holm oak forests are being invaded by other plant species with a more xeric characteristic, such as *Olea europaea*, which causes the substitution of the dominant tree species and changes the ecological characteristics of these forest areas. The process of declining *Quercus ilex* forest has been associated with reduced rainfall and increased temperatures, making many parts of the island are no longer suitable for this species. Similar weakening processes have been documented in the Iberian Peninsula (Gea-Izquierdo et al., 2011; Lloret, 2012).

Moreover, Menorca's holm oak forests are damaged severely by a pest insect (*Lymantria dispar*) which resulted in several consecutive years of massive defoliation of the trees. In turn, it was detected that the expanding of *Botryosphaeria corticola*, a pathogenic fungus, are also severely damaging these trees. The expansion of this fungus may be associated with warmer autumns and winters. In addition, the damaged forests by *L. dispar* were more affected by this fungus. Other holm oak pathogens have expanded due to the weakness of these trees, as *Biscogniauxia mediterranea*. This fungus usually lives on holm oaks but becomes more aggressive when trees suffer water stress (Moralejo, 2010).

In short, the decaying oak forest in Menorca is the result of synergistic effects between weakening trees from tightened weather conditions and expansion of predators and pathogens that take advantage of this weakness.

Increased Risk of Extinction of Endangered Plant Species: The Case of *Apium bermejoi*.

The flora of Menorca has about 60 endemic species representing 5.2% of the total flora of the island (Rita & Palleras, 2006). Seven of these endemic species are protected at the national or international level to be threatened. According to the IUCN criteria, one of these species (*Apium bermejoi*) is in Critical Danger of Extinction. *Apium bermejoi* is a plant that lives in only one location and its habitat is a seasonal stream (it is completely dry during summer). This species has been introduced artificially in five other locations with similar environments. The relationship of this species with wet soils makes it very sensitive to rainfall. It has been documented that the reproduction of this species may fail if there are too long droughts during spring associated with high temperatures. It has also been observed that the germination of this species may be at risk whether there are droughts in the fall as if there is very heavy rain. All these risk factors can be exacerbated if the expected climate change scenarios are accurate (Rita & Cursach, 2013).

Although they are not endemic, three other species that are protected at an European level are associated with seasonal ponds (*Marsilea strigosa*, *Pilularia minuta* and *Damasonium alisma* subsp. *bourgaei*). Their survival is also directly related to the amount of rain, therefore with the change of climate.

2. 2: The Impacts on Geology and Geography

The sea level rising may have significant effects on coastal areas and their associated coastal wetlands. The coast of the Balearic Islands have receded due to erosion (Balaguer et al., 2001). This decline occurred in the rocky coast but also on beaches and dune systems (Balaguer & Prieto, 2008).

The sea level rising associated with climate change will increase this receded coast. However, there are many uncertainties about the extent of this due to the many variables involved (eg. changes in wave direction and the energy associated with the intensity of the winds) (Cendrero et al., 2005). If the prediction of the IPCC (2001) of a 20cm rise in sea level is met, Roig et al. (2013) estimated that the beach line of the longest beach in Menorca (Son Bou) could recede between 6 and 10m by the year 2050. This receding beach line implies a loss of 40 to 65% of the current beach area. In the same prediction, it has been estimated that the flood level for a return period of 10 to 50 years would affect almost all of the dune system. Reduction of the dune systems' surface will cause an increased seawater intrusion in the coastal wetlands, especially if it occurs at the same time with a reduction in freshwater input (due to reduced precipitation and/or increased water consumption). Similar situations will occur in other beaches and dune systems on the island (Balaguer & Prieto, 2008).

2.3: The Impacts on Agriculture

Bluetongue is a viral disease of ruminants transmitted by biting mosquitos

(*Culicoides* spp.). Historically, Bluetongue outbreaks in Europe were rare and short-lived. However, during the last two decades, Bluetongue has become firmly established in southern Europe and since 2006, has occurred in northern Europe. It is considered by many to represent one of the most plausible examples of climate change driving the emergence of a vector-borne disease (Wilson & Mellor, 2008; Guis et al., 2011). There were only two Bluetongue outbreaks in Europe before 1998. This situation changed dramatically after 1998 when the virus was detected in several Greek islands, and has expanded into southern Europe. The spread of this virus is associated with the expansion in southern Europe of *Culicoides imicola*, a mosquito that lives in northern Africa, favored by rising temperatures in recent decades (Wilson & Mellor, 2008). Bluetongue was detected in Menorca in 2003, generating significant damage to sheep on the island. This case suggests that climate change may favor the expansion of other diseases transmitted by Culicoides, such as African Horse Sickness. This is a major risk in Menorca given how important the horses are for the island's culture and festivals.

We have not found documents linking climate change to agricultural production in Menorca. However, if published models of climate change are accurate, it is likely that there will be serious consequences to the island's agricultural/livestock system. The most important agricultural production in Menorca is cow milk and cheese. Livestock production is based on the cultivation of grasses that require a regimen of regular rains in autumn, winter and spring. If an increase of temperature and a reduction of spring rain is the climate trend, it is easy to deduce that farms that do not have their own water resources will undergo serious economically viability problems. In fact, the current trend is the reduction of farm numbers, and the intensification of exploitation of the farms that remain operational. Climate change is likely to exacerbate this trend.

2. 4: The Impacts on Tourist Resort

Climate change will have an undoubted impact on tourism. In 2003, the WTO called for the First International Conference on Tourism and Climate Change in Djerba (Tunisia). Since this conference, there have been countless papers that examine the consequences of global warming on an industry of great importance and are very sensitive to climatic aspects (Agueda et al., 2005). Yet, given the multitude of factors affecting tourism (state of the economy of each country, international conflicts in competing countries, unpredictable natural disasters, etc.), it is very difficult to make predictions considering merely one factor, such as climate change. Nevertheless, Menorca's tourism demands will follow these next trends if applied to the criteria that were specified in those documents.

o Decrease in holiday travel during summer due to too high temperatures and heat waves in the summer.

o An increase of Northern European tourists spending comfortable summer climates in their own countries or region.

o An increase of travel during spring and autumn reducing the strong seasonality that exists today.

Not all authors agree with this prediction, and the real behavior of tourists in the last ten years is opposite to these forecasts, with a concentration of tourism in the summer months. The likely explanation of the reverse trend of the seasonal shift in the Mediterranean region is that beach users prefer the warm weather and tolerate heat stress. In addition, Spanish hotels are air-conditioned and beaches help tolerate the hot weather (Domonkos, 2012).

Moreover, Menorca is a tourist destination that is based on the sun and beaches. It is extremely likely that two elements may affect Menorca's tourism; beach erosion and water scarcity.

Beach erosion can degrade Menorca's main tourist resource and seriously affect its attractiveness as a tourist destination. However, a similar (and in many cases more serious) problem will be in the most of competitive destinations around the Mediterranean, making it difficult to assess what will be its real impact on a specific destination as Menorca.

Water resources can be seriously reduced if precipitation declines and other economic sectors, such as agriculture, increase consumption. However, we already know similar experiences to deduce that the lack of water can be solved by desalination or other technical solutions, and ultimately result in increased energy consumption. As a result, the consequences of the lack of water will be very different depending on the price of energy. Undoubtedly this is a very serious vulnerability for a small territory like Menorca.

Finally, there are many other factors that could affect tourism linked with global change, as the increase of jellyfish in the sea (see section below) or wild forest fires, which could have a big impact on tourists and they are very difficult to forecast.

2.5: The Impacts on Marine Ecology

Decline of Seagrass *Posidonia oceanica*

Posidonia oceanica, a Mediterranean endemic seagrass, which forms extensive meadows, is the dominant ecosystem on sandy sea beds. *P. oceanica* meadows is one of the most valuable Mediterranean sea ecosystems that provides important services including carbon burial, nutrient cycling, coastal protection from erosion, and enhanced biodiversity (Marbà & Duarte, 2010, Jordà et al., 2012). These meadows cover a wide strip of Menorca's coast, distributing from a few meters deep to a depth of between 30 and 35 meters on a sandy seabed and sometimes rocky seabed. It is an almost continuous strip along the south coast, while the north coasts' distribution is discontinuous due to a greater irregularity of the sea bottom (OBSAM, 2010).

This species is particularly sensitive to human disturbances but also have been found that it’s affected by rising seawater temperature. Marbà & Duarte (2010) found that the mortality rates in natural populations in the Balearic Islands increased threefold with a 3◦C increase in maximum annual seawater temperature. Another recent paper (Jordà et al., 2012) that combined empirical data on the reduction of the density of grasslands due to seawater temperature increase of above normal values and models of change in sea temperature in upcoming decades, concluded that this species will reduce their populations in the Balearic Islands to levels below their ecological functionality during the second half of this century. Undoubtedly, if this forecast is accurate, it will be one of the biggest ecological disasters that will occur in the environment of the Biosphere Reserve of Menorca, given the role of this plant as "engineer ecosystems" and the extremely low resilience capacity of this species once an impact on their populations has occurred (Marbà & Duarte, 2010).

Increase of Exotic Invasive Species in the Mediterranean Sea

A direct consequence of sea water warming is an increase in the abundance of thermophilous species, due to shifts in distribution ranges, with a south to north movement trend. Sea water warming affects the entire Mediterranean range, but distribution shifts mainly have been reported in the north western Mediterranean, where Menorca is located (Cardona & Elices, 2000; Lejousne et al., 2010). Species introduced into the Mediterranean sea is a particular case for an expansion of distribution ranges. Most of the species are of tropical origin (Lejousne et al. 2010). Since some years ago, it has been observed that global warming facilitates the invasion of exotic species in the marine environment (Stachowicz, 2002). This relationship between the entry and establishment of tropical species and the heating of the water has been well documented in the eastern Mediterranean (Raitsos et al., 2010), but it also affects the western part and the Balearic islands, where some tropical species of crustacean and fish have been established in our islands due to the heating of the sea water. (p. e. Cardona & Elices, 2000; Lluc & Reviriego, 2000; Mas et al., 2009a; Mas et al., 2009b).

Other well known cases of invasive species of tropical origin are algae, some with a strong ecological impact. 110 species of exotic macrophytes have been cited in the Mediterranean (CIEMS, 2014), nine of which has invasive behavior (Boudouresque & Verlaque, 2002). Five of the latter species found in Menorca (*Acrothamnion preissii, Asparagopsis armata, Lophocladia lallemandii, Womersleyella setacea, Caulerpa racemosa*) all originated in warmer areas (although in Menorca *Womersleyella setacea* lives in deep and cold waters) (Sales et al., 2012). In one case, there has been a synergistic effect between the introduction of an invasive seaweed (*Lophocladia lallemandii*) and a decline of *Posidonia oceanica* in shallow water, probably caused by the heating of seawater (Marbà et al., 2014). On the other hand, it has shown that the colonizing ability of this species of tropical origin increases as the water temperature (Cebrian & Ballesteros, 2010). It is very likely that new invasions of exotic species will occur.

Increase in Iellyfish Populations: The Case of *Pelagia noctiluca*.

For many years ~~ago~~ there are impression and some evidence that the populations of jellyfish and other marine gelatinous organisms are increasing globally. This increase is due to a range of disturbances of human origin, e.g. sea eutrophication, overfishing and rising sea temperatures (Purcell, 2005; Purcell, 2012, Duarte et al., 2013). This opinion is not generally shared, due to the difficulty of obtaining sufficiently long data series and the strong interannual oscillation of the populations of these organisms (Condon et al, 2012). Menorca's case, as in other areas of the Western Mediterranean sea, there seems to be an increase in the presence of a species of jellyfish: *Pelagia noctiluca*. *P. noctiluca* is the most important species of scyphozoan in the Mediterranean sea due to its high abundance, its distribution throughout the Mediterranean sea, and because of its painful sting. It is responsible of most of the bites in the tourist areas in our region (Canepa et al., 2014). Since the late twentieth century there is evidence that blooms of *P. noctiluca* can be conditioned by weather variables (Goy et al., 1989). According to Canepa et al. (2014), the climatic conditions for enhanced reproduction of *P. noctiluca*, and probably the optimal conditions for the formation of blooms, are mild winters, low rainfall, high temperature, and high-atmospheric pressure. Most of these variables correspond to forecasted trends of the models on climate change in our region.

2.6: Others

Health

One of the effects of climate change on health will be the increased mortality associated with increasing temperature. In addition, heat waves that particularly affect the elderly and/or people with pathological conditions make them more vulnerable. In the same way, potential risks associated with climate change would come for the import and installation of vectors of tropical and subtropical diseases like eg *Aedes albopictus* and *Aedes aegypt*i, and ticks of the genus *Hyalomma*. It is also possible the increase in extent of vectors of steppe and dry areas, or even the entry of pathogens from North Africa (Alonso & Vázquez, 2013).

Water Resources

Menora's entire water consumption are either extracted from underground or imported. The reduction in rainfall and increase in temperature that are predicted by climate change models will change the balance of the water cycle in Menorca. The evapotranspiration will increase and the amount of water falling on the island will decline. The expected result is to decrease the water reserve in aquifers, and increased consumption associated with agriculture and tourism. It is also likely that the decline of water quality is from the increase of marine introgression and nitrate pollution. However, the current situation of Menorca is not as complicated as it can be in comparison to other Mediterranean islands (Ljubenkov, 2013; Saurí, et al., 2013).

3. Macchabee-Bel Ombre BR

Up to a few centuries ago, only a few places have maintained their pristine environments only a small number of oceanic islands (Whittaker and Fernández-Palacios, 2007). These islands experienced rapid and distinctive transformations after the arrival of humans and colonisation (Florens et al., 2012; Van der Plas et al., 2012) resulting in biodiversity loss and extinction of many endemic species (Whittaker and Fernández-Palacios, 2007; Caujapé-Castells et al., 2010).

A comparison between the natural settings before and after human arrival indicates the full magnitude of biodiversity loss and ecological transformation that resulted from human impact (Burney and Burney, 2007).

The small tropical island of Mauritius is one of the most recently colonized areas of the world (Cheke and Hume, 2008). After colonization by the Dutch in AD 1638, Mauritius rapidly became deforested (Vaughan and Wiehe, 1937) and several endemic species, such as the enigmatic Dodo went extinct (Cheke and Hume, 2008). Today, native vegetation suffers from many introduced invasive alien plants (Lorence and Sussman, 1986; Safford, 1997; Ragen, 2007; Florens, 2008; Caujapé-Castells et al., 2010; Baider and Florens, 2011). The number of introduced plants (1675 species; Kueffer and Mauremootoo, 2004) far outnumbers the number of native species (691 species of which 39.5% are endemics; Bosser et al., 1976–onwards; Baider et al., 2010).

Despite the small size of the island and the long history of botanical inventories, species new to the Mauritian flora, including endemics, are still being discovered (Florens and Baider, 2006; Le Péchon et al., 2011; Baider et al., 2012; Baider and Florens, 2013). Due to the rapid deforestation of Mauritius, little is known about natural ecosystem dynamics, whereas the ongoing discovery of new species stresses the gaps in the current botanical knowledge and underlines the uncertainties as to which part of the present flora can be considered native.

3.1: The Impacts on Ecology

There has been a relative paucity of research and studies on the impact of climate change on the native vegetation of Mauritius. The majority of studies were concentrated on the impact of invasive alien species on the biodiversity of the native forests which remained the main threat to island biodiversity. However, Strahm (1994) investigated the degradation and restoration of the native forest of Macchabee in 1986. This forest which forms the core area of the BR is about 800ha, is considered as a lower montane rain forest (Vaughan and Wiehe, 1941: Whitmore, 1990) and is severely degraded.

Unfortunately, Macchabee forest rapidly declined; the final blow was from cyclone Carol in 1960 which decimated the forest and caused wide gaps (Strahm, 1994). These were later filled by invasive alien plants (Vaughan, 1968). The 1,000m^2 plot which is now called the Vaughan Plot has been constantly weeded of invasive alien plants since 1986 and is considered as the oldest Conservation Management Area in Mauritius.

Studied by Vaughan and Wiehe (1937, 1941, 1947), the forest was chosen as their study site as it was at that time the least degraded one. In addition to studying Mauritius' vegetation types (Vaughan and Wiehe, 1937), they established a permanent plot of 1,000m^2 in Macchabee and every species occurring there were recorded in detail (Strahm, 1994).

Vaughan and Wiehe (1941) measured and recorded all phanerophytes taller than 50cm high or greater than 1cm diameter. Strahm in 1986 located in the Vaughan Plot and measured all the plants again so that it was possible to measure the species' composition after 49 years (Strahm, 1994). For the study in September 2014, we used the same methodology to record all plant species in the plot so as to try to assess the impact of climate change on the species composition and diversity by comparing the data obtained from these three studies. We expect that seventy six years will be a fair enough time period to assess any possible impact of climate change as the Vaughan plot was constantly weeded since 1986, thus minimizing the threat posed by invasive alien plants.

Change of Species Composition and Number

In the Vaughan Plot, 1,785 individuals comprising of 69 species were measured in 1941 as opposed to 1,137 individuals including 56 species in 1986 and 983 individuals of 67 species in 2014 (<Table 15>).

<Table 15> Comparison of Species Density in the Vaughan Plot in 1937, 1986 and 2014

	Individuals (Inds) ≥50cm tall			Individuals (Inds) ≥ 10cm DBH		
	Number of Individuals	Number of Species	Basal Area (m^2/ha)	Number of Individuals	Number of species	Basal Area (m^2/ha)
Vaughan 1937 (Vaughan and Wiehe, 1941)	1,785	69	126.6	166	35	105.7
Vaughan 1986 (Strahm, 1994)	1,137	56	74.8	130	23	61.8
Vaughan 2014 (un-published)	983	67	72.7	169	33	62.1

The number of individuals in the studied plot decreased sharply by 36% after 49 years and by 14% from 1986 to present time i.e after another 28 years. However, the number of species which decreased significantly in 1986, is now almost at the same level as in 1937 and significantly higher than in 1986. Moreover, the situation is better at the level of individuals greater or equal to 10cm dbh where a significant increase in number of individuals and species has been reported in 2014. It is only the stem basal area which remained almost at the same level as that of 1986.

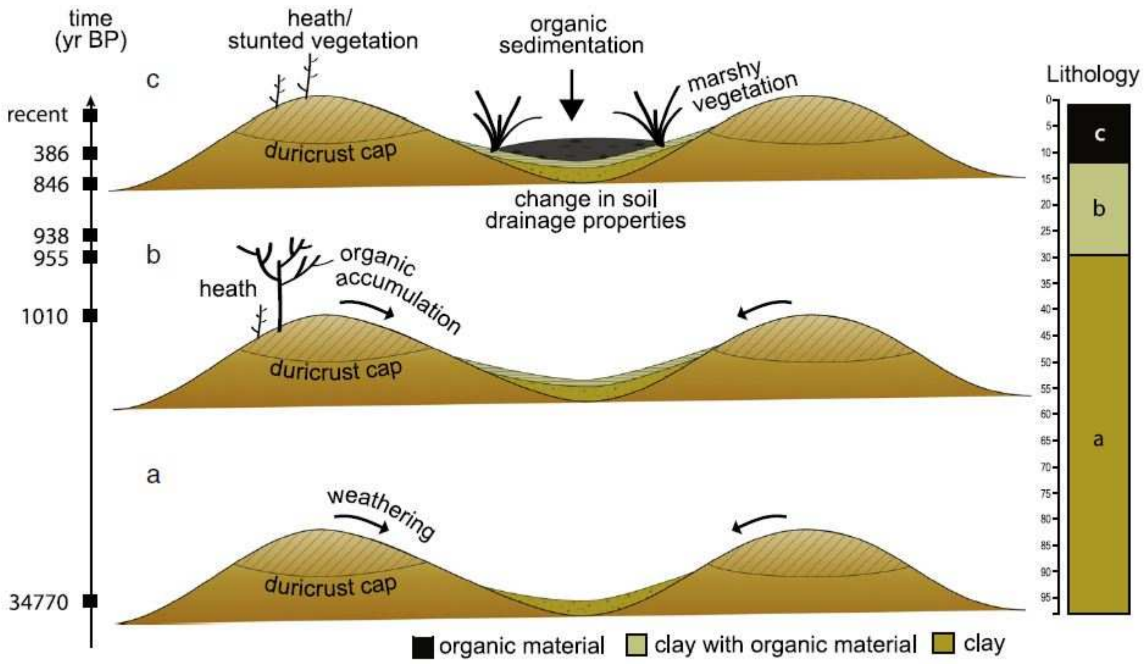
One interesting finding of Srahm (1994) was that in 1986 only 45 species of native plants were found in both 1937 and 1986 and also that 24 species disappeared from the plot and some even from the forest. The most striking example was *Chassalia capitata*, an understorey plant which was abundant in 1937 (285 individuals) was completely absent in 1986 not only in the plot but also in Macchabee forest. However, this species can still be found in wetter areas such as Pigeon Wood, Mt Cocotte and Petrin. The most likely reasons for the disappearance of this species are that the forest canopy was opened due to an intense cyclone which caused more light to enter and the understorey microclimate became drier (Strahm, 1994). This disappearance of *Chassalia capitata* can be assumed to be the first recorded possible impact of climate change in the native forest. As stated earlier, the locations where *C. capitata* occurs now are in fact wetter areas.

Other species which disappeared from the Vaughan plot in 1986 were *Chassalia grandiflora*, *Syzygium cymosum*, *Tambourissa peltata*, *Memecylon cordatum* and *Ochrosia borbonica* (Strahm, 1994) These species occurred as few individuals in 1937. Of interest to the 24 species which were not recorded in 1986, 18 were Mauritian endemics, 2 endemic to the Masarenes and 4 were widespread (Strahm, 1994). This finding showed that endemics are ecologically more restricted and more prone to disappear than those which are more widespread (Strahm, 1994).

It is quite interesting to note that the forest dynamic in the Vaughan plot seem to be working fairly well since 1986. The fact that the weeding invasive alien plants were carried out quite regularly and kept the forest almost in the same conditions as it were in 1986. We noted fewer individuals, a decrease of about 15%. But the number of species now present in the plot has increased from 55 to 67 in 2014. Moreover, *Ochrosia borbonica* which was lost in 1986, has been found once again in 2014. Furthermore, 16 species which were never recorded in 1939, were found in the Vaughan plot in 2014. The management of this fenced area with frequent weeding maintenance has indeed rendered this forest, almost resilient to climate change impact. It should also be pointed out that during the survey in 2014, 1814 seedlings of 54 native plant species have been recorded. This clearly indicates the good health of this area in terms of recruitment and regeneration.

3. 2: The Impacts on Geology and Geography

De Boer et al (2013) carried out a study to investigate the changes of vegetation and environment from a site named Petrin which is found in the BR. His objective was to reconstruct the biotic and abiotic environments from the pristine recent past (pre-AD 1638) into the current era of human disturbance. The results provide a reconstruction of the previously unknown pre-human baseline history and post-colonization environmental development of the Mauritian uplands, more particularly Petrin which is located in the Macchabee/Bel Ombre BR. The result of this study is clearly depicted in <Figure 3>.



<Figure 3> Schematic Figure Showing Changing Edaphic Conditions in Relation to Vegetation Change at Le Pétrin Heathland

Source: De Boer et al, 2013

(a) Period of mainly glacial age: pollen is poor and not preserved due to exposure and oxidation. The few well-preserved pollen grains are plausibly anachronic. Sediments were formed as a result of weathering and the landscape may have been covered by exposed vegetation.

(b) Drainage properties of the soil had changed allowing marshy conditions to develop in the depressions, while heath and later thicket vegetation prevailed in areas at ‘higher’ elevation.

(c) Marshy conditions developed and the proportion of stagnant water increased, resulting in sediments rich in organic material. Heath and thicket vegetation remained present at ‘higher’ elevations.

The sediment record from a heathland area located at 650m elevation in Mauritius shows upland vegetation changed composition before and after human arrival. The sediments of last glacial age contain a poor pollen signal but it is evident that heathland occurred as a natural biome in these exposed uplands with poorly developed soils. The wet environmental conditions reflected by the pollen and diatom spectra suggest locally wet conditions during Holocene times. Marshy vegetation occurred in waterlogged depressions, ericaceous heathland grew on better drained soils, and wet forest was restricted as stunted vegetation in the heathlands and on the surrounding slopes. The colonization of Mauritius in AD 1638 is documented by a sudden appearance of exotic species, deforestation, fire, and increasing abundances of grasses reflecting degraded vegetation. We conclude that a gradual change in edaphic conditions reduced the extent of ericaceous vegetation in the central uplands before colonization.

3.3: The Impacts on Agriculture

Agriculture largely contributes to the economy of Mauritius. It can be directly influenced by the state of the climate. For example, the slightest change in temperature can alter the flowering of plants, the growth and yield of sugar cane is sensitive to precipitation and temperature. Sugar cane is still the main cash crop grown all over Mauritius and can also be seen near or on the boundaries of the Macchabe/Bel Ombre BR, more particularly at Bel Ombre.

Sugar cane, a tropical plant grown in warm countries, is very sensitive to climate variations; any global climate change will definitely impact on sugar production and hence entail serious socio-economic responses. The yield of sugar cane is not closely related to any single weather variable. Climatic parameters like solar radiation, temperature, wind, and rainfall have a profound influence on yield and quality. Low cane productivity of the lowlands has been attributed to lack of available moisture while comparatively lower temperatures and radiation are the limiting factors uplands (Cheeroo-Nayamuth and Nayamuth, 1999). Sugar cane ripening is dependent upon the same climatic factors during this phase of development as well as prior to the latter. It is imperative to understand the plant’s response to the environment to achieve maximum productivity.

Sugar cane yields are clearly adversely affected by cyclones, excessive rain, summer droughts, particularly if they are not irrigated. Quantitative studies using reveal approximately 30% to 56% decrease in the yield (Raghooputh, 1997). The recoverable sucrose content will be lower with increase in temperature. Higher frequencies of climate extremes such as cyclone, droughts and prolonged rainfall will also have an uncertain, more risky, impact on sugar production. This situation has lead some planters to abandon this cultivation specially on marginal lands where it is no more economically sustainable. Suitable change in land use is still under study.

4. Príncipe BR

4.1: The Impacts on Ecology and Biodiversity

The coastal and marine ecosystems of Príncipe Island are rich with flora and exceptional fauna, including endemic bird species. Príncipe Island is a highly important site for marine turtles, as five turtle species breed on the Island’s beaches.

Coastal ecosystems in Príncipe are extremely vulnerable to the climate change scenarios of sea level raise, and represent a risk for habitats, species and ecosystems as well as for the artisanal fisheries.

The terrestrial ecosystems of Príncipe Island have a high biodiversity level with many endemic species of different animal and plant *taxa*. Erosion and exposure to floods and rock falls induced by extreme events may directly impact some restricted habitats, threatening endemic species with small distribution areas. This might result in extinction or in significant changes on the conservation status of endemic species.

Invasive and exotic species will have more probability to succeed due to the destruction and fragmentation of natural habitats.

4. 2: The Impacts on Geology and Geography

The geographic location and climatic conditions, existing and predicted, combined with well preserved forests determine that desertification and soil erosion are not major problems in Príncipe Island. However, during the last years several extreme events lead to the occurrence of landfalls and fast floods causing significant destruction and losses of material and goods affecting some coastal communities. This is the case of Sundy beach where the population is being affected and increasingly exposed by sea level rising and coastal erosion. Other sources of erosion are the unsustainable use of soil, lack of integrated landscape management and sand extraction from the beaches.

4.3: The Impacts on Agriculture

The major culture in Príncipe Island is cocoa, which is exported. Production for local consumption includes banana, fruit bread, maize and some vegetables. In general, the agriculture fields have small density with lack of diseases and pest control resulting in a very low productivity.

According with the NAPA (2006) drought, floods (caused by the rain and waters of the sea), squalls and landfalls are the most important events influencing agriculture and forest. These extreme events are responsible for losses of agricultural production and changes in crops and are becoming more frequent, increasing vulnerability of some communities, particularly in the Northeastern part of the Island. Changes in rain patterns and periods are also considered a major concern as traditional agriculture practices and calendars will need to adapt to the vagaries of climate change.

The Southern part of Príncipe Island benefits from a dense forest cover that ensures protection against heavy rain and high temperatures, thus being less sensitive to climate change.

4. 4: The Impacts on Tourist Resort

Tourism is expected to be the major economic activity in Príncipe Island. There are currently important private sector investments combined and in line with the sustainable development strategy defined by the Regional Government of Príncipe Autonomous Region.

The expected impacts of climate change in the tourism sector will be related with health (accidents during extreme events), limitation of flight connections during storms and eventual damages on existing infrastructures located near the coastal areas. The increment of diseases linked with climate change will also impact tourism as the choice of a touristic destination includes health security.

4.5: Others

Health

The main concerns related with health and climate change include the potential increase of waterborne diseases, such as cholera, typhoid fever, malaria and schistosomiasis (bilharzia), which are exacerbated by the combined effect of floods and lack of sanitation conditions.

Other potential impacts that are related with the increase of temperature and circulation of people and goods are the reintroduction of eradicated diseases like trypanosomes.

The topography of the island also poses the possibility of poly-traumatisms related with rock-falls and landslides during extreme events (storms and fast floods). Some of these health situations have no means of treatment installed on the island.

5. St. Mary's BR

5.1: The Impacts on Ecology and Biodiversity

There are no detailed studies or data addressing the impacts of climate change in the St. Mary's Biosphere Reserve. However, as part of the Island of St. Kitts, the BR is influenced by the same drivers affecting the rest of the Island. According with Jeffers and Hughes (2002), sea level rise and extreme events such as hurricanes and heavy rain are considered as the most relevant adverse effects. As for the rest of the Caribbean islands, sea level rise will affect fresh water supply, beach and coastal erosion in conjunction to the erosion caused by the increased frequency of high-impact weather events. The combined effects of these factors will result in several natural, social and economic impacts.

Natural resources, including marine, coastal and terrestrial ecosystems, habitats and species are under the influence of the extreme events related with climate change. Coastal erosion will result in dramatic changes in the marine and coastal ecosystems. Changes in precipitation and increased evaporation from higher temperatures can affect water supply and water quality, posing threats to irrigation, fisheries and drinking water and directly affecting the ecological conditions. Additionally, wildlife could change as the climate and habitats to which they are adapted to shift to higher elevations depending on the capacity to adapt and other conditions such as the geology, soil, and topography.

Habitat change, from the coastal zone to the higher terrestrial areas will rise conservation concerns as endemic species in general have small distribution areas that may be affected or disappear.

The fisheries sector in St. Kitts is largely artisanal and dependent on coastal fisheries. It is also an important source of employment and nutrition.

These fisheries resources are also likely to be impacted by climate change. The potential negative impacts will occur on the principal fisheries habitats, such as mangroves and coral reefs as a result of increasing sea temperatures, shifts in tidal patterns, intensified hurricane activity and sea-level rise (St. K & N, 1994).

Decreases in forestry productivity will lead to scarcity of food for secondary (herbivorous) and tertiary (carnivorous) wildlife populations. This process would have an additional impact on biological diversity of natural populations already stressed by human actions such as hunting and habitat loss. For some species, this could result in extinction (St K & N, 1994).

Invasive and exotic species will have more probability to succeed due to the destruction and fragmentation of natural habitats.

5. 2: The Impacts on Geology and Geography

Coastal erosion induced by storms and surges and soil erosion, including rock falls, due to heavy rain are the main expected impacts on the geology, geomorphology and topography.

5.3: The Impacts on Agriculture

Changes in rainfall patterns and the increased frequency of extreme events will affect directly agriculture production. Although agriculture is not a relevant activity within the area of St. Mary's Biosphere Reserve, the effects of climate change on agriculture in the rest of the island might lead to a search for other sources of income, increasing and introducing new human activities in the area of the Biosphere Reserve. Potential indirect negative impacts such as erosion, habitat and landscape degradation will result from the increase in the use of the Biosphere Reserve.

With the prediction of a drier climate, rain fed agriculture will be affected with yields being below economically viable levels. This will be the case of sugarcane cultivation that certainly will require irrigation management, ensuring adequate water quantity and quality.

Salinization of coastal lower aquifers will negatively affect availability of water for agriculture.

5. 4: The Impacts on Tourism

The vulnerability of tourism infrastructures to extreme events is becoming more evident with the economic and infrastructural damage, which resulted from two consecutive major hurricanes in 1998 and 1999, obligating the temporary closure of two major hotels (Jeffres & Hughes, 2002). These same authors underline the direct implications of hurricanes with the tourism industry in terms of visitor numbers and, consequently, their expenditure. From 1997-1999, the decline in stay-over visitors in St. Kitts & Nevis has been attributed to the damage caused by hurricanes Georges and Lenny, which caused destruction to several hotel plants. The depth of the impact from these two storms also negatively affected the number of airline charters from the major markets.

In the long term, the changes and destruction of coastal areas including beaches will also result in a lower quality of beaches and seafront areas, which are extremely sensitive and have a high value in terms of tourism. Other implications will include structural damage to coastal infrastructure (harbors, roads) and increases in the costs of insurance.

5.5: Others

Health

An increase in mean air temperature will contribute to aridity and more periods of drought, resulting in changes of water quality. This increases the potential of occurrence of diarrhoea and other water related diseases.

The dengue is expected increase in prevalence as a result of climate change with an expected enhancement of breeding conditions of the mosquito *Aedes aegypti*. Consequently it is expected an increase of morbidity and mortality associated with the dengue.

Chapter 7
The Similar and Dissimilar Vulnerabilities to Climate Change

The impacts of climate change on the five research BRs were analyzed in Chapter 6. This chapter attempts to draw the similar and dissimilar vulnerabilities to climate change by comparing the five research BRs from the findings from Chapter 6. As identified in Chapter 6, the five research BRs cover very similar categories of climate change impact - Terrestrial Ecology (or Ecology and Biodiversity), Geology and Geography, Agriculture, Tourist Resort (or Tourism), Marine Ecology. The reason for this is because biosphere reserves' climate change impact occur in very similar categories.

We have analyzed that each BR has significantly different climate change effects. Surely the differences in terrestrial and marine ecosystems, geology and geography, as well as different socio-economic usage of the land justify this heterogeneity.

Due to such different real impacts of climate change by research BR, it is not possible to directly draw similar and dissimilar vulnerabilities to climate change among the five research BRs. Therefore, this chapter has approached the comparison of similar and dissimilar vulnerabilities by following these two steps below.

Firstly, this chapter will compare the salient characteristics of the real climate change impact by the five categories of impact at a very macro level. This is the summary found in Chapter 6, and will result in indirect comparison of similar and dissimilar vulnerabilities.

Secondly, direct comparison of similar and dissimilar vulnerabilities will be drawn from the salient characteristics.

1. Indirect Comparison of Similar and Dissimilar Vulnerability

1. 1: The Impacts on Terrestrial Ecology

Jeju Island BR: Overall, temperate and arctic plants in the vegetation belt moved

200-1,200m northwards. The areas of alpine plants were reduced by plants located in the lower part to move upland. Their blooming, fruiting and fertility of seeds have changed.

Due to higher temperature and severe summer drought, pine wild disease has occurred since 2004. Some rain forests emerged in coastal areas, valleys, waterfalls, cave terrain, and lava fields.

Warm temperate evergreen lucidophyll forest and number of population decreased at high latitude, but increased at low latitude.

The development day of insects decreased. An earlier insect outbreaks with a decrease in their number of population, while the appearance ratio of subtropical insects increases.

Subtropical birds emerge, while the migrating birds in winter moved their destination to the southernmost regions of the Korean peninsula.

Menorca BR: Like Jeju Island BR, vegetation belt changes. Wetland ecosystem undergo~~es~~ changes in a direction of desiccation and an increase in salinity. Holm oak forest is declining and dying-back by the invasion of other plant species. Some endangered plant species increase the risk of extinction.

Macchabee-Bel Ombre BR: Like Jeju Island BR and Menorca BR, vegetation belt changed in the central upland area. The forest is severely degraded. The native plant species disappeared. The weeding invasive alien plants were carried out, and the number of species has increased.

Príncipe BR: Erosion and exposure to floods and rock falls impact restricted habitats, threatening endemic species, and these result in extinction or in significant changes on the conservation of endemic species. Invasive and exotic species will have a higher probability in succeeding.

St. Mary’s BR: Natural resources, habitats and species are influenced by extreme climate events. As a result, endemic species are affected or becoming extinct. In addition, forestry productivity decreases. This results in biological diversity of natural population and the extinction of some species.

1. 2: The Impacts on Geology and Geography

Jeju Island BR: Naked lands and caved valleys in grass areas in the subalpine zone have started to spread. Slope collapse, soil erosion, and sedimentation are progressed rapidly. Coastal areas are eroded due to sea level rise.

Menorca BR: Coastal erosion including the receding of beaches lines occurred. Underground fresh water reserves were reduced.

Macchabee-Bel Ombre BR: Soil drainage and edaphic conditions changed.

Príncipe BR: Several extreme events lead to the occurrence of landfalls and erosion.

St. Mary's BR: Floods and rocks fall induced storms, surges and soil erosion.

1.3: The Impacts on Agriculture

Jeju Island BR: The available existing published data are not on Jeju Island BR, but of the entire Jeju Island. The arable land of subtropical fruits moves northward, while subtropical or tropical crops can be cultivated in the naked land.

Agricultural products are damaged by the invasion and settlement of exotic diseases and insect pests. Exotic plants invade new sites. Exotic weeds invaded and settled down. An earlier seeding period for barleys and leafy vegetables, and their production output is decreasing.

Menorca BR: Bluetongue outbreak affected to ruminants during the beginning of the 21st century. This viral disease is transmitted by mosquito (*Culicoides* spp.). It is considered a climate change driving vector-borne disease. The production of cow milk, cheese, and livestock undergo serious economically viability problems. The reduction of farm numbers and the intensification of exploitation of the farm is the current trend.

Macchabee-Bel Ombre BR: The growth, yield, and quality of sugar cane near or on the boundaries of Macchabee-Bel Ombre BR are impacted from climate change. Some planters abandon the cultivation of sugar especially on marginal lands.

Príncipe BR: Two impacts are dominant. One is the loss of agricultural production, and the other is change in crops.

St. Mary's BR: Like Príncipe BR, the production of sugar cane is impacted. In addition, salinization affects water availability for agriculture in coastal low aquifers.

1.4: The Impacts on Tourist Resort (Tourism)

Jeju Island BR: Statistical Year Book of Tourism is published annually. However, no existing published data are available on Jeju Island BR.

Menorca BR: Seasonal shifts could happen if the summer became very hot or if heat waves increase significantly. The trends could be a decrease of tourists during summer and increase during spring and autumn. In addition, appearance of jelly fish impacts on the quality of beaches, which is the main tourist attraction of Menorca.

Macchabee-Bel Ombre BR: No existing published data are available.

Príncipe BR: Indirect climate change impacts occur on tourism. They are related with limitation of flight connections during storm and eventual damages on existing infrastructures located near the coastal areas and increment of diseases linked with climate change.

St. Mary's BR: The major hurricanes are the main causes impacting on tourism due to less number of airlines, decline in visitor numbers (consequently, their expenditure) and stay-over visitors. Lower quality of beaches and seafront areas occurred by climate change are also the major causes impacting on tourist resorts.

1.5: The Impacts on Marine Ecology

Jeju Island BR: Sea lettuce is reproduced throughout the year. Sea lettuce restrains the reproduction of other sea algae. The rapid increase in reproduction of both crustose coralline algae and articulate coralline algae promotes the spreading of whitening (efflorescence marine). Sea algae that are discovered in the subtropical ocean are reproducing. Green algae have flowed into the coast.

A new fishing ground of cutlassfish was formed. Cold current fish species are disappearing, while tropical species are appearing.

Menorca BR: The coast has receded due to erosion. The decline occurred in the rocky coast beaches and dune systems. Other significant impacts are the decline of seagrass communities. Exotic invasive species increase mainly of thermophilous species (both algae and fish) due to the rise of sea water. Jelly fish populations also increases.

Macchabee-Bel Ombre BR: There is no marine area in Macchabee-Bel Ombre BR.

Príncipe BR: Artisanal fisheries and coastal habitats are affected with potential negatives impacts (erosion) of coastal zone and natural coastal ecosystems.

St. Mary's BR: Fisheries habitat and resources are impacted. Potential negative impacts are mangroves and coral reefs as a result of increasing sea temperatures.

2. Direct Comparison of Similar and Dissimilar Vulnerability

As identified in '1. Indirect Comparison of Similar and Dissimilar Vulnerability', there are large differences among the five research BRs. In order to directly compare the similar and dissimilar vulnerabilities, the detected impacts of climate change can be grouped in more or less synthetic categories as below.

First: The reduction in the profitability of traditional agricultural production seems to be the only impact for all research BRs. Therefore, it is likely that climate change will mean significant changes in the primary sector of the islands, and those changes will occur in agricultural land use and crops.

Second: Two other impacts appear to occur in four of the five islands, which are: '~~i~~Increase of risk of some endangered plants' and 'soil erosion and other related phenomena'.

It is plausible to think that both impacts can, in fact, occur in all the islands and the lack of data prevents the consideration that these vulnerabilities are global.

Third:At least four common impacts on three islands of the five have been found.

They are ‘changes in the distribution of main plant communities’, ‘increase of exotic invasive species’, ‘changes in certain ecosystems that threaten vulnerable species’, and ‘coastal, beaches and dune erosion’.

As explained in the previous session, the lack of data preventing the impacts cannot be ruled out, and in any case they should be considered as serious vulnerabilities that will surely occur globally.

Fourth: There have been some sort of impact on the tourism industry in three of the five assessed islands. According to the islands, these impacts are of different types and in some cases are exclusive of only one. But it seems clear that the islands' tourism may be affected in some way due to climate change. Beach erosion and increased hurricane are two impacts that have been cited at least two of the five islands.

Fifth: Two BRs do not have a marine area, as a result, the impacts on marine ecology have been analyzed in only three of the five islands.

It is noteworthy that Jeju and Menorca present four common types of impact, most of them may be related to seawater warming in temperate islands. The impacts are ‘significant demographic changes in algae and seagrasses communities’, ‘increase of invasive species of algae from warmer habitats’, ‘shifts in the distribution areas of some fish linked to changes of sea water temperature’, and ‘increase of marine invasive species from tropical areas’. Moreover, there are occurring changes in fisheries in Jeju and St. Mary.

Sixth: In addition, other impacts have been observed in one or two islands. These additional impacts should be considered in future assessments to see if they are particular impacts of a unique territory or if they are more of a general impact that have gone unnoticed. The examples include ‘changes in the phenology of some insects’, ‘shifts in the distribution areas of migratory birds’, ‘increase of forest pathogens and insect pests’, ‘reduction of fresh water resources’, ‘shifts in the areas where we can grow some crops’, ‘emergence of new diseases or insect pests in crops or livestock’, ‘reduction of touristic quality of coastal areas due to increase increasing jelly fish’, ‘spreading whitening of algae’, and ‘likely impact on mangroves and coral reefs due to rising temperatures'.

In any case, we considered the interesting summarizations of the different impacts and vulnerabilities observed in each island. We developed both <Table 16> and the above conclusions from Chapter 6.

<Table 16> Direct Comparison of Similar and Dissimilar Vulnerability to Climate Change among the Five Research BRs.

BR / Category of Impact	**A**	**B**	**C**	**D**	**E**
The Impacts on Terrestrial Ecology					
Changes in the distribution of main plant communities	O	O	O		
Changes in the phenology of some insects	O				
Shifts in the distribution areas of migratory birds	O				
Increase of forest pathogens and insect pests		O			
Increase of risk of some endangered plants		O	O	O	O
Increase of exotic invasive species		O	O	O	
Changes in certain ecosystems that threaten vulnerable species		O		O	O
The Impacts on Geology and Geography					
Increase of naked lands and caved valleys	O				
Soil erosion and other related phenomena	O		O	O	O
Coastal, beaches and dune erosion	O	O		O	
Reduction of fresh water resources		O			
The Impacts on Agriculture					
Reduction in the profitability of traditional agricultural production	O	O	O	O	O
Shifts in the areas where crops can be grown	O				
Emergence of new diseases or insect pests in crops or livestock	O	O			
The Impacts on Tourist Resort (Tourism)					

BR / Category of Impact	A	B	C	D	E
The reduction in quality of beaches due to erosion or other related phenomena		O			O
Impact of hurricanes on touristic island attractiveness				O	O
Likely changes in the duration of the tourist season		O			
Reduction of touristic quality of coastal areas due to increasing jelly fish		O			
The Impacts on Marine Ecology					
Significant demographic changes in algae and seagrass communities	O	O	-	-	
Spreading whitening of algae	O		-	-	
Increase of invasive species of algae from warmer habitats	O	O	-	-	
Shifts in the distribution areas of some fishes linked to changes of sea water temperature	O	O	-	-	
Increase of marine invasive species from tropical areas	O	O	-	-	
Changes of fisheries	O				O
Likely impact on mangroves and coral reefs due to rising sea temperature					O

A: Jeju Island BR

B: Menorca BR

C: Macchabee-Bel Ombre BR

D: . Príncipe BR

E: St. Mary’s BR

Chapter 8
Summary and Conclusion

The goal for this research is analyzing the impacts of climate change on island and coastal biosphere reserves at a desk research level by collecting and using existing published data. The research sites were Jeju Island BR, Menorca BR, Macchabee-Bel Ombre BR, Príncipe BR, and St. Mary's BR.

In order to achieve the research objectives, the data collected from each of the five research BRs were core socioeconomic, ecological and geological characteristics, current state of climate change in the island where the research BR is located, climate change policies being implemented, and climate change impact. The similar and dissimilar vulnerabilities to climate change were analyzed from the findings of the climate change impact on the five research BRs.

1. Summary

1. 1: Socioeconomic, Geological and Ecological Characteristics

Jeju Island: Jeju Island is a special self-governing province located in the southernmost part of the Korean peninsula. It is 73km from east to west, 41km from south to north, and its total area is 1,847km^2, which is about 1.83% of South Korea.

A total of 830.94km^2, which is about 45% of the island, was designated as a Biosphere Reserve site. Various policies of conservation and sustainable use are being implemented. Conservation examples include 'Application of Cultural Heritage Protection Act' for the core area, 'Management of Mountainous Districts Act' for the buffer zone, and 'Zonation of Relative/Absolute Conservation in Land-use' for the transition area. Sustainable use examples are 'operation of six designated tracking paths for hiking, rest areas, monitoring and research, etc.', 'allowance of cultivating mushrooms are designated in some areas', and 'public tourism resorts' such as Deer Eco-Park and Saryeoni Forest Trail.

Jeju Island has experienced a remarkable socioeconomic structural transformation from 1998 to 2013. Jeju's population increased by 11.2%, a 160.0% increase of gross regional domestic product (GRDP), and a 229.76% increase of tourists during that period. The implementation of a highly industrialized economic structure took place, showing that tertiary industry occupies 80% of the GRDP in 2013.

Jeju Island is a typical shield volcanic island, formed approximately two million years ago until historic times. The lavas form a wide range of volcanic topographies and about 360 small volcanoes called Oreum, including Mt. Hallasan (1,950m above sea level) is located in the center of Jeju Island. In relation to the conditions and time of the volcano, the mountain system, water system, and coastal topography shows various characteristics.

Jeju Island BR holds various types of land cover that maintains a biological diversity, and its ecological profiles of Jeju Island BR are characterized in terms of the geographic distribution of habitats and characteristic species, habitats of special interest, and endangered or threatened species.

.**Menorca Island:** Menorca (Spain) is located in the western basin of the Mediterranean Sea, its total area is about 702km^2 and its maximum height is 358m. It has a typical Mediterranean climate.

Menorca’s population was about 95,000 in 2012. Menorca's actual economy is based on the service sector, which accounts for over 70% of GRDP of the island. Tourism is the primary driver of this economy, as more than 1,100,000 tourists visit the island annually. The secondary sector is currently (2012) less than 25% of the economy of the island, which is divided between 15.7% in construction and 8.5% in the industry. Currently, the primary sector is residual, which represents less than 2% of the GDP of the economy. The main productions of agrarian system for Menorca are milk and cheese.

Menorca is geologically divided into two nearly symmetrical areas. The northern part of the island is in fact a mosaic of materials from Paleozoic (Devonian and Carboniferous periods) and Mesozoic (Lower Triassic period) eras. Most of these materials are siliceous and generate acids and impermeable soils. The southern and western parts of the island are constituted by a fairly homogenous platform formed by limestone and calcareous rocks that formed in the Miocene period (Tertiary Era). Distributed throughout the territory of the island there also are geologically recent materials (Quaternary Era).

The vascular flora of Menorca is composed of 1,072 native species, of which 60 are endemic (5.6%), 31 of them are legally protected. The vertebrate fauna of Menorca is composed of 3 amphibians, 12 reptiles (including a sea turtle), 218 birds and 27 mammals (including 15 species of bats and without cetaceans). Ten animal species have a high legal protection status.

Menorca has 40,660ha (including 8,664 marine ha) integrated in the European Natura 2000 network with a protected area status as LIC and/or SPAs. These terrestrial areas protected at European level represent approximately 45.7% of the total surface of the island.

The unique natural park on the island is the Albufera des Grau NP, it comprises a land area of 3331.5ha and a marine area of 1735.5ha. This park is the core area of the Biosphere Reserve. On the north coast of the island a marine reserve was established that covers an area of 5085.6ha.

About 28% of the surface of the island is covered by forest vegetation. Main trees forming forest or maquis are *Quercus ilex*, *Pinus halepensis* and *Olea europea*.

Mauritius Island: The total land area of Mauritius is 2,040km^2 with an Exclusive Economic Zone extending over more than 2 million km^2. The population increased to 1,293,542 in 2012 with a mean growth rate of about 0.8% per year since 1997.

Gross tourism receipts grew from US$ 475 million in 2000 to US$ 1.48 billion in 2012. It has been one of the most dynamic sectors of the Mauritian economy, with its contribution to GDP increasing from 4.2 % in 2000 to 13.2 % in 2012 with the number of tourists visiting Mauritius reaching nearly one million (965,400) in 2012.

The geology is of volcanic origin and encircled by fringing coral reefs enclosing lagoons of various widths and studies describe Mauritius as being 7.8 million years old.

The BR includes the largest remaining tract of native forest on Mauritius and is entirely of volcanic origin. The soils of the BR can be described as a complex of mountain soils ranging from moderately deep brown silty clay loam to very shallow lithosols.

The need to conserve the remnants endemic forests lead to the creation of two reserved areas at Macchabee and Bel Ombre in the late 1950's. Due to the uniqueness of these two reserves which occupies an area of 3,964ha, they were later in 1977 proclaimed as UNESCO Man and Biosphere Reserve.

The Macchabee/Bel Ombre BR displays not only impressive geological features that has created breathtaking sceneries and landscape, but also has a unique biological diversity. The BR includes the largest remaining tract of native forest on Mauritius and most of the areas are important for wildlife on mainland Mauritius.

Príncipe Island: Príncipe Island Biosphere Reserve (PIBR) corresponds to the whole island of Príncipe (Democratic Republic of São Tomé e Príncipe) including a vast surrounding marine area and islets.

Príncipe has a population of 7,324. The most important economic sectors are fisheries and agriculture with a small but growing tourism development.

The island of Príncipe is part of the biodiversity hotspot of tropical forests of West Africa, having a significant endemic component including 44 endemic species of flora. The forest of Príncipe Island, together with the island of São Tomé and Annobon, was considered as Africa's second most important forests in terms of conservation and thus classified by the World Wide Fund for Nature (WWF) as one of the 200 most important eco-regions in terms of biodiversity. The indigenous terrestrial fauna of Príncipe Island, accounts for seven mammals, twenty-eight birds, thirteen reptiles and three amphibians with many invertebrate endemic species.

Príncipe beaches are important nesting sites for all Atlantic marine turtles. Príncipe Island is classified as an IBA by Birdlife International due to the occurrence of several endemic species, such as the Dohrn's Thrush-babbler (also known as the Príncipe Flycatcher-babbler).

The island of Príncipe is the oldest group of three oceanic islands, with an age estimated at 31 million years, followed by the island of Sao Tomé with 14 million years and the island of Annobon is the most recent with an approximate age of 5 million years.

The topography of Príncipe Island shows a geomorphology divergence between the southern and northern portion of the island The northern and central parts of the Island of Príncipe consisting of plains and hills, have a relatively gentle relief, while the southernmost area has a more abrupt terrain, with a small mountain range where it is found the highest point the island

St. Kitts Island: St. Mary's Biosphere Reserve (SMBR) belongs to the St. Kitts Island, that together with Nevis Island, form the Federation of St. Kitts & Nevis, located in the northern part of the Lesser Antilles chain of Islands, in the Eastern Caribbean. The SMBR covers an area of 4,297.125 ha.

St Mary's Parish, which includes the main towns and smaller settlements in the biosphere reserve, contained a population of 3,541 with 1,171 households, approximately 10% of the island's population. The main economic activities and employment sectors are related with public administration, tourism, agriculture and artisanal fisheries.

There is a significant diversity of land cover in St. Mary's, including dry evergreen forests, palm cloud and evergreen cloud forest, dry scrub woodland, littoral vegetation and the barrier/coral reef and sea grass beds.

The geology of St. Mary's has a ridge-to-reef topography: the mountain ridges of the cloud forest in the Central Forest Reserve National Park to near shore coral reefs in Keys and Cayon. The highest elevation reaches 812m above sea level and the lowest elevation above sea level corresponds to the 0. For the coastal/marine areas the maximum depth below sea level is approximately 200 feet.

The island, which remains seismically active, is composed almost exclusively of volcanic rocks of andesite or dacite mineralogy. Most soil types on the island are a product of weathered volcanic parent material.

1. 2: Current State of Climate Change

Jeju Island: Greenhouse gases emitted in 2005 was 4,070,146 ton as CO_2-equivalent. The quantity of emission is estimated as 4,593,386 ton in 2015, 4,944,539 ton in 2020 and 5,881,791 ton in 2030. In 2005, the emission from home/public/others was 38.4%, 31.9% from industry and 29.7% from transportation.

In comparison to 1930, Jeju Island's annual average temperature rose by 1.5℃ in the 1990s. The temperature rise in Jeju Island is significantly higher when compared to the global temperature increase during the last 100 years (0.74℃) and the Korean peninsula (1.50℃).

There have been less rainy days during the recent 20 years. This means that there has been a remarkable intensity in precipitation. In comparison to the 1930s, Jeju Island's winter was shortened by 36 days and autumn by 4 days in the 1990s.

There was an average annual number of 1.2 typhoons before 2000, but increased to 2.2 after the year 2000. During the past 86 years, from 1924 to 2009, its annual average was 16.59℃ and increased by 1.94℃. From 1970 to 2007, the sea level rose 225.7mm during a 38 year period.

Menorca Island: The total CO_2 emissions in 2012 amounted 616,942.7 tons, representing an overall reduction of 16.3%. The emissions per capita in 2012 were 7 tons/inhabitant *di jure*, representing a reduction of 21.7% from 2005's maximum value. CO_2 emissions represent 92.2% of the total GHG (Source: OBSAM, 2013).

There has been an increase in the daily maximum temperatures of 0.5°C/decade and daily minimum of 0.61°C/decade for the period 1976-2006. The temperature has been increasing especially in spring and summer, while winters have been fairly stable.

The changing trends in rainfall have a greater degree of uncertainty that with temperature, the analysis of the period 1950-2011 is inconclusive. There is no evidence of changes in the intensity or the number of extreme atmospheric phenomena during the last decades of the twentieth century although meteorologists of the islands have talked about an increase in extreme weather events as a manifestation of climate change on the islands.

It is indisputable that the deep waters of the Western Mediterranean have increased temperature and salinity throughout the twentieth century, and that these changes have accelerated in the last decades of the twentieth century. For the whole period 1948-2007 the average increase in the surface temperature of the Western Mediterranean was between 0ºC and 0.5ºC (the maximum corresponds to an increase of 0.083°C/decade). In the deep layers, the temperature increase was between 0.03°C and 0.1°C, and the increase of salinity of between 0.05 and 0.06 ups.

The Western Mediterranean sea level fell from early 60s to mid-90s because in this period the atmospheric pressure was higher than normal. But from the 90's the Mediterranean sea level rose rapidly at rates between 2.4 and 8.7mm/year. Models predict a sea level rise of 35-40cm by 2100 only by the effect of temperature increase, regardless of the increase produced by the melting of the poles.

Mauritius Island: The greenhouse gases emitted in 2012 was 3,743,400 ton as CO_2-equivalent compared to 2,456.800 tons in 2000. It is estimated that the total quantity of emission will be 5,562,000 ton in 2020, 6,442,000 ton in 2030 and 7,837,000 ton in 2040.

Mauritius enjoys a mild tropical maritime climate throughout the year, with a warm and humid summer extending from November to February. Between June and September is a relatively dry cool winter. During 1950-2007, temperature data show that the mean temperature is rising by about 0.16 °C per decade. On average, temperatures have increased over the region by 0.74 °C to 1.2 °C since 1950.

Annual rainfall has decreased by about 63mm per decade over the past century (1905-2007), thus the situation of water stress occurs.

Though no change has been observed over the last 30 years in the number of tropical storm formations in the SWIO, the frequency of intense tropical cyclones (wind gusts between 234 and 299km/h) has increased. 326 flood-prone areas out of which half are highly vulnerable areas.

The cumulative sea level in the South West Indian Ocean has risen on an average of 7.8cm at Port Louis. Analysis of datasets from the tide gauge sited at Port Louis indicates an average rise of 3.2cm during 1988-2007.

The summer of 2008-2009 experienced abnormally high sea surface temperatures in the South West Indian Ocean which reached 31°C, which is greater by 3 degrees above the long term mean temperature for the region around Mauritius.

Príncipe Island: There is no specific estimation of greenhouse gas emissions for the Island of Príncipe. Instead, São Tomé & Príncipe Government estimated the two Island's greenhouse gas emissions in 230,089 ton in 1998 and 196,636 ton in 2005.

Despite the lack of specific estimation of greenhouse gas emissions for the Island of Príncipe, the island should not be considered a greenhouse gas emission source. Instead, Príncipe Island plays a role as a CO_2 depletion due to the vast and well preserved forest areas. It is expected some growth in the energy sector as domestic electric power is being installed in different communities. On the other hand, industry and transportation have a very low contribution.

The climate of Príncipe will have a loss of precipitation combined with an increase in the mean temperatures. No data is available for sea water surface temperature as well as to the variation of sea level.

As for the temperature, there is a record of a slight increase of 0.032ºC in the maximum and minimum temperature, since 1977. For 2050, it is expected an increase of 1ºC to 2ºC in the mean temperature.

After 1977 and until the year 2000 the mean precipitation was lower, reaching the value of 816mm per year. The projection for the period 2040-2060 indicates the possibility of a precipitation loss that can reach 12 to 14mm (worst scenario) and 8 to 10mm (best scenario).

St. Kitts Island: CO_2 emissions derive mainly from the combustion of fuels that are used in the power-generation, transports, manufacturing industry, construction and international bunkers (aviation). St. Kitts & Nevis has a reduced manufacturing and industrial sector thus resulting on a small contribution to CO_2 emissions. From the agriculture and farming sectors the only perceptible greenhouse gases are the methane (CH_4) and nitrous oxide (N_2O). Forest and water sectors also have minor contributions to the greenhouse gases emissions.

No data is available for sea surface temperature as well as for the sea level variation. The air temperature is expected to increase 0.9ºC for 2030, 1.5ºC for 2050 and a maximum of 3.0ºC for the year 2100.

The scenario for precipitation indicates also an increment of the annual mean precipitation values, respectively, 12.9% for 2030; 20.6% in 20150 and up to 42.3% in 2100.

1. 3: Implementation of Climate Change Policies

Jeju Island: Jeju Government launched three strategies of climate change policies, with setting up vision and goal. The vision was set up as the opportunity to transform climate change to green growth, and goal as the global standard responding to climate change.

The three strategies are ‘Realization of Low-Carbon Green City’, ‘Promotion of Green Growth Industry’, and ‘Precautionary Prevention and Utilization of Opportunity’. A total of 15 climate change policies are included in the three strategies (each strategy includes five policies).

The examples are ‘Expansion of Carbon Sink’ and ‘Creation of Low-Carbon Green City’ for the first strategy, ‘Expansion of New and Renewable Energy’ and ‘Transformation to Low-Carbon Industrial Structure’ for the second strategy, and ‘Maintenance and Expansion of Biodiversity’ and ‘Efficient Management of Water Resource’ for the third strategy.

Menorca Island: Menorca is under four levels of political decision: the European Union (EU), the Government of Spain, the Government of the autonomous region of Balearic islands, and the insular government of Menorca. Effective action to reduce emissions, necessarily requires coordination of these four levels of political decision.

Spain, as a member of the EU, has to reach the "20-20-20" targets. For our country it means the next targets: Increase until +35% gas emissions from 1990 levels. Raising the share energy consumption produced from renewable resources to 20%. A 20% improvement in the energy efficiency.

To reach these goals, Spain has adopted the following strategy and planning documents: Spanish Strategy on Climate Change and Clean Energy 2007-2012-2020 (EECCEL 2007-2012-2020), National Action Plan for Renewable Energy in Spain 2011-2020 (PANER 2011-2020), National Action Plan for Energy Efficiency in Spain 2011-2020 (PAEE 2011-2020), Strategy for Sustainable Mobility (EEMS), and National Plan for Adaptation to Climate Change (NAPCC).

In 2013, the Autonomous Government of Balearic Islands approved the Balearic Climate Change Strategy 2013-2020. Until now, the main result of this document has been the adoption (2014) of a "Plan to Mitigate Climate Change in the Balearic Islands from 2013 to 2020" (PMCCIB), which currently is the main regional document to address the problem of climate change. The plan proposes a target of reducing 20% of GHG emissions by 2020 in comparison to emissions from 2005.

The Insular Government of Menorca has not yet developed strategies or planning documents on climate change. But, nowadays Menorca generated 17.2% less CO_2 than in 2005, which implies that CO_2 emissions have been reduced by 123.2Kt compared to the reference year of PMCCIB, then to achieve the target of the Plan Menorca should reduce only 20.3Kt of CO_2 in the next seven years.

On the other hand, in 2013, the production of wind energy was 6,035MW.h, it accounted for 1.25% of the electricity consumed on the island. It has been estimated that the park could reduce the emission of 6,000t of CO_2 a year. Moreover, in 2008, two solar parks that generated 1MW and 3MW, respectively, were installed. Both wind and solar power provide 3.2% of the island's electricity consumption. Waste production in Menorca was reduced in a 13.3% since 2003, meanwhile, the recovered waste achieved 20.6% of urban waste. So the total reduction of waste not recovered was 17.6% from its 2003 peak. Urban waste is a major source of GHG emissions, for Baleares accounted 3.2% of total GHG.

Mauritius Island: Mitigation measures include renewable energy; reducing traffic congestion which is one of the main causes of high level of CO_2 emission in the transport sector; managing landfills to reduce emissions, possibly through direct conversion to electricity or through methane produced during composting or gasification; programs in the agricultural sector to reduce burning of residues and promote their conversion to composts, to be used in lieu of inorganic fertilizers; and enhancing sink capacity through better management of existing forests while reducing timber exploitation.

The main mitigation measures implemented since 2000 include ‘Shift to Energy-efficient Appliances and Buildings’, ‘Promotion of Solar Water Heaters through Financial Incentives’, ‘Installation of Four Wind Turbines in Rodrigues’, ‘Flaring of Landfill Gas’, ‘Partial Replacement of Sodium Vapor Lamps for Street Lighting with Energy Saving Lamps’, ‘Setting-up of Endemic Gardens in Schools to Enhance Sink Capacity and Promote Awareness’, ‘Planting of Mangroves as Sinks to CO_2 and Initiation of an Afforestation and Tree Planting Campaign’, ‘Phasing out of HFCs and PFCs’, ‘Replacement of Household Incandescent Bulbs with Energy Saving Lamps’, and ‘Increasing the Energy Conversion Efficiency of Bagasse’.

Príncipe Island: Mitigation measures are established for the most relevant sectors, covering energy and transportation, land use, forests, agriculture and farming, waste, industry and building.

Increasing the renewable component of energy production through hydroelectric, wind and solar sources are among the planned activities combined with new legislation and energy price policies. Agro-forestry techniques will be improved together with land planning and urban development rules.

Other planned mitigation and adaptation measures include ‘Mini-hydric Damns and Electric Power Production Units’, ‘Reutilisation of Rain Water for Irrigation and Domestic Use’, ‘Introduction of Improved Stoves Allowing the Reduction of Charcoal Consumption and Consequently Decreasing the Use of Forest’, ‘Massive Reforestation with Indigenous and Endemic Species’, ‘Introduction of Environmental Issues in the National School Curricula’, ‘Resettlement of Particular Fishing Communities by Installing Social Facilities and Infrastructures away from the Shore Line;, and ‘Introduction of Climatic Alert Systems for Preventing Natural Disasters’.

St. Kitts Island: The measures for responding to climate challenge are based on two major aspects: ‘Reduction in emission of greenhouse gases’ and ‘Adaptation to the identified sources of vulnerability’.

The established strategy addressing the two main objectives includes several actions, such as ‘Building and strengthening human and institutional capacity’, ‘Establishment of adequate legal and institutional frameworks and mechanisms facilitating the integration between the economy and the environment’, Revision and harmonisation of national planning and environmental legislation’, ‘Encouraging the adoption of more effective environmental management practices and technologies’, ‘Ensure compliance with all environmental, planning and infrastructure guidelines, standards and regulations’, ‘Application of the polluter-payer principle’, and ‘Promote regional and international cooperation in environmental matters’.

1. 4: The Impacts of Climate Change

Jeju Island BR: Overall, temperate and arctic plants in the vegetation belt moved 200-1,200m northwards. The areas of alpine plants were reduced by plants located in the lower part to move upland. Their blooming, fruiting and fertility of seeds have changed.

Some rain forests emerged in coastal areas, valleys, waterfalls, cave terrain, and lava fields. Warm temperate evergreen lucidophyll forest and number of population decreased at high latitude, but increased at low latitude.

An earlier insect outbreaks with a decrease in their number of population, while the appearance ratio of subtropical insects increases. Subtropical birds emerge.

Naked lands and caved valleys in grass areas in the subalpine zone have started to spread. Slope collapse, soil erosion, and sedimentation are progressed rapidly. Coastal areas are eroded due to sea level rise.

The arable land of subtropical fruits moves northward, while subtropical or tropical crops can be cultivated in the naked land. Agricultural products are damaged by the invasion and settlement of exotic diseases and insect pests. However, no existing published data on tourism are available on Jeju Island BR.

Sea lettuce is reproduced throughout the year. A new fishing ground of cutlassfish was formed. Cold current fish species are disappearing, while tropical species are appearing.

Menorca BR: It's expected that the bioclimate of the islands will change from "Dry" to "Semi-arid" and from "Mesomediterranean" to "Termomediterranean". This means that the mesophilic plant communities will suffer water stress and they may be more affected by pathogens and pests, in the hottest and driest borders of the distribution area. It is very likely to be a substitution of forests of holm oak (*Quercus ilex*) by other woody communities dominated by *Olea europea* or *Pinus halepensis.*

Wetlands ecosystems (ponds included) that depend on rainfall may undergo major changes (desiccation, increased salinity) due to the reduction of freshwater input. Beaches and dunes ecosystems will significantly reduce their extension and complexity due to increased sea level. This process can be accelerated by the use of mass tourism beaches without appropriate management systems.

Some species of plants and animals from being deeply affected by habitat change ~~and~~ may reduce their populations or even disappear from the islands.

The sea level rise associated with climate change will increase the receded of beaches and dune systems and it will cause an increase of seawater intrusion in coastal wetlands, especially if it occurs at the same time that a reduction in freshwater input.

For agriculture climate change could mean the emergence of a vector-borne disease and the loss of profitability of livestock farms.

It is likely that climate change will causes changes in trends in tourism demand but it is very difficult to make predictions considering only one factor. Nevertheless, the beaches erosion can degrade the main tourist resource of Menorca and seriously affect its attractiveness as a tourist destination. In the same way, the increase of jelly fish outbreaks, and wild forest fires, could have a big impact on tourists, as well.

For marine ecology, it is likely that climate change will causes a decline of *Posidonia oceanica*, an endemic seagrass. It can also expect there to be an increase of exotic invasive species, because nowadays some tropical species of crustacean, fish and algae already have been established in our islands. On other hand, seems to have been an increase in the presence of jelly-fishes (e.g. *Pelagia noctiluca*). This species is responsible for most of the bites to bathers of the tourist areas in our region.

The reduction in rainfall and increase in temperature will change the balance of the water cycle in Menorca. The expected result is to decrease the reserve of water in the aquifers, and also increased consumption associated with agriculture and tourism.

Macchabee-Bel Ombre BR: Native vegetation suffers from many introduced invasive alien species. Due to the rapid deforestation, little is known about natural ecosystem dynamics, whereas the ongoing discovery of new species stresses the gaps in the current botanical knowledge and underlines the uncertainties as to which part of the present flora can be considered native.

There has been a relative paucity of research and studies on the impact of climate change on the native vegetation of Mauritius.

A permanent plot, commonly known as the Vaughan plot, of $1000m^2$ in Macchabee was established in the 1930's and every species occurring there were recorded in 1937, 1986 and 2014 using the same methodology. This present study tried to assess the impact of climate change on the species composition and diversity.

In the Vaughan Plot, 1,785 individuals comprising of 69 species were measured in 1941 as opposed to 1,137 individuals including 56 species in 1986 and 983 individuals of 67 species in 2014.

The number of individuals in the studied plot decreased sharply by 36% after 49 years and by 14% from 1986 to present time i.e. after another 28 years. However, the number of species which decreased significantly in 1986, is now almost at the same level as in 1937 and significantly higher than in 1986.

Quite interesting is to note that the forest dynamic in the Vaughan plot seem to be working fairly well since 1986 and the number of species now present in the plot has increased from 55 to 67 in 2014.

Drainage properties of the soil had changed allowing marshy conditions to develop in the depressions, while heath and later thicket vegetation prevailed in areas at 'higher' elevation. Marshy conditions developed and the proportion of stagnant water increased, resulting in sediments rich in organic material. Heath and thicket vegetation remained present at 'higher' elevations.

The sediment record from a heathland area located at 650m elevation in Mauritius shows upland vegetation that changed composition before and after human arrival.

Sugar cane is very sensitive to climate variations; any global climate change will definitely impact on sugar production and hence entail serious socio-economic responses. Sugar cane yields are clearly adversely affected by cyclones, excessive rain, summer droughts, particularly if they are not irrigated.

Príncipe BR: The geographic location and climatic conditions, existing and predicted, combined with well preserved forests determine that desertification and soil erosion are not major problems in Príncipe Island. However, during the last years several extreme events lead to the occurrence of landfalls and fast floods causing significant destruction and losses of material and goods affecting some coastal communities. Erosion, loss of habitats and soil depletion are the most relevant expected impacts inducing economic and natural capital losses.

The tourism sector will be affected in several sectors, like health (accidents during extreme events), limitation of flight connections during storms and eventual damages on existing infrastructures located near the coastal areas. The increment of diseases linked with climate change will also impact tourism as the choice of a touristic destination includes health security.

St. Mary's BR: Natural resources, including marine, coastal and terrestrial ecosystems, habitats and species are under the influence of the extreme events related with climate change. Changes in precipitation and increased evaporation from higher temperatures are expected to affect water supply and water quality. Habitats and species will be impacted through changes of land cover, erosion and coastal degradation. In consequence, invasive and exotic species will have more probability to succeed due to the destruction and fragmentation of natural habitats.

The changes and destruction of coastal areas including beaches will also result in a lower quality of beaches and seafront areas which are extremely sensitive and have a high value in terms of tourism. Other implications will include structural damage to coastal infrastructure (harbors, roads) and increases in the costs of insurance.

1. 5: The Similar and Dissimilar Vulnerabilities to Climate Change

In order to draw the similar and dissimilar vulnerabilities to climate change among the five research BRs, this research compared indirectly and directly the impacts of climate change among the five research BRs. The above ‘1.4: The Impacts of Climate Change’, which implies the vulnerabilities to climate change, is the indirect comparison, showing the impacts by research BR. Direct comparison is drawing the similar and dissimilar vulnerabilities to climate change in a framework as ~~is~~ shown in <Table 16>.

The Impacts on Terrestrial Ecology

Three BRs (Jeju Island, Menorca, Macchabee-Bel Ombre) are vulnerable to ‘change in the distribution of main plant community’. Only Jeju Island BR is vulnerable to both ‘change in the phenology of some insects’ and ‘shift in the distribution areas of migratory birds’. Only Menorca BR is vulnerable to ‘increase of forest pathogens and insect pests’. All BRs except Jeju Island are vulnerable to ‘increase of risk of some endangered plants’. Three BRs except Jeju Island and St. Marry are vulnerable to ‘increase of exotic invasive species’, while three BRs except Jeju Island and Macchabee-Bel Ombre are vulnerable to ‘changes in certain ecosystems that threaten vulnerable species’.

The Impacts on Geology and Geography

Four BRs except Menorca BR are vulnerable to ‘soil erosion and other related phenomena’, and three BRs except Macchabee-Bel Ombre and St. Mary experience ‘coastal, beaches and dune erosion’. However, only Jeju Island BR experiences ‘increase of naked lands and caved valleys’, and only Menorca BR is vulnerable to ‘reduction of fresh water resources’.

The Impacts on Agriculture

All of the five BRs are vulnerable to ‘reduction in the profitability of traditional agricultural production. Only Jeju Island BR experiences ‘shifts in the areas where crops can be grown’. Meanwhile, Jeju Island and Menorca BRs experience ‘emergence of new diseases or insect pests in crops or livestock’.

The Impacts on Tourist Resort (Tourism)

Menorca and St. Mary BRs are vulnerable to ‘the reduction in quality of beaches due to erosion or other related phenomena’, and Príncipe and St. Mary BRs are vulnerable to ‘impact of hurricanes on touristic island attractiveness’. However, only Menorca BR is vulnerable to both ‘likely changes in the duration of the tourist season’ and ‘reduction of touristic quality of coastal areas due to increasing jelly fish’.

The Impacts on Marine Ecology

Two BRs, Macchabee-Bel Ombre and Príncipe, do not have a marine area. Two BRs, Jeju Island and Menorca, are vulnerable to ‘significant demographic change in algae and seagrass communities’, ‘increase of invasive species of algae from warmer habitats’, ‘shifts in the distribution areas of some fishes linked to changes of sea water temperature’, and ‘increase of marine invasive species from tropical area’. Meanwhile, Jeju Island BR experiences ‘spreading whitening of algae’, and only St. Mary’s BR experiences ‘likely impact on mangroves and coral reefs due to rising sea temperature’. However, Jeju Island and St. Marry’s BRs are vulnerable to ‘changes of fisheries’.

2. Conclusion

Global warming is the cause of for climate change. There are two scholar groups that argue the cause of global warming. One group argues the natural factors (eg. Sylvestre, 2000: 273-275; Flannery, 2005: 78; Ruddiman, 2007: Chapters 3-4; Choi, 2008: 325-329), and the other group argues the emission of greenhouse gases induced by human activities in the process for improving material affluence and convenience in everyday life (eg. Kraus et al, 1992: 4, 28; Miller, 2002: 452-453; IPCC, 2007).

Climate change has impacted on both human society and nature. The impact of climate change on society including impacts from humans cover a wide range of areas, such as water supply, population structure, food, land-use, energy, economic structure and development, world trade system, role and organizational structure of government, health, and population structure, etc. (Jeong, 2013). At a broad level, the impacts of climate change on nature are a decrease in biodiversity, change in the habitat of plant and animal, destruction of original ecological system, and destruction of ecological services, etc. (Jeong, 2013).

If the dominant cause of climate change is human-induced greenhouse gas being emitted in the process to improve material affluence and convenience, humans commit a self-contradictory; humans are both the contributors to climate change and victims.

This research focused on the impacts of climate change with a special reference to island and coastal biospheres. The following were identified from this research. The islands where the five research BRs are located implement climate change policies including not only both adaptation and mitigation, but special measures to conserve own BR. However, it may be argued that the policies and measures are not effective enough to prevent BRs from climate change impact. This is evidenced from the fact that the most climate change impacts identified are those caused not by human-induced activities related to greenhouse gas emission in own island, but by greenhouse gas emitted at global level.

This fact would imply that region-specific policies and measures contribute to reducing the strength of climate change, but do not contribute directly to preventing or reducing the impact of climate change on its own BR. In addition, this fact informs that government-led policies and measures for conserving BRs are not enough for conserving BRs, but other local agents should take a role in conserving BRs together with the activity of the government. The local agents responding to climate change would be enterprises, environmental non-governmental organizations (environmental NGOs), and citizens. Their desirable roles in relation to less emission of greenhouse gas are enterprises' green management, environmental NGOs' active environmental movement, and citizens' environmentally friendly behavior in everyday life.

For enterprises, the traditional management has focused on maximizing profit with less consideration on nature being impacted from the process of resource extraction, production of goods and service, and distribution of goods and service. Green management is defined as a management through which enterprises fulfill their social and ethical responsibilities by saving and using resources and energy efficiently and by minimizing the emission of greenhouse gases and the occurrence of environmental pollution in their business activities (Seo, 2013).

Environmental NGOs are an intermediary group between government/enterprises and citizens. In relation to environmental conservation, their major role is to act as a pressure group towards government/enterprises and an educator to citizens through environmental movement activities (Jeong, 2014).

Citizens are the direct contributors to climate change through the process of consuming goods and services produced by enterprises. This is based on consumerism as a cultural ethos in relation to the traditional conception of quality of life. Citizens' consumption has a wide range of behavior. However, they are converged into two categories (Jeong, 2014). One is saving resources and the other is saving energy. The former includes reducing water use, refraining the purchase of luxury items, recycling home-products, and reducing waste discharge, etc. The latter includes reducing vehicle usage, electronic products, and heating/cooling systems, etc.

There is no doubt that government-led climate change policies will be more effective when enterprises' green managements, environmental NGOs' active environmental movements, and citizens' environmentally friendly behaviors are promoted together with climate change policies. Despite the implementation of these cooperative activities, the government, which acts as an agent that responds to climate change for the better conservation of biosphere reserve, is faced with some constraints that need to be overcome. The terminology for overcoming the constraints is capacity building, which can be categorized into internal and external (Jeong, 2012).

Internal Capacity Building: This includes an increase in financial capacity and advanced technology development. The reason for this increase is due to a large budget that is necessary for launching climate change policies, and clean energy that requires advanced technology.

As mentioned earlier, a cooperative network with enterprises, environmental NGOs, mass media, and citizens should be established. This is because the goals of these policies are difficult to achieve without social consensus with enterprises, environmental NGOs, mass media, and citizens as the major social components.

In addition, there should be an institutionalized decision-making during the process of the internal governance system. In case of a possible conflict, this institutionalized decision-making process is for drawing social consensus with social components, such as stakeholders, on the policies through internalization. Finally, the current socio-economic system should be changed to a new system. This may be termed the social system approach, in which the existing social system as the source of greenhouse gas emission should be attempted to be restructured. The major targets of the restructuration includes change in economic market system in terms of production and distribution, change in citizens' lifestyle in terms of purchase and consumption behavior, and change in cultural ethos from consumerism to environmentalism.

External Capacity Building: Climate change is a global environmental problem that arises from both internal and external sources of greenhouse gas emission. In this sense, it would be necessary to establish a cooperative network with other regions and countries. The network should include, at the least, mutual understanding, exchange of information, and collaborative activities. Mutual understanding includes the seriousness of climate change, the necessity of collaborative response to climate change, and the effectiveness of collaborative response to climate change. Exchange of information covers the state of climate change, the data related to climate change, and the training program necessary for climate change education. The fields of collaborative activities are a mutual exchange of administrative/professional staffs, collaborative research, and holding joint professional conferences, etc.

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