CHANGES IN LAND USE AND COVER IN ARCHIPELAGO LAS PERLAS: A PROPOSAL FOR A PROTECTED AREA

By

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DEDICATION

“To God, for allowing me to accomplish my goals. To the memory of my aunt Cely who day by day gave me the necessary strength to keep moving forward in this venture.”

ABSTRACT

This study uses a simple multi-temporal analysis method to provide follow up both in land use and forest cover change in Las Perlas Archipelago, Panama. To carry out this study a time period of 26 years was covered, where three satellite images from diverse high spatial resolution sensors of the years 1974, 1986, and 2000 were used (Landsat MSS, TM, and ETM). A supervised classification analysis was made for the ETM image from November 2000 where seven (7) categories were identified between land use and forest cover. Then a retrospection of previous decades was made analyzing unsupervised classification of the images MSS of 1974 and TM of 1986. To estimate the deforestation rate, the land use classes were regrouped in two categories: forested and non forested. The formula proposed by FAO (United Nations Food and Agriculture Organization) was used to obtain the deforestation rate at the Las Perlas Archipelago resulting in -1.01 %, which indicates the loss of 7,154.55 ha of forest. Results obtained from multi-temporal analysis by means of the Geographic Information Systems were interrelated or combined with other important physical variables such as infrastructure, slopes, hydrography, nesting sites for marine birds, endemic birds and reef location. In this manner, it was possible to understand the existing relation among the variables and thus to model different scenarios with the main objective of proposing terrestrial protected areas.

INTRODUCTION

1.1 ECOSYSTEMS RELEVANCE IN ISLANDS

Animal and plant species richness can be lost due to deforestation causing species extinction at the local and regional levels. The result of forest cover reduction and population isolation increases the risk of extinction, either by demographic factors (low numbers of individuals) or by stochastic factors (natural disturbances) (Kattan, 2002).

Islands are characterized by diversity of endemic species, which makes them important areas for biodiversity conservation. Many species require the different habitats present in islands for their reproduction, as is the case of marine birds and turtles (Tershy & Croll, 1994; Moran, 1996; Tershy & Brees, 1997; Whittaker, 1998). It has been estimated that one of every six plant species in the world inhabits in oceanic islands and that 17% of the world's bird species are confined to islands. In both cases islands make a disproportionately high contribution, considering the small terrestrial surface (3%) when compared to the continents (Whittaker, 1998).

It seems that the relevance that insular ecosystems have has been overlooked since each year they are disturbed and in many cases degraded at such level that species extinction level in islands is probably 40 times larger than what could occur in continental species (Johnson & Stattersfield, 1990). Extinction causes have diverse origins; nevertheless, the most common include overexploitation of some resource, the introduction of exotic species, and habitat destruction or partial disruption (Saunders *et al*, 1991; Bush, 1996). In terms of recent animal extinctions, 75% of the total have been of insular species. In the particular case of birds, 85% of the total extinction in historic times has occurred in islands (Steadman, 1997). In regard to mammals, this number is 58% and for terrestrial mollusks it is 80% (Whittaker, 1998). One of

every three threatened plant species and 23% of threatened birds are currently insular species (Groombridge, 1992).

Throughout the world there have been many efforts to try to stop species extinction in the insular systems, to reach this objective conservation plans have been developed to address island protection. These efforts have resulted highly efficient due to the following: 1) islands have a large amount of endemic species per area; 2) low economic costs since human permanent population is usually small or human activities are non-existent, and 3) islands are complete ecosystems relatively easy to protect when compared to continental habitats (SEMARNAT & CONANP, 2005). Every day new studies and research generate information on the fragility of ecosystem originated in insular systems; in consequence, it is important that governments increase their efforts to protect many species from extinction.

1.2 THE DARWIN PROJECT INITIATIVE

The United Kingdom, through the Department of the Environment, Food, and Rural Affairs (DEFRA) promotes biological diversity conservation and sustainable development of natural resources by financing projects around the world. The Panamanian Government has benefited by means of the Heriot Watt University, which together with the Smithsonian Tropical Research Institute has been carrying out studies in Las Perlas Archipelago with the purpose of assisting the National Environmental Authority (ANAM, acronym in Spanish) in the identification of marine areas that require protection.

Darwin Initiative, in Panama, started in the year 2002, their first field trip on the RV Urraca had as objectives to familiarize with the study area, to demarcate and obtain sample stations of sediment and of some heavy metals that were completed in May 2005. Another important point was to locate and evaluate areas with well-conserved reefs and, in the other hand, observe the existing

dynamics among natural resources versus the economic activities in the area at the artisanal and industrial levels.

This was the opportunity that opened doors to a series of Panamanian, Colombian and British to carry out Masters and Doctorate level studies through the Darwin Project in Panama, besides having the opportunity to participate with renown scientists from the United Kingdom, Venezuela and Panama.

At the beginning of January 2003 the Smithsonian Tropical Research Institute, part of the Darwin Project in Panama, had a Geographic Information System. In it all the available cartographic information of the Tommy Guardia National Geographic Institute (IGNTG, acronym in Spanish), in scale 1:50,000 had been incorporated in digital format thus facilitating access, integration and exchange of information between Scotland and Panama.

In mid June and November 2003 students, interested in carrying out studies regarding the marine environment and environmental education, arrived to Panama City. The marine environment studies covered mollusks, fish, fishing, reefs, sponges, and heavy metals. Besides, a student conducted her doctoral studies in the tele-detection of coral reefs and another master's student made a multi-temporal analysis of satellite images to assess degradation of the terrestrial environment in the Las Perlas Archipelago during the last three decades.

In addition to the cultural exchange, in terms of education and research, between the governments of the United Kingdom and Panama through the Darwin Initiative, the most important legacy for Panama, is the numerous scientific investigations that will serve as a baseline to understand current marine and terrestrial natural resources conditions in Las Perlas Archipelago. When safeguarding natural resources this information is, at the same time, an important tool that can be funneled through research institutes or non

governmental organizations to the governmental sector in charge of the decision making process.

1.3 LAS PERLAS ARCHIPELAGO

Las Perlas Archipelago is located in the Gulf of Panama in the Pacific Ocean. It is approximately 60 km to the southeast of Panama City. Within this complex, there are relevant islands with considerable extension such as: Isla del Rey with 23,922.22 ha, Isla San Jose with 4,400 ha and Isla Pedro Gonzalez with 1,462.62 ha. These islands show sandy and separated beaches, with flora and fauna relatively intact in a lowland moist tropical forest surrounding and a rich marine life, showing one of most important socioeconomic and tourism potentials in the country.

Las Perlas Archipelago has been designated as a special tourism development area for Panama, named Tourism Zone 8 (Law 8, June 14, 1994) and it is part of the Whale Sanctuary of Panama (including territorial waters: Pacific and Caribbean). This special development area can represent progress for some people but may bring with it the degradation of the insular and coastal marine ecosystems.

Some of the islands in the archipelago are currently subject to pollution, as is the case of Isla de San Jose, which was the object of chemical weaponry tests by the American Government in programs that focused the defense of the Panama Canal during the Second World War and later during the Cold War (1943 to 1968). In Isla de San Jose tests with chemical ammunition were performed in the period 1944 - 1948 (Linsday-Poland, 2003). The rest of the other islands have been subject to degradation by activities such as agriculture, cattle raising and wood extraction for house and boat construction.

Main Panamanian fishing resources are in the Gulf of Panama where they are located within the Las Perlas Archipelago. There are species of great economic

importance: 26 crustacean species with 12 shrimp varieties, 5 lobster species and 9 crab varieties. Marine fish are among the principal resources of the country with approximately 1,200 species, considering to this moment some 140 species of commercial importance (MICI, 1992).

Due to its geographical position, Panama has become an important place for the convergence of fauna coming from North and South America. Precisely, within the Las Perlas Archipelago there are 10 islands important for marine bird nesting such as: Neotropic Cormorant (*Phalacrocorax brasilianus*), Brown Pelican (*Pelecanus occidentalis*), Great Egret (*Ardea alba*), Black-crowned Night-Heron (*Nyctycorax nycticorax*), Yellow-crowned Night-Heron (*Nyctanassa violacea*), Brown Booby (*Sula leucogaster*), Blue-footed Booby (*Sula nebouxii*) and Magnificent Frigatebird (*Fregata magnificens*) with the largest nesting colony in Isla Pacheca (Angher, 2003).

The largest islands (del Rey, San Jose and Pedro Gonzales) are important places for understory birds, including threatened species at the national level: Yellow-crowned Amazon[a] (*Amazona ochrocephala*), White-fringed Antwren[a] (*Formicivora grises*), Uniform Crake[a] (*Amaurolimnas concolor*), etc., with 16 endemic subspecies, it is an important sub-specific differentiation center, 11 of these reports are from Isla San Jose, one of which the Rufus-necked Wood-Rail [b] (*Aramides axillaris*), that is restricted to this island and Pedro Gonzales (Angher, 2003)[1].

Little information is available regarding terrestrial fauna in terms of amphibians, reptiles, and mammals. In San Jose island there are reports of the toad Eleutherodactylus *ranifrons* and an isolated population of the Brown Brocket Deer (*Mazama gouazoubira*) which is found again in South America to the East of the Andes (Colombia, Venezuela, Brazil to southern Uruguay and north of Argentina). Among most representative reptiles there are the Green Iguana (*Iguana iguana*) and sea turtles arrive to nest to some of the islands: Olive

[1] Species [a] are threatened at the National Level and species [b] are endemic (Angher, 2003)

Ridley (*Lepydochelys olivacea*) and the Green Turtle (*Chelonia mydas*), these species are used by these islands inhabitants (*com. pers. inhabitants, 2004*).

Due to the low population density within the nine communities of the archipelago, I consider that there still is in equilibrium in terms of the terrestrial ecosystem. Nevertheless, the threat may increase since in the archipelago, there are no protected areas or land use planning that can protect these fragile ecosystems and create conditions for a cultural and socioeconomic change in the insular region regarding the need to protect the natural resources to guarantee the sustainable development of the archipelago.

1.4 ENVIRONMENTAL DETERIORATION THREAT

Las Perlas Archipelago currently confronts large threats of environmental deterioration, due to numerous social, economic and political factors that negatively influence both in people's well being as well as in the status of natural resources and biodiversity. Among some of the identified causes, the following are relevant:

- To this moment, there are no National Parks or other reserve category within the Archipelago or an integral management plan focused on environmental conservation and the care of natural resources.
- Expansion of the agricultural frontier in detriment of the forest.
- Crops and cattle raising in inappropriate lands and without the application of conservation practices.
- Hydrocarbon spill in watercourses and coasts.
- Exotic species introduction.
- Furtive hunting.
- Wildlife habitat destruction through deforestation and forest fires.
- Illegal commercialization of wild flora and fauna.
- Water courses pollution.
- Deficiencies in solid wastes collection and final disposition systems.

These causes environmental deterioration, in general, and the degradation of insular and coastal-marine ecosystems, in particular, can generate problems and consequences such as:

- Deforestation in land with steep slopes.
- Soil compaction and alteration of soil structure.
- Erosion and accelerated loss of land productivity capacity.
- Uncontrolled fires of secondary vegetation and scrub.
- Water flow increase.
- Accelerated sedimentation of river and creek flows.
- Significant reduction of water availability in the dry season for human, industrial and agricultural and cattle raising purposes.

1.5 SETTING THE PROBLEM

In general, many of the components of the coastal zone in the Central American countries (beaches, mangroves, estuaries, and reefs) are legally considered as a public good and of governmental property (Windevoxhel *et. al*., 1998). This has caused terrestrial and marine resource competition, among the different interest groups, as well as for the available space (coastal communities, fishermen, aquaculture, agricultural and tourism enterprises), which has brought as a consequence important social conflicts and the destruction of resources and functions of the coastal zone (Cicin-Sain & Knecht, 1998).

This resource use influences not only on the direct activities of the coastal zone, but also in the ones performed in the upper parts of the hydrographic basins, due to poor management of industrial, agricultural, domestic wastes, as well as the deforestation in the mountains slopes and river borders.

Due to these reasons, we consider that it is important to know what has been the trend of the pattern in regard to the forest cover and land use along a

considerable time period. It is important to determine its current status within each of the island in the Archipelago and to present measures that can be adopted in the future with the purpose of protecting natural resources in this valuable insular system.

1.6 OBJECTIVES

1.6.1 General

Assess current condition in terms of forest cover and land use and propose natural reserve areas within the archipelago.

1.6.2 Specific

- Estimate deforestation rate.
- Identify changes in forest cover and land use in a period of 26 years (1974-2000), through the multi-temporal analysis of satellite images.
- Identify areas prone to erosion, by means of a classification of the ranges of slopes in the study area.
- Identify main watersheds that provide water to the communities within the Archipelago, which may be in peril due to siltation risks.
- Through the Geographic Information System, determine the distribution and conditions of natural resources to propose the establishment of protected areas within archipelago.

LITERATURE REVIEW

Economic and social development, constitutes a fundamental commitment for the Latin American governments, which has to be consistent with the potentialities in the area giving attention to appropriate and rational use of natural resources and to the application of technological styles and forms of organization that respect natural ecosystems and socio-cultural patterns (Miller, 1980).

Protected Areas (PAs) originated in the last century in the United States of America with the establishment of Yellowstone National Park (1872). More than 25,000 PAs had been established at the beginning of the 90s, thus covering 5% of the land and, in Central America, it has reached beyond 16% of its territory (Cifuentes, *et al*. 2000, McNelly *et al*. 1994, UICN/BID, 1993).

National Parks can play a very important role in the implementation of scientific, ecological, economic and political objectives of a country demonstrating that they are useful to maintain habitat for humans as well as for the natural and cultural heritage. Nevertheless, conservation activities in PAs have forced their administrators to incorporate innovative management, planning and management elements and strategies to ensure long-term maintenance of their natural, cultural and social values. A flexible and dynamic planning strategy is required to guide appropriate management of a protected area (Cifuentes, *et al*. 2000, Miller, 1980).

In Panama, the General Environmental Law defines a Protected Area as a *"geographical area, terrestrial, coastal, marine or lacustrine, legally declared to satisfy the conservation, recreation, education or research objectives of the natural and cultural resources".* They can be declared through different legal instruments such as: laws, decrees, resolutions or municipal accords (ANAM, 1998). Besides, PAs will be administered by ANAM's National System of

Protected Areas (SINAP, acronym in Spanish), which currently has 63 PAs in 17 management categories, representing 32.6% of the national territory or 2,458,842.69 ha. (Amend, 2004; ANAM, 2004).

In Central America, 30 % of all PAs have not progressed beyond their legal establishment and more than 60% have not yet solved land tenure problems (UICN/BID, 1993). Thus, a disciplined and strategic focus is required to perform conservation actions in priority sites.

Projects as PROARCA/Costa and organizations as The Nature Conservancy (TNC) are developing and applying planning methodologies for protected areas to offer the greatest scientific information possible, as the Site Conservation Planning (SCP), and Rapid Ecological Assessment (REA).

In the last five years in Panama, ANAM has established the requisites to declare a protected area among them there is the production of a characterization of the area (baseline studies) that include the proposed management category to later conduct a Rapid Ecological Assessment (REA) and a Participatory Rural Appraisal (PRA) and the preparation of the area polygon (map). ANAM will prepare a draft project with legal base (law, executive decree or administrative resolution) together with a motives account or justification for the appropriate establishment of the protected area, which is legalized when it is published in the Official Gazette (Amend, 2004).

MARINE PROTECTED AREAS IN PANAMA

The Republic of Panama occupies a territory of 75,517 km2, having a coastal zone of 2,988 Km, bordering the Pacific and Atlantic Oceans, where highly productive marine life and important coastal resources converge. The Pacific coast is characterized by a large urban development since approximately 80% of the population is located in this zone that has an extension of 1,700 km and a wide platform that reaches up to 150 km (GEO Panama, 2004).

The country currently has 24 protected areas with coastal zones covering an approximate extension of 1,561,707.60 ha; of these areas, five are insular and are located in the Pacific with a surface covering 310,614 ha.

Table 2.1 Insular Protected Areas in the Panamanian Pacific Region

Management Category	Name	Surface (ha)
National Park	Coiba	270,125
National Park	Golfo de Chiriquí	14,740
Wildlife Refuge	Isla Iguana	58
Wildlife Refuge	Taboga y Urabá	258
Wildlife Refuge	Isla Cañas	25,433
	Total	**310,614**

As a tool to provide velocity and precision for environmental studies, and a wide variety of uses in ecological studies in tropical forests, new tele-detection technologies have addressed their attention to tropical regions (Chinea, 2002).

Luckman *et al.* (1997) used Landsat TM images in seven different dates between 1986 and 1992, for studies on secondary succession in tropical forests, when combining radar and Landsat data (Rignot *et al.* 1997).

Our study is based in the development of methodologies used by different authors, in this study we relate deforestation, and satellite multi-spectral images study. All this with the purpose of integrating these different experiences to prepare a baseline data with criteria that will allow us to propose protected areas within the Las Perlas Archipelago.

In a study made by Chuvieco *et al* (2002) a multi-temporal analysis was made to follow up on the deforestation process in the Ticoporo Reserve in Venezuela. Aerial photographs of the year 1962 and satellite images comprised among years 1972 and 1997 were used with the object of monitoring deforestation during the periods 1962-1972, 1972-1989, 1989-1993, and 1993-1997. The

classification for each period was grouped in two large categories, forests and agricultural, they performed cross-reference tabulation for each period, and also of the first and last date to obtain change and stable zones during this time interval (Chuvieco et al 2002). For Las Perlas Archipelago, satellite images of the years 1974, 1986 and 2000 were used and we were able to incorporate this technique using two study periods (1974-1986 and 1986-2000) where the agriculture class used by the previous authors was replaced by a class named non-forested. In this manner, it was possible to perform the cross reference for each period to obtain the deforestation degree and detect the form in which the deforestation process happened in each of the islands studied.

Postner *et al* (2002) present a simple method to apply geo-referenced data and Geographic Information System (GIS) to improve land use in Andean regions. In its simple analysis he emphasizes in only two variables that have close relation with the degree of current erosion, the slopes and forest cover. The slope factor is probably the most influential in an area with strong slopes and the forest cover factor allows us to focus in most affected areas (barren land) and with more potential to be affected (annual crops) (FAO, 1993). They applied this methodology at the watershed level nevertheless we used it at the level of islands obtaining in a fast and simple manner an erosion risks map based on the slope classification and the land use classification map.

Acuña (2005) uses an un-supervised forest classification and performs a multi-temporal analysis on satellite images provided by the sensor Thematic Mapper for the years 1987, 2001-2002. In his analysis, he identified and analyzed 3 forest types (secondary flooded forests, well conserved mainland secondary forests). In our study, we used the same technique used by Acuña for the classification of the images of the years 1974 and 1986, but we defined seven land use categories. The criteria for the multi-temporal analysis were made based on the Tables that corresponded to each class per year and to estimate the pattern of change per class.

METHODS

3.1 STUDY AREA

Las Perlas Archipelago is a complex of approximately 255 islands and islets located in the Gulf of Panama; its surface is of 33,176.57 ha. It is located in the Balboa District within the Province of Panama, between the following coordinates: 8º 11'31.47" and 8º 40'16.33" North Latitude and 78º 46'21.95" and 79º 08'39.72" West Longitude, at 60 km from Panama City (Figure 3.1).

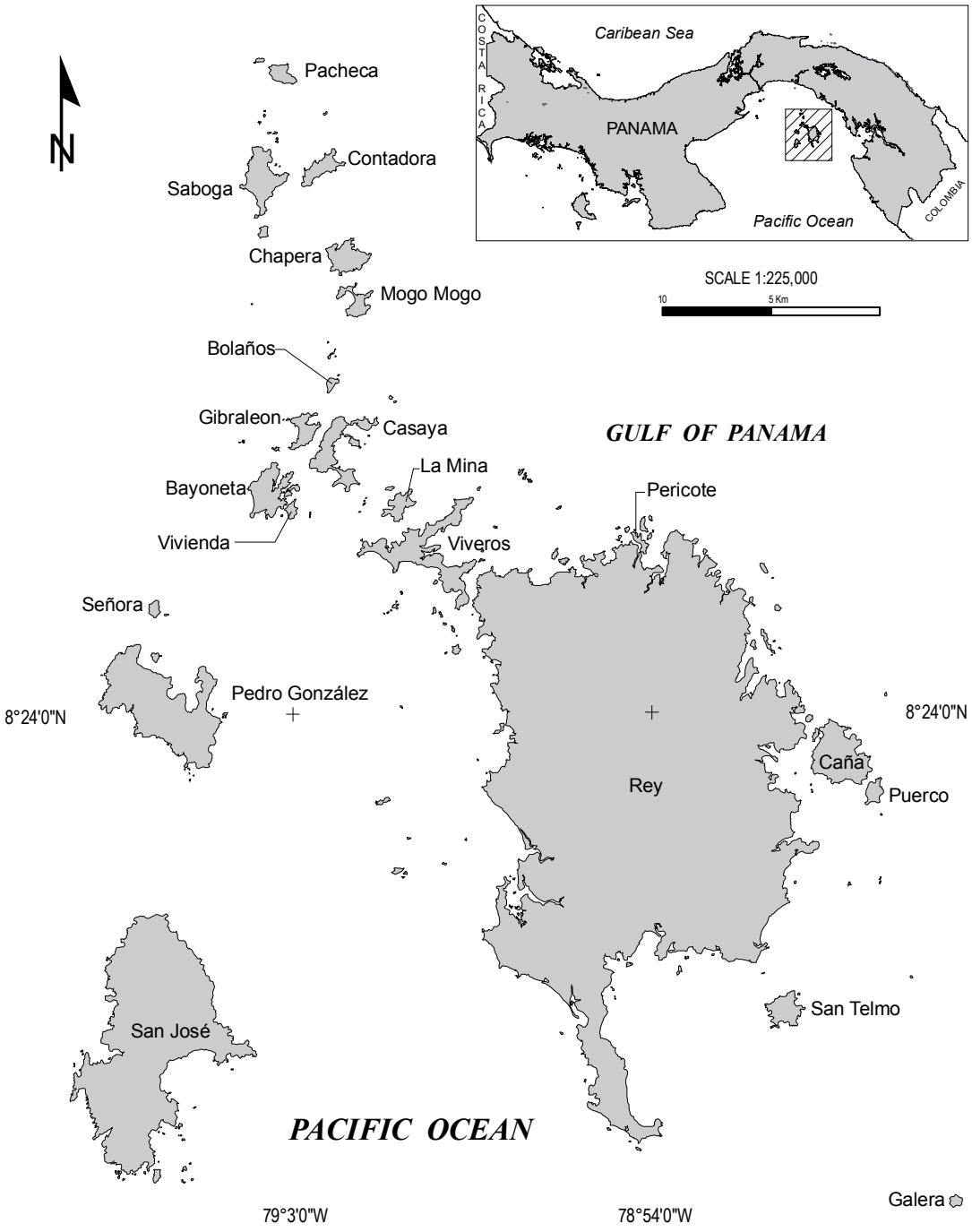
Total population of the Archipelago was 2,336 inhabitants distributed in the communities of Contadora, Saboga, Casaya, Pedro González, San Miguel, La Ensenada, La Esmeralda, La Guinea and Martin Perez as reported by the population and household census of the Republic of Panama for the year 2000.

3.2 PHYSICAL CHARACTERISTICS

3.2.1 Oceanography

The Gulf of Panama is shallow and has a soft slope to the south, nevertheless, it shows in its central portion a submarine valley that originates approximately at 40 meters under the sea level, to the south of the Bayano River outlet (Panama province), moving from the South to the border of the continental platform (200 m) to the West of Las Perlas Archipelago. The depth increases considerably from the border of the platform of the Gulf of Panama, changing in a 10 km distance from 200 m to 3,000 m.

Figure 3.1. Geographical Location of Las Perlas Archipelago, Panama.



In the Isthmus of Panama, the climate shows marked seasonal variations that are related to the position of the Intertropical Convergence Zone (ITCZ). North winds separate the ITCZ from the isthmus, while the south winds push the ITCZ over the isthmus. The rainy season, regularly starts in May and it extends into November. The dry season, which generally extends from January to April, is the result of a South migration of the ITCZ. It is characterized by the high intensity of winds from the north, which generally reach their greatest speed in the months of February and March. The effect of these winds is stronger in the Caribbean that reflects in the production of more waves than in the Pacific.

Among the main effects of the winds in the Panamanian coasts there is the oceanographic phenomenon named “coastal upwelling”, which occurs in the Gulf of Panama during the dry season and is characterized by the upwelling to the surface of the sea of waters from the deep ocean, probably a depth of 150 meters. The most evident oceanographic consequence of this phenomenon is the reduction of the surface temperature of the sea, which in the most extreme cases diminishes from 28 °C to 20 °C. This reflects a high productivity of commercially important species. Consequently, productivity of phytoplankton and marine algae is greater in the Pacific when compared to the Caribbean Sea.

This “upwelling” also influences water salinity being this the reason behind the presence of the highest values of salinity in water during the dry season (greater than 34 0/00). Surface salinity of water for the Gulf of Panama, and thus for Las Perlas Archipelago, can vary between 34 0/00 during the dry season and 32 0/00 during the rainy season.

The tides in the Panamanian Pacific region are semi-diurnal, with amplitude of 6 m, and are predictable, while the pattern of the currents is in the western direction.

3.2.2 Climate

The Archipelago has a tropical moist climate with annual rainfall that oscillates between 2,500 and 3,000 millimeters per year, and following Holdridge's Life Zone classification diagram (Atlas Nacional de la República de Panamá, 1988), Las Perlas Archipelago is within the life zone named tropical moist forest.

3.2.3 Geology

Of the Archipelago's Western sector, 79% is conformed by sedimentary rock of the Cenozoic Era corresponding to the Superior and Inferior Tertiary period, Las Perlas Formation, where the following are common: andesites, basalts, lavas, and pyroclastics. The other 21% is located only in the East of Isla El Rey, to the South of the Archipelago and is conformed by igneous rocks of the Cenozoic Era and the Superior and Inferior Tertiary period, Maje Formation presenting lavas and pyroclastics, andesitic-basaltic of the Maje complex (Dirección General de Recursos Minerales de Panamá, Geological Map of Panama, scale: 1:250,000, 1991). In its coasts we find sand accumulations or littoral strips that border the coast.

3.2.4 Soils Agrological Capability

The classification system used in Panama was developed by the Soil Conservation Service of the United States Agriculture Department. It is based on the agrological capability or the potential use for a mechanized agriculture and of high technical level.

Characteristics assessed to estimate agrological capability are: soil depth to allow the development of roots, permeability, drainage, presence of stones or rocks, topography, erosion, flooding risks, salinity and fertility.

Las Perlas Archipelago does not represent the most favorable characteristics for the development of industrial production due to its soil conditions. Only 36 % (12,228 ha) are considered as soils with appropriate agrological capacity for production; nevertheless, this would be very limited to the selection of plants to

be produced. The other 64 % (20,947 ha) of the lands are not in condition to be used for agriculture production and their use is restricted to pasture, forests and reserve land.

3.4.2 DATA COLLECTION AND ANALYSIS

Topographical data was obtained form maps of the scale 1:50,000 from the Instituto Geográfico Nacional Tommy Guardia (sheets San Miguel 4441-III and Esmeralda 4440-IV), where contour lines and elevations were digitalized to generate a Digital Elevation Model and a Gradient Map.

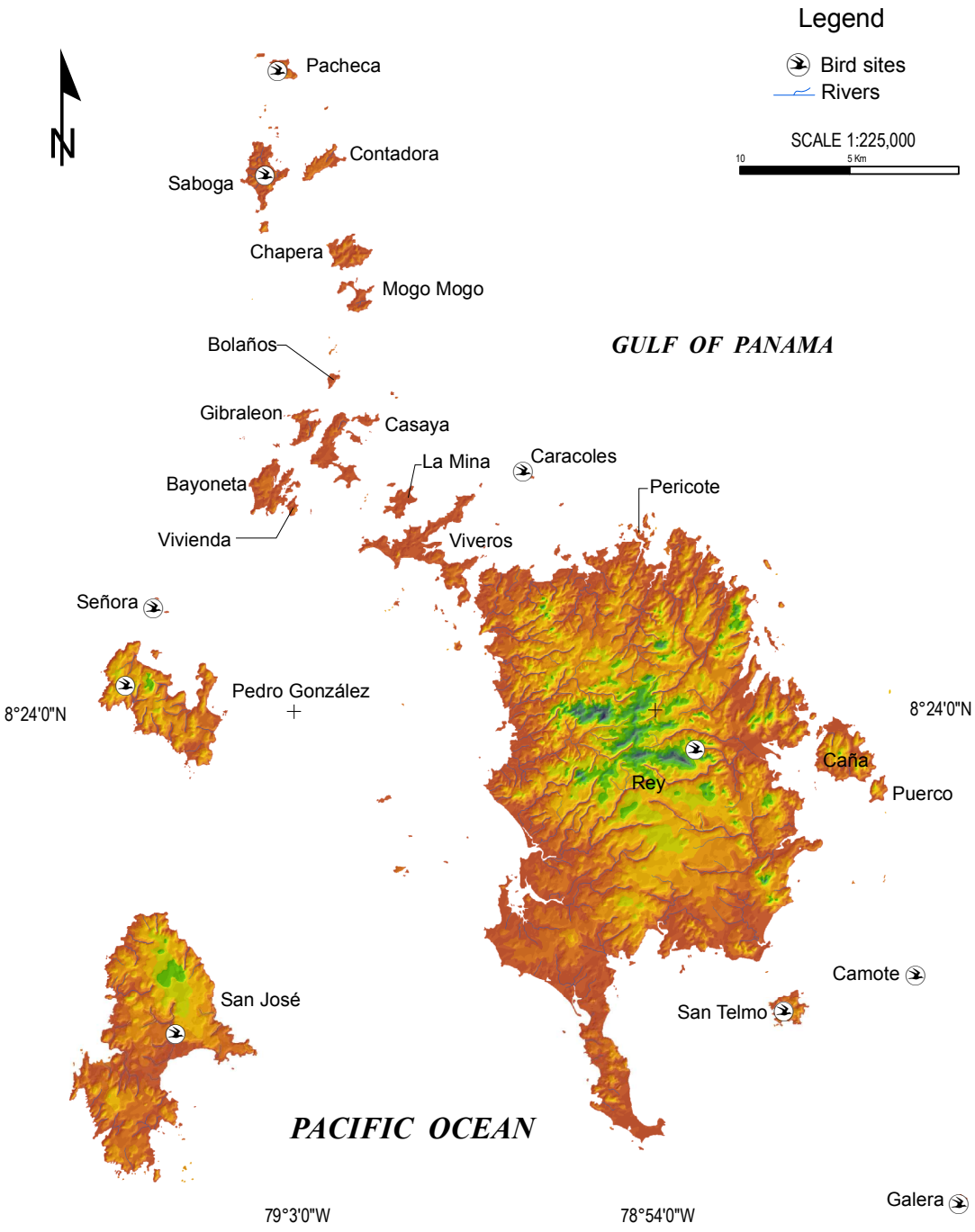
Hydrographic data was obtained from previously mentioned maps, allowing us to extract information on the drainage web in the islands, which together with topography was helpful to demarcate the different hydrographic basins within the study area and evaluate which were the watersheds supplying with water the different communities of the Las Perlas Archipelago.

Marine birds nesting sites were obtained from the Directory of Important Areas for Birds in Panama (Angehr, 2003), Table 3.1 and Figure 2, show the 10 sites identified within Las Perlas Archipelago.

Table 3.1 Marine Birds Nesting Sites in Las Perlas Archipelago, Panama.

NAME	LATITUDE NORTH	LONGITUDE WEST
Isla Cangrejo	8° 29' 56"	78° 57' 16"
Isla Galera	8° 11' 41"	78° 46' 30"
Isla Monte and Camote	8° 16' 30"	78° 48' 00"
Islas Perlas Norte (Pacheca, Pachequilla, Bartolomé)	8° 39' 55"	79° 03' 20"
Isla Pedro Gonzáles	8° 24' 40"	79° 07' 12"
Isla Rey	8° 23' 00"	78° 53' 00"
Isla Saboga	8° 37' 20"	79° 03' 40"
Isla San José	8° 16' 00"	79° 06' 00"
Isla San Telmo	8° 16' 30"	78° 50' 50"
Isla Señora	8° 26' 36"	79° 06' 30"

Figure 3.2 Bird sites of Las Perlas Archipelago, Panama



3.3 DESCRIPTION OF THE CATEGORIES USED IN THE SATELLITE IMAGE CLASSIFICATION.

We have determined a priori seven classes or categories of coverage of forest and land-use, which we consider that they properly adjust to the necessities of our study. The following are said categories:

Class 1. Mangrove Areas: conform by perennifolia vegetation and made up of few tree species that are adapted to grow on liming soils, almost anoxic, and that are periodically or permanently covered by salt water or brackish.
Class 2. Humid Forest of Low Terrain with little intervention: it is characterized by precipitation range 1,500 - 3,500 per year. Approximately half of the trees lose their foliage the dry season: oftentimes, its structure and composition has been altered by human activity.
Class 3. Intervened Forest: is considered a forest that is naturally regenerating after total or partial logging, burning, or other earth converting activity, without being completely recuperated.
Class 4. Brushwood – Stubble: represent the transition of much altered zones, where natural vegetation has been eliminated and where the regeneration process towards the natural forest is in an advanced phase.
Class 5. Paddocks, Grasslands, and Farming Areas: include paddock areas that are primarily destined to cattle range pasturing, its vegetation is of little height, usually less than 25 cm. The grasslands are undefined use areas supplied with herbaceous vegetation, where the herbs reach different heights up to 1.5 meters. Farming lands are those that at rising time were under farming production.
Class 6. Populated Areas: comprised by semi-urban areas whose dimensions allowed its identification on the Landsat imagery. These zones were interpreted by means of existing cartographic material.
Class 7. Beaches – Barren Land: include lands that at the time of the satellite image classification were devoid of vegetation.

3.4 SATELLITE IMAGE ANALYSIS

To carry out the forest degradation analysis the land use current status within the study area, in first place I compiled all available material. In this sense, the remote sensor oldest documentation available of Las Perlas Archipelago is a Landsat MSS image of February 23, 1974, an intermediate image Landsat TM of February 01, 1986 was obtained as well as a final image Landsat ETM of November 23, 2000.

The first step to develop a multi-temporal analysis is generally oriented towards radiometric calibration among the images that are part of the process. This procedure is necessary when the work is done with digital levels, to be sure that the values of all images to be compared are matchable, since the original ones are dependent on the sensor and the date of acquisition (Chuvieco, 2002). Nevertheless, this calibration is not required if the work is done with previously classified images, that is categorical images; in the case of the 3 images used in this analysis they were classified in 7 categories, thus no radiometric homogenization was required. This decision was taken in part because of the lack of calibration coefficients for the analyzed images.

At the beginning of this study, there was no detailed map of the scope and structure of the forest, nor of the condition of land use for this sector of the country. The only available documentation was the vegetation map of the country in a scale 1:250,000, which does not satisfy the needs for the development of this study, since our analysis requires more detail.

In the first place, a supervised classification was made for image ETM November 23, 2000 where seven (7) categories were identified between land use and forest cover. This first step helped in the understanding of the different categories (use types and cover) that are being developed in Las Perlas Archipelago. Then we made a retrospection of previous decades through an unsupervised classification for images MSS of 1974 and TM of 1986.

3.4.2 Supervised Classification

The Landsat ETM satellites have a 25 x 25 meters spatial resolution, spectral response in this unit is the product of sampling of radiation reflected by objects located over it. As primary source for the digital treatment, an ETM Landsat image of November 23, 2000 was used. The software ERDAS IMAGINE version 8.7, under Windows 2000 operative system was used in the analysis of bands 1, 2, 3, 4, 5 and 7.

Supervised classification was divided in four phases:

First: the definition of the training areas, through which it was necessary to perform field trips to allow the acquisition of samples of the different categories to be classified with the help of a global positioning system instrument (GPS). The process of sample collection was made by transects that started to the North of Isla Saboga in January 2004 and finished in the West of Isla El Rey, to the South of Las Perlas Archipelago, in the month of May 2004.

Second: the application of enhancement and improvement of the visual quality of the scene through color composition using spectral bands corresponding to the positions blue, green and red of the spectrum. "This process allows simultaneous visualization of images of different regions of the spectrum, facilitating the visual interpretation of some forest cover." (Chuvieco, 1990).

Third: the color composition was subject of a process named equalization of the histogram with the purpose of improving the contrast allowing better differentiation of different existing covers of the study area.

Fourth: the supervised classification used in widely known zones over the image offering the possibility of identifying the different existing tones and spectral responses in our color composition and then relate them with the uses and cover identified in the field.

For each category a supervised classification was made, the objective was to have a specific knowledge of the geographic distribution of the categories considered and being able to identify the satellite image. All classifications were made through a method of maximum verisimilitude, one of the most employed due to its methodological robustness and rigorousity.

The identification and verification in the field for each category for the most recent image (ETM 23/11/2000), gave us a confident base, when carrying out the retrospection of the forest and the land use for the images Landsat TM of 1986 and MSS of 1974.

3.4.2 Unsupervised Classification

The unsupervised classification process was applied to historic images. This type of classification does not use training areas but classes or *clusters* present in the image. The algorithms of classification examine and recognize the pixels, and in accord to their values, add them to a different class based on their digital number. The classes resulting from this process are called spectral classes (Lillesand & Kiefer, 2004).

Images resulting from the unsupervised classification were used to carry out a historic retrospection in terms of forest condition and land uses for the years 1986 and 1974.

3.5 GEOMETRIC ADJUSTMENT

The 3 images that were part of this study were adjusted geometrically beginning from a series of points with known coordinates, referred to the coordinates and projection systems used in the Republic of Panama, based on the Universal Transverse Mercator Projection (UTM), Spheroid WS84, Zone 17. Selected points were homogenously distributed throughout the image.

For each image, 35 points were taken, a number that is found in standard recommendations for study area characteristics (study zone size and surface relatively flat). The transformation was based using the *polynomial model*, while the RMS (*root mean square*) during the geometric correction was of 0.75 pixels.

The method used for the resampling of images was of the *nearest neighbor*, with an output pixel of 45 x 45 meters; what assumes an average commitment among the resolution of the entrance or input image MSS of 1974 with 80 x 80 meters. Image TM of 1986 with 30 x 30 meters and ETM of 2000 with 25 x 25 meters. In strict terms it should have been adapted to the output size with wider pixels (80 x 80 m), but this would mean sacrificing spatial resolution in the rest of the images and compromising the quality of the results.

3.6 DEFORESTATION RATE

Deforestation in the tropics is currently one of the aspects that cause more concern in the forestry sector. To determine deforestation rate, updated information and an appropriate registry of previous conditions, is required.

In this study, we regrouped in two large groups categories previously described:

1- Forest: where the classes belonging to mangrove, tropical moist forest with low intervention and highly disturbed tropical moist forest.
2- Non Forest: includes the classes of brushwood-stubble, pastureland, grassland and cropland, populated area, barren land-beaches.

This focus allowed the generation of a map and a Table with the crosses found among the categories of the two input maps for the different periods studied (1974-1986 and 1986-2000).

The FAO formula (Gasparri, 2004) was used to find the deforestation rate

$$q = \left(\frac{A_2}{A_1} \right)^{1/(t_2 - t_1)} - 1$$

Where

A1: forest surface at the beginning of the period

A2: forest surface at the end of the period

t1: year starting the period

t2: end year for the period

3.7 ANALYSIS OF FOREST COVER AND CURRENT LAND USE

For this analysis only islands with surface beyond 20 hectares were considered, they are identified in Table 3.2

From the land use and forest cover maps prepared for the years 1974, 1986 and 2000, I prepared tables for each period of crosses found for each category of land use and I evaluated in this manner the pattern of change in the islands studied.

Table 3.2 Islands with more than 20 hectares surface at Las Perlas Archipelago, Panama.

NAME	SURFACE (hectares)
Isla Bolaños	21.72
Isla Casaya	286.17
Isla Chapera	186.31
Isla Contadora	119.40
Isla Caña	508.98
Isla Puerco	63.66
Isla San José	4400.90
Isla Rey	23922.22
Isla Galera	23.25
Isla Gibraleon	112.35
Isla La Mina	98.49
Isla La Vivienda	27.40
Isla Mogo Mogo	95.46
Isla Pacheca	71.89
Isla Pedro González	1462.63
Isla Pericote	28.63
Isla Saboga	294.07
Isla San Telmo	162.43
Isla Señora	28.84
Isla Viveros	629.47
Isla Bayoneta	269.63

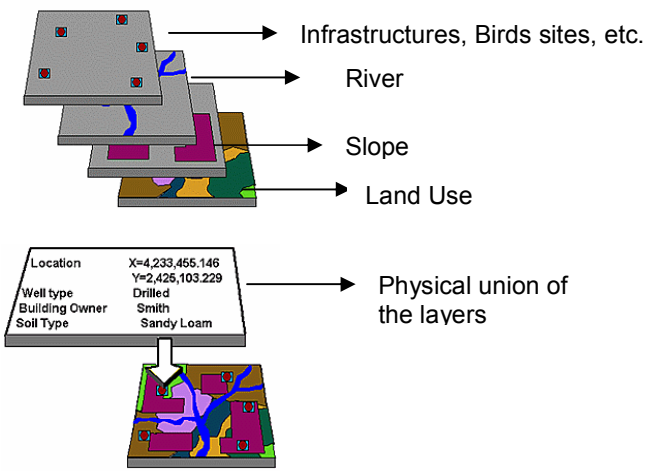
Total surface of this set of islands is of 32,813.90 ha, which represents 98.9% of the total surface of the Archipelago.

3.8 OVERLAY ANALYSIS

The integration of different information layers involves a process called overlaying. In its most simple phase, this can be a visual operation, but analytical operations require the physical union of one or more layers of data. By using the Geographic Information System, we were able to overlay each of the variables that we generated along the development of this study.

Figure 3.3 shows how the Geographic Information System integrated the variables of infrastructure, nesting sites, reefs sites, slopes and land use, to obtain a map that would allow understanding of the status and interrelation among the Archipelago's resources.

Figure 3.3 Overlay variables analysis



RESULTS

4.1 SLOPE CLASSIFICATION

In terms of the erosion factor it is important to have availability of slopes classification with the purpose of determining categories in regard to erosion risk. Table 4.1 shows how these categories are divided in Las Perlas Archipelago. In Figure 4.1 it is shown that 91.16 % of the slopes are classified between flat and slightly undulated, what makes me suppose that the study area has a relatively flat topography.

Table 4.1 Slope classification in Las Perlas Archipelago, Panama.

Slopes (degree)	Description	Surface (ha)	Percentaje
0 - 12	Flat to undulated	2632.28	74.25
12 - 25	Lightly undulated	5611.86	16.91
25 - 40	Very undulated	2428.94	7.32
40 - 50	Lightly slope	386.59	1.17
50 - 60	Lightly slope	100.48	0.30
> 60	Mountains	16.41	0.05
	TOTAL	**33176.57**	**100.00**

As Table 4.2 shows, nevertheless, there are some areas with erosion risks. Isla El Rey appears with slopes classification ranges considered of high risk and with an approximated surface of 403.14, ha that represents only 1.6 % of the total surface of this island. However, it is important to pay attention to this type of slopes, which even though in low percentage, most of the time is located in the headwaters of the basins or in the sources of the rivers or creeks, which in a given moment can supply with water some of the villages within the Archipelago.

In a smaller surface proportion but requiring equal attention, are the islands of San José (40.73 ha), Pedro Gonzales (34.71 ha), Caña (11.12 ha) and Viveros (1.37 ha).

Figure 4.1 Areas with erosion threat within the Las Perlas Archipelago, Panamá.

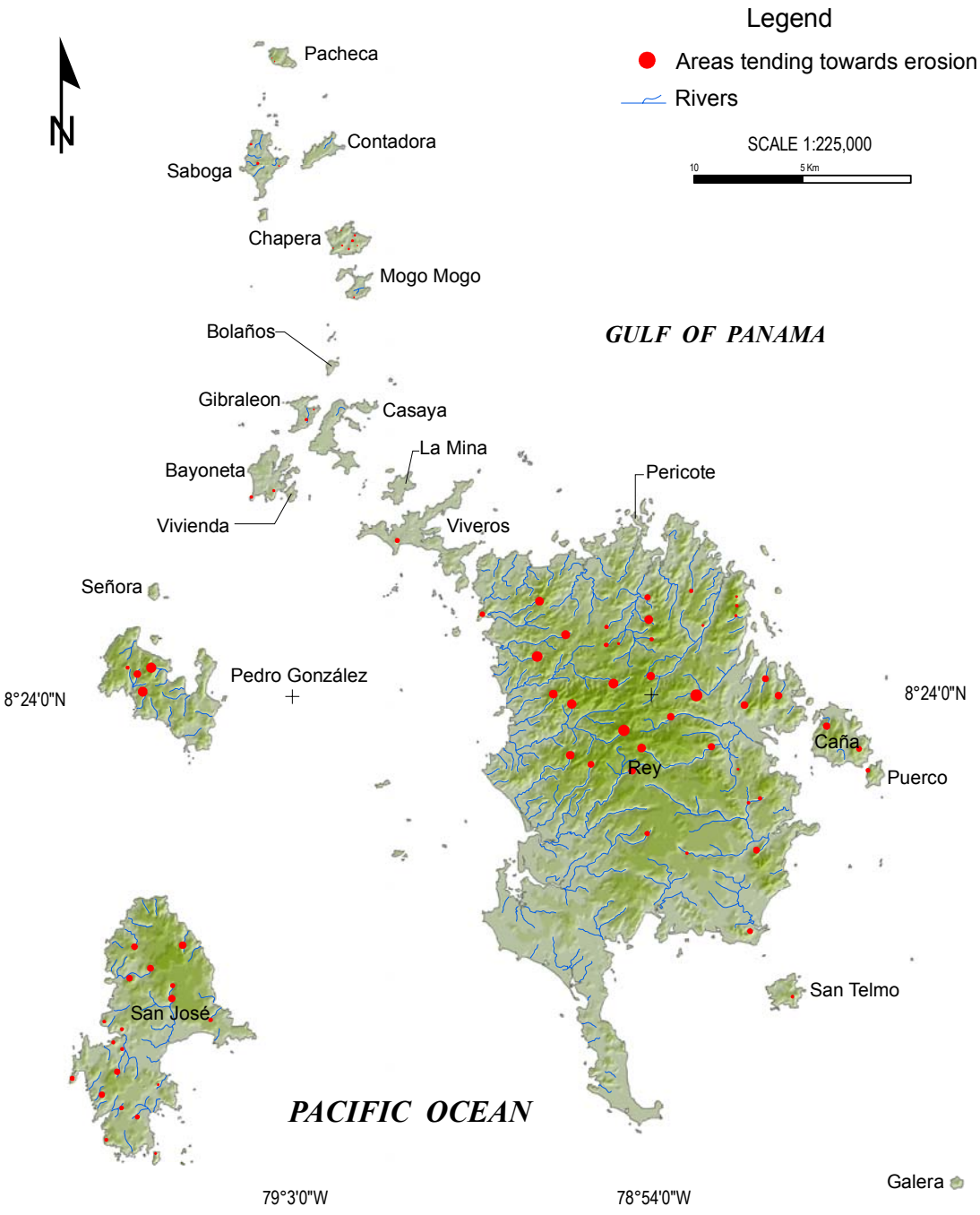


Table 4.2 Surface by slopes in the islands, Las Perlas Archipelago, Panama.

NAME / SLOPE	0 -12 %	12 - 25 %	25 - 40 %	40 - 50 %	50 - 60 %	> 60 %	Total
ISLA BAYONETA	236.82	27.97	4.62	0.21			269.63
ISLA BOLAÑOS	19.66	1.80	0.26				21.72
ISLA CAÑA	321.01	106.08	70.77	9.79	1.33	0.00	508.98
ISLA CASAYA	273.65	11.75	0.77				286.17
ISLA CHAPERA	136.14	36.72	13.03	0.42			186.31
ISLA CONTADORA	96.34	18.90	3.87	0.29			119.40
ISLA GALERA	17.90	3.64	1.47	0.24			23.25
ISLA GIBRALEON	90.84	17.43	3.51	0.50	0.066		112.35
ISLA LA MINA	96.67	1.78	0.05				98.49
ISLA LA VIVIENDA	20.93	6.14	0.33				27.40
ISLA MOGO MOGO	82.01	12.32	1.11	0.03			95.46
ISLA PACHECA	46.39	16.72	7.14	1.55	0.10		71.89
ISLA PEDRO GONZÁLEZ	935.82	330.61	161.80	29.38	4.82	0.21	1462.63
ISLA PERICOTE	22.38	3.73	2.33	0.19			28.63
ISLA PUERCO	36.54	14.95	9.67	2.50			63.66
ISLA REY	17451.87	4188.00	1879.21	302.44	85.57	15.13	23922.22
ISLA SABOGA	239.16	46.78	7.85	0.29			294.07
ISLA SAN JOSÉ	3493.49	646.07	220.61	31.76	7.77	1.19	4400.90
ISLA SAN TELMO	120.43	29.39	11.07	1.54			162.43
ISLA SEÑORA	18.15	7.51	2.90	0.29			28.84
ISLA VIVEROS	569.68	50.36	8.07	0.74	0.45	0.17	629.47
						TOTAL	**32813.90**

4.2 HYDROGRAPHIC ANALYSIS

River drainage pattern within the Archipelago belongs to the dendritic parallel system, with ever present rivers that are characterized by continuously transporting water all year round in the islands located to the South of the Archipelago, such as Pedro Gonzales, El Rey and San José. The rest of the islands show deficit in supplying water during the dry season since the dendritic drainage system is intermittent.

In Isla El Rey the watersheds of the rivers Santa Ana, Mosquito, Grillo, La Guinea and Martin Perez were identified. These watersheds are the ones

supplying water to the communities of San Miguel, La Ensenada, La Esmeralda, La Guinea and Martin Perez, respectively.

In San José Island, the only watersheds identified are those of the rivers San José, Mata Puercos and Rio Bodega that are the ones supplying water to the small hotel complex present in the island.

The Pedro Gonzales Island has been the most disturbed along the last four decades, thus no watershed in good conditions were identified.

4.3 DEFORESTATION RATES 1974 - 2000

Results indicate that the deforestation rate for the Archipelago was of -1.01 %, with the loss of 7,154.55 ha of forest in 26 years. This deforestation was larger during the first period, 1974-1986, where forest loss was of 12.35 % (3,998 ha). The second period, 1986-2000, was characterized by a reduction in deforestation which was of 9.07 % (3,056.60 ha.). Figure 4.2 shows how the forests in Las Perlas Archipelago were diminishing.

Table 4.3, shows forest surface for the 21 islands (> a 20 ha.), where the highest deforestation percentages for the first period were in Rey Island (12.20%) and Pedro González (0.40 %). For the second period, an increase in the number of islands showing some level of deforestation is observed. Such is the case of Puerco Island, Caña and Bayoneta, we also observed that deforestation in Rey Island diminished to 5.08 %, while in Pedro Gonzales Island it increased to 1.35 %.

Figure 4.2 Forest Cover Evolution in Las Perlas Archipelago years: 1974, 1986, and 2000.

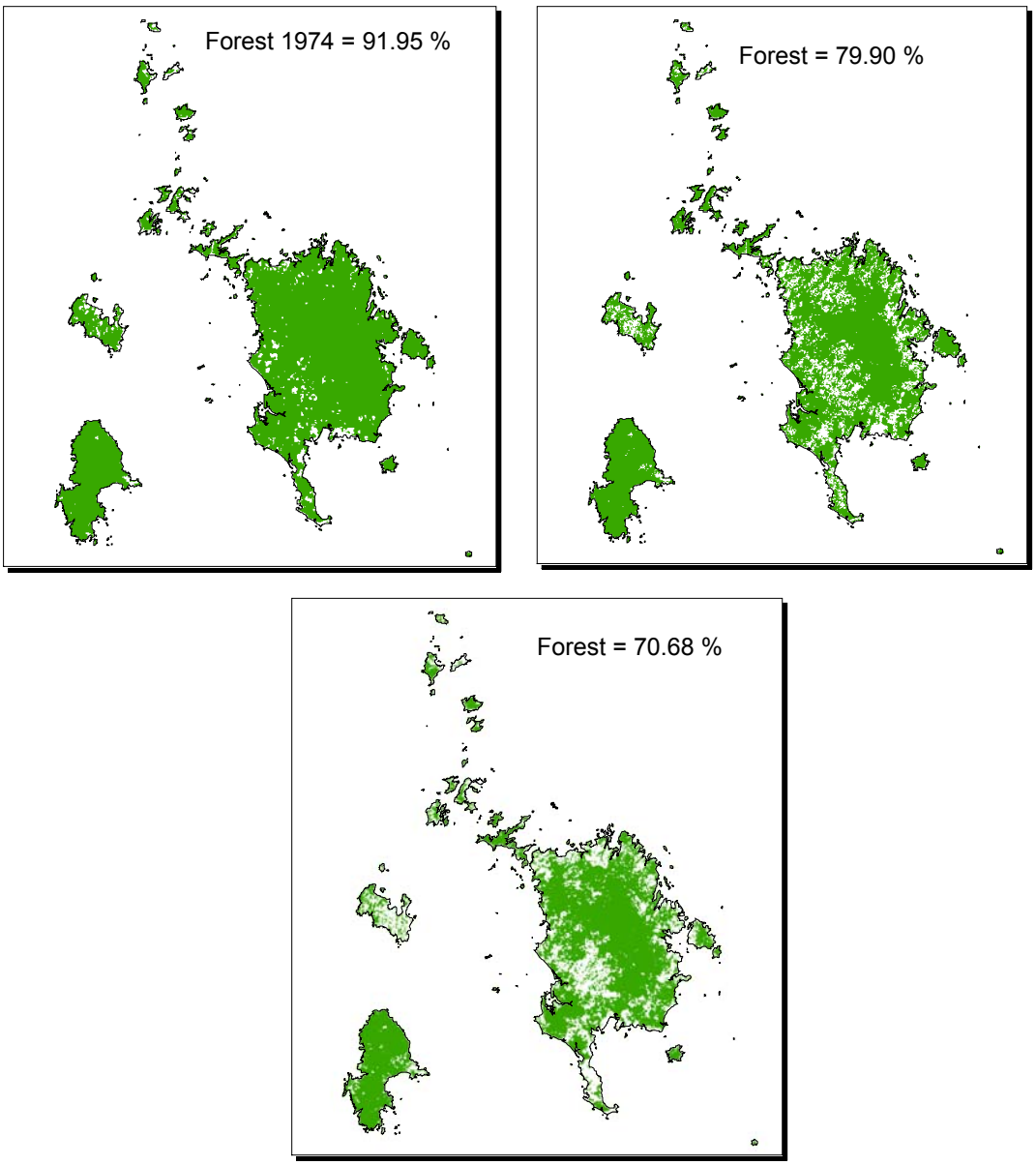


Table 4.3 Forest surface cover, Las Perlas Archipelago, years 1974, 1986, 2000

NAME	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
ISLA BAYONETA	208.96	77.50	240.96	89.37	135.22	50.15
ISLA BOLAÑOS	19.39	89.27	17.87	82.28	12.57	57.90
ISLA CASAYA	185.41	64.79	238.64	83.39	133.98	46.82
ISLA CHAPERA	154.98	83.19	169.23	90.83	139.51	74.88
ISLA CONTADORA	38.56	32.30	51.65	43.26	24.73	20.71
ISLA CAÑA	481.17	94.54	463.69	91.10	307.00	60.32
ISLA PUERCO	56.03	88.00	45.65	71.70	41.73	65.55
ISLA SAN JOSÉ	4237.50	96.29	4208.85	95.64	4002.47	90.95
ISLA REY	22471.07	93.93	18468.90	77.20	16800.65	70.23
ISLA GALERA	15.07	64.82	15.92	68.46	11.97	51.48
ISLA GIBRALEON	96.83	86.19	95.27	84.80	61.99	55.17
ISLA MINA	80.13	81.36	87.70	89.04	72.17	73.27
ISLA VIVIENDA	22.68	82.77	23.33	85.16	18.63	68.00
ISLA MOGO MOGO	60.96	63.86	85.02	89.07	68.80	72.07
ISLA PACHECA	35.55	49.45	50.50	70.24	40.40	56.21
ISLA PEDRO GONZÁLEZ	1168.65	79.90	1037.48	70.93	593.71	40.59
ISLA PERICOTE	23.51	82.11	21.48	75.03	8.27	28.88
ISLA SABOGA	233.93	79.55	233.80	79.50	182.94	62.21
ISLA SAN TELMO	142.25	87.58	132.85	81.79	118.56	72.99
ISLA SEÑORA	24.40	84.63	24.44	84.74	13.25	45.96
ISLA VIVEROS	536.25	85.19	526.77	83.69	474.49	75.38

4.4 LAND USE STATUS AND FOREST COVER

The results of land use and forest cover change in islands with surfaces larger than 20 ha, are the product of interpretation of Tables 4.4, 4.5 and 4.6. Nevertheless, appendices 1 to 21 show in detail these changes per island while in appendix 23 and 24 present examples of some of the soil uses found in the archipelago.

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4.4.1 Period 1974 – 1986.

This period was characterized by the strong pressure exerted on the forests of the Las Perlas Archipelago.

Mangroves diminished in 2.94 %, the islands where there were larger disturbances were: El Rey, Viveros, San José, Caña and Bayoneta with a total of 2.74 %. The remaining 0.20 % is distributed in the rest of the islands of the Archipelago.

Moist Tropical Forest with low disturbance was the one that showed the largest level of disturbance with 25.85 % that represented the loss of 8,483.61 ha, being the most affected islands; Rey, San José, Pedro González and Caña. In the other hand, this period showed a recovery of 0.7 % in regard to the year 1974 in islands as Bayoneta, Bolaños and Casaya.

The *Highly Disturbed Moist Tropical Forest*, increased in a considerable manner with 16.44 %, especially in those islands where a greater pressure has been exerted on their forests, as is the case of the islands; Rey, San José and Pedro Gonzales with a total of 15.49 %.

Brushwood-Stubble, is another land use category that experimented an increase in its surface cover. Rey Island with an increase of 13.49 % and Pedro Gonzales Island with 1.04 %, represent 14.53% of a total of 15.19%.

The *Pasture, Grasslands and Crops*, shows they have diminished 2.88 % in the most part of the studied islands nevertheless islands as Puerco, Gibraleon y Pericote present a slight increase of 0.3%.

Populated places increased in 0.03% being the islands; Rey, Saboga, San José, Contadora, Casaya, Pedro González and San Telmo the ones showing this growth.

The last land use category corresponded to Beaches-Barren Land, in this period it only showed an increase of 1.09 ha.

4.4.2 Period 1986 – 2000

This period is characterized by a reduction in deforestation due to significant changes in land use as follows:

Mangroves were diminishing their surface in 0.76 % (248.06 ha), islands Rey and San José showed the largest percentage of loss with a total of 2.27%. An important aspect is that for this period some of the studied islands showed recovery in their mangroves, among the ones showing the largest increase were Pedro Gonzales Island, Viveros and Saboga.

The *Moist Tropical Forest with low disturbance* presents a reduction in almost all islands within the Archipelago, except for Contadora Island, which does not have that type of forest and in Casaya Island, it shows a recovery of 0.01%. Nevertheless, although there was an increase in the number of islands with disturbance in this forest type, the degree of intervention was of 6.54, very much lower than what reported for the previous period.

The *highly disturbed Moist Tropical Forest*, reduced its growth in 1.78 % (583.67 ha). In San José the surface of highly disturbed forest diminished in 0.46%, which is related to the regeneration showed in this forest type within this island. On the contrary, in Pedro González Island, there was reduction of 0.82 % due to deforestation.

Brushwood – Stubble: its increase for this period was of 4.39 %, being the islands; Rey, Pedro González, San José, Caña and Bayoneta, the ones showing the largest increase in their surface with a total of 3.28 %.

Grasslands, Pastures and Crops show an increase of 5.58 % in almost all islands studied, Puerco Island, was the only one where there was a reduction which was 4.37 ha (0.01%). Islands with greater increase in this category are: Isla El Rey 13.16 %, and Pedro González with 0.74%.

Populated Places increased in 0.07 %, Contadora Island showed the largest increase with 0.06% (19.65 ha), followed by Isla El Rey, San José Island, Pedro González and Saboga with a total of 27.97 ha.

The greatest increase presented in the category Beaches – Barren Lands were in the islands San José with 0.02 % and Casaya 0.01 %. The total increase for the whole study area was of only 0.04 %.

Table 4.4 Coverage of forest and land use. Islands bigger than 20 hectares. Year 1974

Land Cover 1974															
Name	**1.00**	**%**	**2.00**	**%**	**3.00**	**%**	**4.00**	**%**	**5.00**	**%**	**6.00**	**%**	**7.00**	**%**	**Total**
ISLA BAYONETA	59.49	22.06	46.08	17.09	103.39	38.35		0.00	40.00	14.83		0.00	20.67	7.67	269.63
ISLA BOLAÑOS		0.00	15.51	71.44	3.87	17.83		0.00	1.62	7.47		0.00	0.71	3.25	21.72
ISLA CASAYA	61.88	21.62	55.42	19.37	68.10	23.80		0.00	65.25	22.80	0.32	0.11	35.19	12.30	286.17
ISLA CHAPERA	14.80	7.94	57.65	30.95	82.53	44.30	1.23	0.66	23.49	12.61		0.00	6.59	3.54	186.31
ISLA CONTADORA	4.60	3.85		0.00	33.96	28.44	10.69	8.95	61.34	51.37	0.65	0.54	8.16	6.83	119.40
ISLA DE CAÑA	59.13	11.62	336.20	66.05	85.83	16.86		0.00	6.68	1.31		0.00	21.14	4.15	508.98
ISLA DE PUERCO	8.74	13.73	46.96	73.76	0.32	0.51		0.00	0.31	0.49		0.00	7.33	11.51	63.67
ISLA DE SAN JOSÉ	105.97	2.41	3885.95	88.30	245.58	5.58	7.57	0.17	82.27	1.87	14.80	0.34	58.76	1.34	4400.90
ISLA EL REY	2288.22	9.57	16793.83	70.20	3389.02	14.17	116.00	0.48	1116.21	4.67	23.22	0.10	195.72	0.82	23922.22
ISLA GALERA	1.59	6.82	9.71	41.76	3.78	16.24		0.00	1.53	6.58		0.00	6.65	28.60	23.25
ISLA GIBRALEON	15.47	13.77	39.00	34.71	42.36	37.70		0.00	1.48	1.32		0.00	14.04	12.50	112.35
ISLA LA MINA	48.78	49.53	7.76	7.88	23.59	23.95		0.00	7.59	7.71		0.00	10.77	10.94	98.49
ISLA LA VIVIENDA	2.53	9.23	10.25	37.41	9.90	36.14		0.00	0.92	3.36		0.00	3.80	13.87	27.40
ISLA MOGO MOGO	18.63	19.52	20.31	21.27	22.02	23.07		0.00	25.96	27.19		0.00	8.54	8.95	95.47
ISLA PACHECA		0.00	13.22	18.39	22.33	31.07	10.85	15.10	17.69	24.61		0.00	7.79	10.84	71.88
ISLA PEDRO GONZÁLEZ	32.26	2.21	545.70	37.31	590.70	40.39	7.14	0.49	259.43	17.74	2.23	0.15	25.18	1.72	1462.63
ISLA PERICOTE	1.72	6.01	9.47	33.08	12.32	43.03		0.00	0.67	2.34		0.00	4.45	15.54	28.63
ISLA SABOGA	3.15	1.07	139.85	47.56	90.93	30.92		0.00	50.04	17.02		0.00	10.10	3.43	294.07
ISLA SAN TELMO	4.43	2.73	102.06	62.83	35.76	22.01		0.00	3.54	2.18		0.00	16.64	10.24	162.43
ISLA SEÑORA		0.00	5.85	20.29	18.55	64.35		0.00		0.00		0.00	4.43	15.37	28.83
ISLA VIVEROS	136.36	21.66	234.02	37.18	165.87	26.35		0.00	40.90	6.50		0.00	52.34	8.31	629.49
														Total	**32813.90**

1. Mangrove Areas
2. Humid Forest of Low Terrain with little intervention
3. Intervened Forest
4. Brushwood – Stubble
5. Paddocks, Grasslands, and Farming Areas
6. Populated Areas
7. Beaches - Barren Land

Table 4.5 Coverage of forest and land use. Islands bigger than 20 hectares. Year 1986

Land Cover 1986															
Name	**1.00**	**%**	**2.00**	**%**	**3.00**	**%**	**4.00**	**%**	**5.00**	**%**	**6.00**	**%**	**7.00**	**%**	**Total**
ISLA BAYONETA	26.94	9.99	140.12	51.97	73.90	27.41	7.65	2.84	0.86	0.32		0.00	20.16	7.48	269.63
ISLA BOLAÑOS		0.00	16.58	76.34	1.29	5.94	0.27	1.24	0.05	0.23		0.00	3.53	16.25	21.72
ISLA CASAYA	25.93	9.06	101.49	35.46	111.22	38.87	20.64	7.21	3.24	1.13	0.85	0.30	22.80	7.97	286.17
ISLA CHAPERA	8.23	4.42	93.29	50.07	67.72	36.35	3.03	1.63	3.49	1.87		0.00	10.56	5.67	186.31
ISLA CONTADORA	2.76	2.31		0.00	48.89	40.94	8.31	6.96	39.68	33.23	2.27	1.90	17.49	14.65	119.40
ISLA DE CAÑA	30.02	5.90	242.58	47.66	191.09	37.54	18.92	3.72	4.99	0.98		0.00	21.39	4.20	508.98
ISLA DE PUERCO	9.81	15.41	15.70	24.66	20.14	31.63	0.81	1.27	10.18	15.99		0.00	7.03	11.04	63.67
ISLA DE SAN JOSÉ	85.06	1.93	3246.82	73.78	876.97	19.93	75.00	1.70	53.64	1.22	9.42	0.21	53.99	1.23	4400.90
ISLA EL REY	1563.85	6.54	9148.06	38.24	7756.99	32.43	4542.32	18.99	685.35	2.86	29.87	0.12	195.79	0.82	23922.22
ISLA GALERA	0.45	1.92	7.31	31.45	8.16	35.09	0.09	0.39	0.17	0.74		0.00	7.07	30.40	23.25
ISLA GIBRALEON	9.08	8.09	57.54	51.22	28.65	25.50	0.50	0.45	2.56	2.28		0.00	14.01	12.47	112.35
ISLA LA MINA	44.47	45.15	20.78	21.10	22.45	22.79	0.15	0.15		0.00		0.00	10.64	10.80	98.49
ISLA LA VIVIENDA	1.51	5.49	16.75	61.14	5.08	18.52	0.40	1.45	0.50	1.83		0.00	3.17	11.57	27.40
ISLA MOGO MOGO	9.20	9.64	33.92	35.53	41.90	43.89	1.59	1.67	0.35	0.37		0.00	8.50	8.90	95.47
ISLA PACHECA		0.00	7.02	9.76	43.48	60.48	13.00	18.09	0.54	0.75	0.00	0.00	7.85	10.92	71.88
ISLA PEDRO GONZÁLEZ	11.38	0.78	352.60	24.11	673.49	46.05	349.95	23.93	46.44	3.18	3.51	0.24	25.25	1.73	1462.63
ISLA PERICOTE	7.91	27.64	4.12	14.39	9.45	33.00	1.98	6.92	0.85	2.97		0.00	4.32	15.09	28.63
ISLA SABOGA	2.70	0.92	76.66	26.07	154.44	52.52	36.40	12.38	7.26	2.47	6.03	2.05	10.59	3.60	294.07
ISLA SAN TELMO	2.00	1.23	104.47	64.32	26.38	16.24	12.31	7.58	0.18	0.11	0.12	0.08	16.96	10.44	162.43
ISLA SEÑORA		0.00	5.38	18.65	19.06	66.09	0.27	0.94		0.00		0.00	4.13	14.32	28.83
ISLA VIVEROS	60.58	9.62	200.01	31.78	266.18	42.29	45.32	7.20	2.50	0.40		0.00	54.87	8.72	629.49
														Total	**32813.90**

1. Mangrove Areas
2. Humid Forest of Low Terrain with little intervention
3. Intervened Forest
4. Brushwood – Stubble
5. Paddocks, Grasslands, and Farming Areas
6. Populated Areas
7. Beaches - Barren Land

Table 4.6 Coverage of forest and land use. Islands bigger than 20 hectares. Year 2000

	Land Cover 2000														
Name	**1.00**	**%**	**2.00**	**%**	**3.00**	**%**	**4.00**	**%**	**5.00**	**%**	**6.00**	**%**	**7.00**	**%**	**Total**
ISLA BAYONETA	22.06	8.18	26.24	9.73	86.91	32.23	88.54	32.84	24.97	9.26		0.00	20.90	7.75	269.63
ISLA BOLAÑOS	0.37	1.71	4.62	21.26	7.58	34.92	4.13	19.04	0.37	1.73		0.00	4.63	21.34	21.72
ISLA CASAYA	20.55	7.18	41.68	14.56	71.75	25.07	82.70	28.90	44.02	15.38	0.68	0.24	24.78	8.66	286.17
ISLA CHAPERA	4.30	2.31	42.11	22.60	93.11	49.98	27.09	14.54	8.33	4.47		0.00	11.37	6.11	186.31
ISLA CONTADORA	0.68	0.57		0.00	24.05	20.14	3.36	2.82	51.09	42.79	21.92	18.36	18.30	15.32	119.40
ISLA DE CAÑA	16.95	3.33	92.62	18.20	197.42	38.79	118.32	23.25	63.12	12.40		0.00	20.54	4.04	508.98
ISLA DE PUERCO	7.56	11.87	4.69	7.36	29.49	46.32	8.96	14.08	5.81	9.13	0.00	0.00	7.16	11.25	63.67
ISLA DE SAN JOSÉ	68.72	1.56	3208.65	72.91	725.10	16.48	260.73	5.92	66.68	1.52	10.73	0.24	60.29	1.37	4400.90
ISLA EL REY	1356.34	5.67	7779.36	32.52	7664.95	32.04	5176.62	21.64	1720.65	7.19	28.39	0.12	195.91	0.82	23922.22
ISLA GALERA	0.05	0.23	4.64	19.94	7.28	31.30	3.30	14.19	0.62	2.68		0.00	7.36	31.65	23.25
ISLA GIBRALEON	11.85	10.54	18.69	16.63	31.45	28.00	31.58	28.11	4.55	4.05		0.00	14.23	12.67	112.35
ISLA LA MINA	15.02	15.25	16.21	16.45	40.94	41.56	13.21	13.41	2.83	2.88		0.00	10.28	10.44	98.49
ISLA LA VIVIENDA	1.53	5.57	7.50	27.37	9.61	35.05	3.82	13.94	1.72	6.27		0.00	3.23	11.79	27.40
ISLA MOGO MOGO	7.11	7.45	19.46	20.39	42.23	44.24	12.49	13.09	5.98	6.27		0.00	8.19	8.58	95.47
ISLA PACHECA	0.16	0.23	4.18	5.81	36.06	50.16	18.56	25.82	5.14	7.16		0.00	7.77	10.81	71.88
ISLA PEDRO GONZÁLEZ	31.71	2.17	156.09	10.67	405.91	27.75	548.95	37.53	287.97	19.69	6.47	0.44	25.52	1.74	1462.63
ISLA PERICOTE	2.51	8.78	4.13	14.43	1.62	5.68	12.78	44.64	3.10	10.83		0.00	4.48	15.65	28.63
ISLA SABOGA	7.51	2.55	80.76	27.46	94.67	32.19	54.83	18.64	38.92	13.24	6.52	2.22	10.86	3.69	294.07
ISLA SAN TELMO	6.91	4.26	72.46	44.61	39.19	24.13	22.38	13.77	4.75	2.93	0.06	0.04	16.68	10.27	162.43
ISLA SEÑORA	0.61	2.12	2.06	7.15	10.58	36.68	8.85	30.70	2.06	7.14		0.00	4.67	16.20	28.83
ISLA VIVEROS	71.29	11.33	159.86	25.40	243.34	38.66	77.53	12.32	22.46	3.57	0.06	0.01	54.92	8.72	629.49
														Total	**32813.90**

1. Mangrove Areas
2. Humid Forest of Low Terrain with little intervention
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4. Brushwood – Stubble
5. Paddocks, Grasslands, and Farming Areas
6. Populated Areas
7. Beaches - Barren Land

DISCUSSION

Island protection allows maintenance of the normal flow of nutrients that arrive to the sea through the rivers. Later these nutrients are transformed into food for many commercial species which guarantees sustainable fisheries. Besides, they help in the conservation of important ecosystems that constitute both habitat for endemic species and places for reproduction and nesting of marine birds, turtles, fish and crustaceans.

5.1 FOREST COVER CHANGE (1974-2000).

From the multi-temporal analysis of the satellite images, the deforestation process that has occurred in this period can clearly be observed, showing in a simple manner the process that the forests have followed within the study area.

Deforestation rate represents an absolute loss of -1.01 % of the forests in 26 years, what results in a mean annual loss of 271.33 ha. This annual rate recorded for Las Perlas Archipelago continues to be low when compared to the -1.12 % of the annual deforestation rate recorded for the whole country and the -1.53% for the province of Panama (location of the study area) in accord to the report regarding forest cover and land use in the Republic of Panama years 1992 – 2000 (“Cobertura Boscosa y Uso del Suelo de La Republica de Panamá: 1992-2000”) prepared by ANAM.

The deforestation rhythm was greater in the period 1974-1986, forest loss was mainly recorded for the islands El Rey and Pedro González. In this period agriculture activity maintained local population in Saboga, Pedro González, San Miguel, La Ensenada, La Esmeralda and La Guinea. Commercial flow among Panama City and most of the villages in the Archipelago was low in this period, except for Isla Contadora, which was emerging as a tourist destination and vacation residence area.

In the period 1986-2000, deforestation rhythm decreased due to a change in economic activities, agriculture was replaced by fishing, which increased the economical income among the villagers. Another important aspect is that the improvement in communication routes (aerial and maritime) provided better supply of provisions to the communities.

Agriculture activity is currently based on the slash and burn method which consist of felling wood in small patches of forests to establish traditional crops (rice, corn, pigeon peas, plantain, etc.). After a period of 2 to 4 years, people see the need to move on to another area due to land impoverishment because of nutrients loss. This is observed in islands that previously had not shown that degree of intervention in the forests as is the case of the islands as is the case of the islands of Bayoneta, Casaya, Caña, Saboga and Viveros.

Isla de San José shows a reduction in the forests, nevertheless, these values are only approximations since we could not perform ground verification because this island is privately owned. Besides this island also has a special condition because part of it was used as a testing area for chemical weapons in the past.

5.2. LAND USE CHANGE (1974-2000).

5.2.1. Period 1974-1986

Mangroves: during this period 965.87 ha were lost which represents 2.74 % of the total surface in the study area; the islands El Rey and Viveros suffer the greatest degree of loss with 2.44 %. For this period, a small recuperation is shown in the mangrove part in islands Puerco and Pericote with 0.02%.

The *Tropical Moist Forest with Low Disturbance*, was the most affected with a deforestation of 8483.61 ha representing 25.85 % of the total surface. For this period forests were affected by two factors: the first was the need to find lands for the proposed activities as agriculture to sustain basic feeding needs of the

population located at the islands El Rey, Pedro González and Casaya. The second factor is related to the tree cutting of some species to build boats and to sell wood. Most affected islands were: Caña, El Rey, Pedro González and San José. This period in contrast to the year 1974 showed a recuperation of 0.7 % in this type of forest in islands such as: Bayoneta, Bolaños and Casaya.

The *Highly Disturbed Tropical Moist Forest* increased in 16.44% given that for this period inhabitants of the different communities were exerting greater pressure on forest to satisfy their feeding and commercial needs. The islands that increased their surface of highly disturbed forests were El Rey, San José and Pedro Gonzáles with a total of 15.49 %.

The *Brushwood – Stubble* category increased in 6425.25 ha (19.58%) in a period of 26 years (1974-2000). For the year 1974, surface occupied by this category was only of 153.49 ha and was located in the islands Chapera, Contadora, San José, El Rey and Pedro González. This category appears in those zones that have been deforested so that it can be considered a natural regeneration. For this reason at the end of 1986 this number increased because there were many clearings in this period and after 2 to 4 years they were abandoned. For the period 1974-1986, the islands that showed experienced a considerable increase in this category are the islands El Rey, Pedro González, San José and Viveros with 14.88 % of the total surface of the study area.

The category *Grasslands, Pastures and Crops* decreased in 2.88 % (944.10 ha) in regard to the year 1974, thus we see that by the end of the year 1986, surface covered by this category had diminished in almost all the islands except for the islands Puerco, Gibraleon and Pericote. The islands where there was a notorious reduction were El Rey and Pedro Gonzales with 1.96 %.

The category *Populated Areas* increased in 10.86 ha (0.03%), this growth is the result of construction of new infrastructure in the different populated centers

within the Archipelago, islands showing more increase were El Rey and Saboga which as a set add up to 12.68 ha (0.01 %).

The category *Beaches – Barren land*, for this period it showed an increase of 1.09 %. Isla Contadora is the one showing more change in regard to the rest of the islands, this is due to the constant change in land use, especially due to elimination of the sparse existing plant cover for the construction of diverse infrastructure.

5.2.2. Period 1986-2000

Mangroves diminished in 0.76 % which reflects a loss at a lower rhythm to the one registered in the previous period (2.94 %); for this period the greatest reduction of mangroves was in Isla San José, El Rey and Mina. In the other hand, recovery of this category was observed in islands that before had suffered a reduction of their mangroves. This is the case of the islands Pedro González and Viveros

Tropical Moist Forest with Low Disturbance presented a reduction of 6.54 % (2145.19 ha), showing that the pressure exerted in the previous years is decreasing. This is maybe due to the fact that young population from the communities have shown a loss of interest in agriculture and are more interested in products that come from the sea and that guarantee economical benefits in a shorter period of time. Nevertheless, this condition does not seem to have changed in Isla de Pedro González since it maintains the deforestation rate in 0.6 %.

The *Highly Disturbed Tropical Moist Forest* category diminished in 1.78 %. The reasons for this reduction are varied; in Isla San José the reduction is due to a small recovery of these forests and to the change in land use since in recent years a hotel complex has been built in this island. In islands El Rey and Pedro González the pressure for this type of forest is due to deforestation of small land plots for the cultivation of basic crops.

The *Brushwood – Stubble* presented an increase of 4.39 % (1439.82 ha), in islands that in the previous period were characterized by deforestation of their vegetation. Thus we see that in Isla El Rey the increase was of 1.93 % (634.30ha), in Pedro González it was of 0.61% (199.0 ha) and in San José it was 0.57% (185.73 ha).

The category *Grasslands, Pasture and Crops* indicates an increase of 4.58 %; for this period all the islands showed an increase in this category, except for Isla Puerco where its surface was reduced in 0.1%. In Isla El Rey the increase of this category was due to the transformation of old cultivation plots into areas dedicated to cattle raising. It is important to mention that this is the only island within the Archipelago where this activity is done and that this is the island supplying red meat to the rest of the islands, at least once a week. In Isla Contadora the increase in this category is due to the size of the gardens that the vacation type residences have. In the rest of the islands the number of small subsistence cultivation parcels seems to have increased.

The category *Populated Areas,* increased in 0.07 % (22.76 ha), Isla Contadora is the one experimenting the greatest growth with 0.06 % (19.65 ha) which is the result of the construction of diverse infrastructure to serve the growing tourism and the construction of new houses.

Beach – Barren Land, experimented a growth of 0.04 % (11.99 ha), the islands where the increase is present are: Casaya and San José.

5.3 RISK OF SOIL EROSION

The classification of slopes ranges allow us to understand the areas that in a given moment can be subject to erosion. Our results have shown that islands El Rey, San José and Pedro González are the ones more prone to erosion risks, in accord to the land use and forest cover map (Figure 5.1). The zones identified in these islands as having high risk of erosion are currently protected

by forests that guarantee a good status of the watersheds that drain their waters to the sea and some supply water to the villages especially in Isla El Rey.

If tourism development occurs in the Archipelago and especially the one that is proposed to be carried out in Isla El Rey where the construction of urbanizations, golf courts, and other infrastructures that can jeopardize the equilibrium that currently exists, since the heads of the rivers Mendaño, Chuche, Chenillo and Mosquitos can transfer a large number of tons of silt affecting water quality and causing reduction of primary production of the ecosystem, affecting particularly coral reefs and oysters banks.

Other sectors that can present the same situation would be the Northeast and Northwest of Isla Pedro González and Isla San José (Dr. Héctor Guzmán. Smithsonian Tropical Research Institute, *com. pers.)*

5.4 HYDROGRAPHIC WATERSHEDS.

Taking in consideration the topography of the study area, the islands El Rey, San José and Pedro González have watersheds very well defined which guarantees the water supply to the communities existing in the islands El Rey and Pedro González throughout the year. The rest of the islands in the Archipelago have water deficit during the dry season, so they depend on wells as is the case of the islands Saboga and Casaya.

Isla Contadora has lakes to contain rainfall water, nevertheless the impounding of this vital liquid is not enough especially during the dry season months. This is due to the high demand from vacation residences, which in some cases have swimming pools that increase the problem.

5.5 OVERLAY ANALYSIS

Geographic Information Systems allow the preparation of basic systematic surveys, prospections and studies related to the distribution of natural resources through the overlaying of different physical variables.

The overlaying of variables such as nesting bird sites (terrestrial and marine), populated areas, infrastructure, hydrography regarding current land use and reef distribution within the study area, allowed us to understand the distribution and interrelation of natural resources existing within the Archipelago (Figure 5.2).

Nesting sites for marine birds in the Northern islands of Las Perlas (Pacheca, Pachequilla, Bartolome), Isla Cangrejo, Isla Galera and Isla Monte, are located in areas relatively small so that they have not raised interest to build residences except for Isla Pacheca where currently there are three houses and related structures. One of the biggest threats is that the owners of these houses the introduction of household pets (cats and dogs) that can endanger the offsprings of these birds, the rests of the islands are threatened by the disturbance that can be caused by fishermen and people arriving in recreational boats.

In terms of studies on biogeography and ecology of islands, the larger islands as Saboga, San Telmo, Pedro González, San José and El Rey, are very valuable for understory bird species due to the amount of endemic species present in these islands. Besides there are reports of marine birds nesting in the first four islands. Current threats to which the bird colonies are exposed in Isla Saboga, Pedro González and El Rey, are related to tree cutting and burning of their forests. In the other hand part of these threats are not evident in San José and San Telmo, since these islands are private and to this moment maintain a conservation oriented matter.

Nevertheless, tourism development plans in the Archipelago can change the conservation minded environment that to this moment is kept in these two islands.

Another variable used for the overlay analysis was the one of the reef distribution (Dr. Héctor Guzmán. Smithsonian Tropical Research Institute, *com. pers*.), which are located almost in all of the island within the Archipelago, nevertheless the largest concentration of these are found in the northern sector of the archipelago in islands such as Contadora, Saboga, Chapera, Mogo Mogo and Bolaños, also present are at the East of Isla Viveros.

To the East of Isla El Rey, specifically in small islands such as San Pedro, San Pablo, Espiritu Santo, Caña, Elefante, Isletilla Puerco and Monte, while in the southeastern side we find Isla San Telmo, Camote and Galera. To the West there are located in Isla Cocos; islands Señora, Pedro Gonzales and San José have important reefs sites distributed around them.

The current threat to which the reefs are exposed is due mainly to the damage caused by anchorage of tourism and fishermen boats and to the practice of trawl net fishing.

It is important to note that reefs are very sensible and that a change in the coastal zone such as developments for housing, hotel, industrial, ports, or marine activities can increase sedimentation and cause direct physical damages to the corals.

Another potential threat is the unsustainable management of watersheds and coastal lands adjacent to them, including deforestation, agriculture, and other inappropriate land uses that carry to the drainage pesticides (that can poison reef organisms), fertilizers (that can cause nutrient overload) and silt.

The elimination of industrial and municipal wastes carries an increase in the nutrient and toxins level in the reefs. The discharge of sewage waters directly to the ocean causes a nutrient overload and the excessive algae growth. Wastes rich in nutrient coming from sewage waters and other sources particularly harmful, given that they cause a gradual but important change in the structure of the reef. With time algae can possibly dominate the reef and exclude the corals (Done, 1992; Hugues, 1994).

Shipping enterprises activities can affect the reefs with oil spills and ballast elimination. Although these consequences are least known these could be significant at the local level. The physical direct damage can come from ships anchored on the reefs and of accidental hitting against reefs.

Figure 5.1 Land use and areas with erosion trends, Las Perlas Archipelago, Panama.

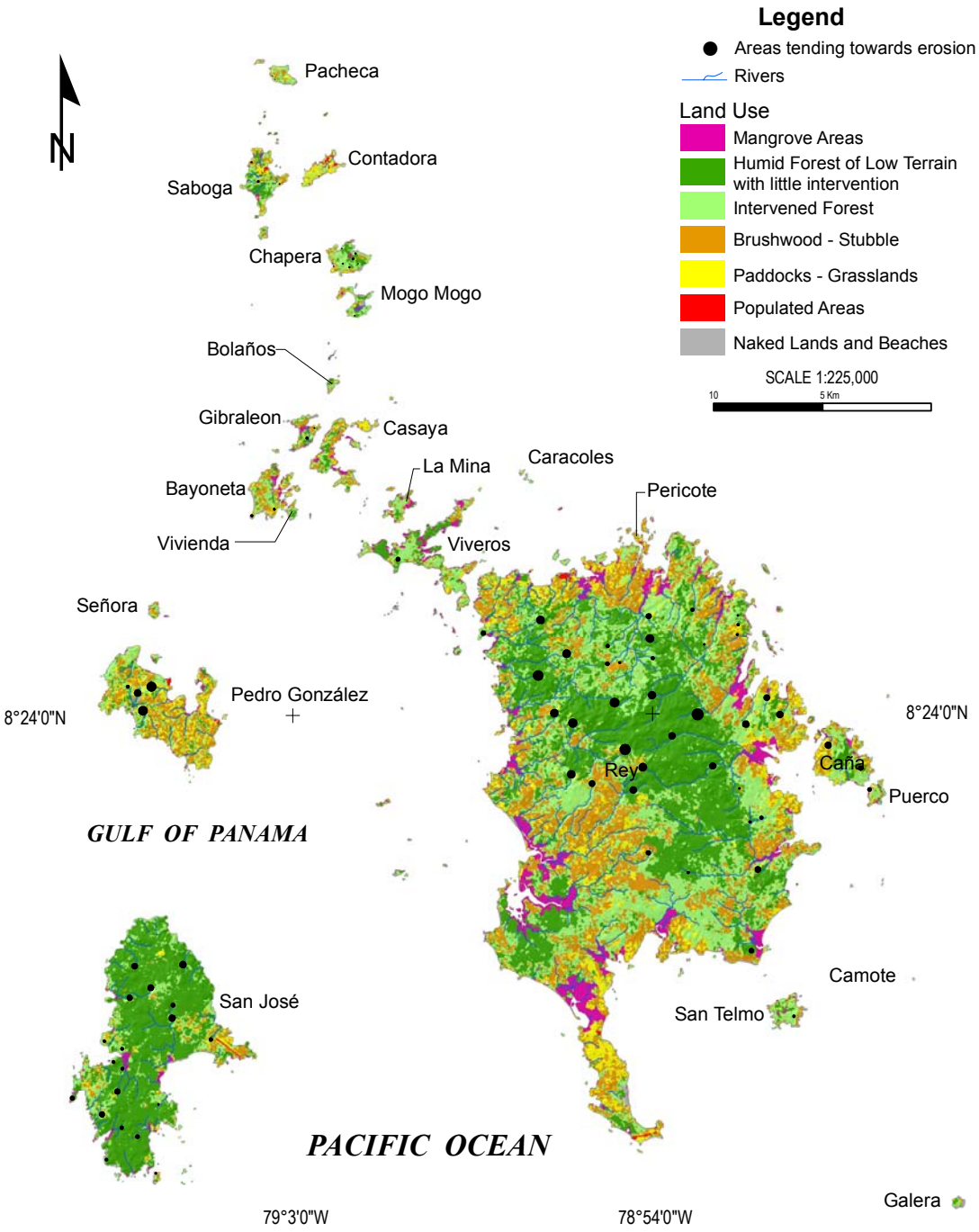
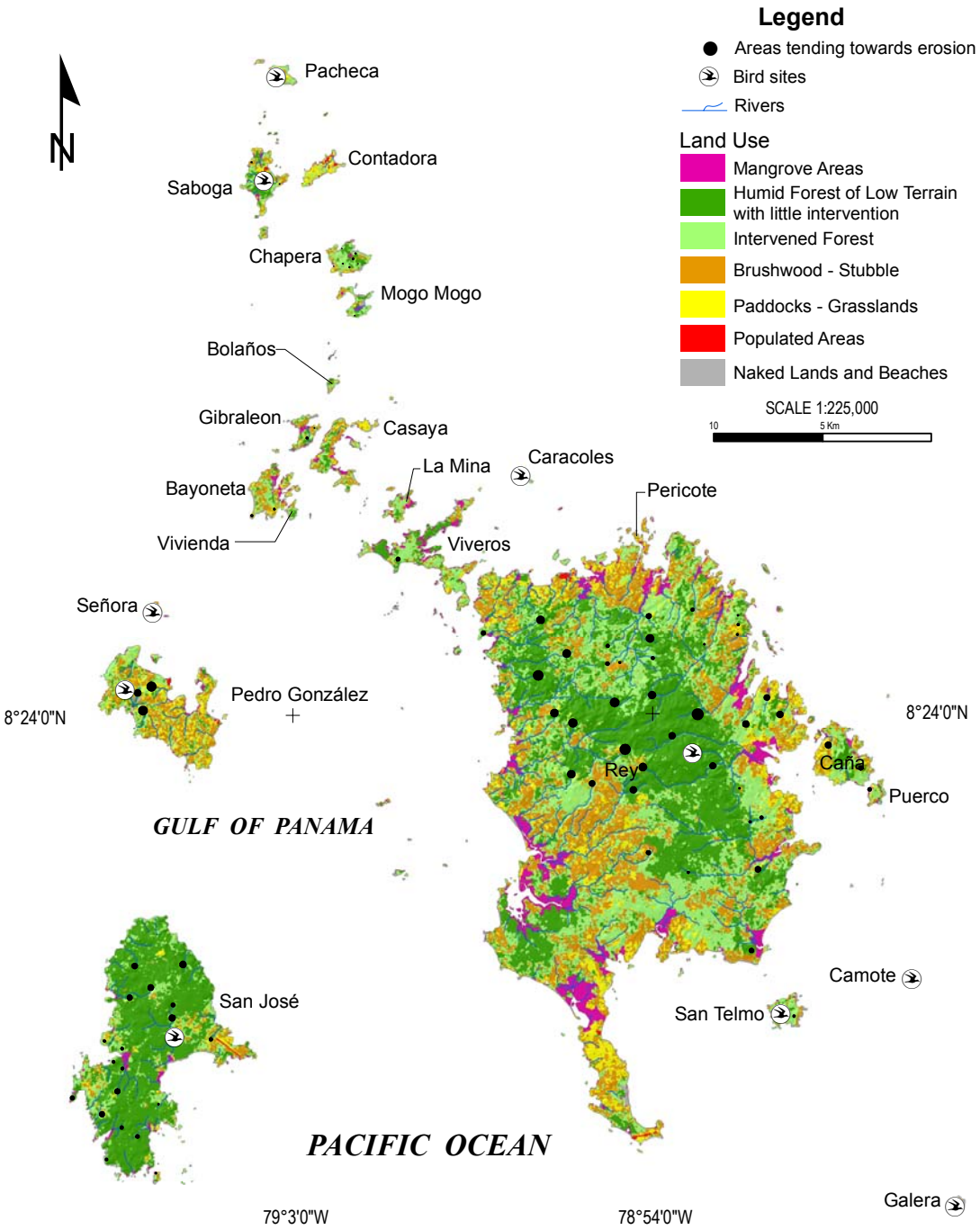


Figure 5.2 Overlay map of physical variables Las Perlas Archipelago, Panama.



CONCLUSION

The methodology used in this research allowed us to prepare an updated cartography of the natural resources and to measure in a span of 26 years the change process in forest cover and land use in Las Perlas Archipelago.

Through the estimation of the deforestation rate I became aware of the amount of forest that was lost through the period comprised between 1974 and 2000 and to detect that the pressure being exerted on the resources was greater during the period 1974 -1986.

Through the multi-temporal analysis of images, I was able to identify changes in the time of land use and determining that the rhythm of the agricultural activity has dropped considerably what has given space for natural regeneration of the forests.

The method employed to locate areas prone to erosion is very simple, and can be applied in a short period based on data that are generally available. Thanks to this simple and fast method, it was possible to identify the islands with the greatest erosion risks, to the South of the Archipelago.

The overlay analysis with variables such as reefs, nesting sites for marine birds or endemics, and incubation sites of marine turtles, allowed me to understand not only the geographical distribution within the Archipelago but also the habitat on which they develop. This is very important because when the physical environment is altered it results in conflicts when a resource use activity produces a decrease in the availability o quality of a resource used by other activity.

Results obtained in this study are being analyzed by the Darwin Initiative as part of the proposal to establish a special management area in the Archipelago that comprises a polygon of 237,618 ha, which includes all islands and islets with a surface area of 33,177 ha and a water area of 204,441 ha.

consider that this special management area should be established with a zoning that imply the establishment of protected areas following the categories of administrative management from ANAM.

In agreement with the physical and biological characteristics of each island, it is suggested the creation of national parks in (appendix 22):

The central region of Isla El Rey, which in addition to conserve the natural resources, guarantee the protection of the hydrographic watershed that supplies water to the main communities established on the island and supplies nutrients to coral reefs located on the east region of the island.

Also the Isla San José should be considered as a natural reserve area due to the good condition of its forests.

On the Isla Pedro González, the establishment of a national park that includes the areas of SW and NO region, of the community which has the same name, this park will have the function to protect the few remnant forests on the island, to help on the recovery of coastal-marine zone, to prevent erosion, river sedimentation and to conserve the natural habitats that are useful for birds that select this island as nesting site.

It is also appropriate to establish protected areas in the category of wildlife refuge on Bartolome, Pacheca, Pachequilla, Caracoles, Camote, Galera, San Telmo and Señora islands.

Finally, protect all mangrove forests, because within this habitat the development of terrestrial and marine organisms occurs. In addition mangroves have important ecological functions such as the protection of the littoral against the sea wave erosion and the protection of the larval stage of fish, shrimp and lobsters species which are of great economic value (PNUMA 2000).

RECOMENDATIONS

- To facilitate environmental education in the Archipelago's communities so that the population becomes conscious of preserving and giving good use to natural resources.

- More studies are required regarding the Archipelago's flora and fauna to know in details the biodiversity and endemism that might be in each one of the islands.

- To carry out studies at detail scale regarding soils and geology that will serve as complement for other type of ecological studies.

- To conserve and manage the water resources taking in consideration the integral management of the hydrographic watersheds.

- To preserve the biogeographical regions and the landscape value in a way to secure the continuity of the evolutionary and reproductive processes of plant and animal species.

- To gather base line data follow ANAM regulations for the formal establishment of a protected area.

- A normative plan is needed to develop urban and tourist development for Las Perlas Archipelago with the objective to preserve the current fragile ecosystems of the archipelago.

REFERENCE

Acuña, E. E., 2005. Clasificación no supervisada de bosques y análisis multitemporal sobre imágenes de satélite en el área de influencia de la Corporación Autónoma de Santander (CAS) a escala 1:100.000. 35p.

Amend, S. & A. Almanza 2004. Áreas protegidas de Panamá. Orientación para su Manejo. Agencia de Cooperación Alemana (GTZ) y Autoridad Nacional del Ambiente (ANAM), 15 - 40, 53 - 56

Autoridad Nacional del Ambiente (ANAM). 1998. Ley No. 41 "por medio del cual se dicta la Ley General del Ambiente de la Republica de Panamá y se crea la Autoridad Nacional del Ambiente" (Gaceta Oficial No. 23,578, del 3 de julio de 1998).

Autoridad Nacional del Ambiente (ANAM). 2004. Informe 2001-2003. Programa de Monitoreo de la Efectividad del Manejo de las Áreas Protegidas. Autoridad Nacional del Ambiente (ANAM) y The Nature Conservancy (TNC), 1 - 3.

Angehr, G.R., 2003. Directory of Important Birds Areas in Panama. [Directorio de Áreas Importantes para Aves en Panama]. Sociedad Audubon de Panamá, Birdlife/Vogelbescherming Nederland. 267 - 279

Bush, M.B., 1996. Amazonian Conservation in a Changing World. Biological Conservation, **76**:219-228.

Chinea, J. D. 2002. Teledetección del bosque. En: M.R. Guariguata, G.H. Kattan (Eds.), Ecología y conservación de bosques Neotropicales. Pp.625-646. Libro Universitario Regional (EULAC-GTZ), Cartago, Costa Rica.

Chuvieco E., J. Salas, E. Meza and F. Vargas. 2000. Empleo de la Teledetección en el Análisis de la Deforestación Tropical: El caso de la Reserva Forestal de Ticoporo (Venezuela). Serie Geográfica No. **10**: 55-76.

Cicin-Sain, B. & Knecht, RW 1998. Integrated Coastal and. Ocean Management:Concepts and Practices. Island Press, USA. 517 p.

Cifuentes, M., A. Izurieta V. and H. H. de Faria. 2000. Medición de la Efectividad del Manejo de Áreas Protegidas. Serie Técnica No.2. WWF, IUCN Y GTZ. Costa Rica. **1**, 1 – 4.

Conglanton R.G. 1988. Using Spatial Autocorrelation Análisis to Explore the Errors in Maps Generated from Remotely Sensed Data. Photogrametric Engineering & Remote Sensing. **54**: 587-592.

FAO, 1993. El Estado Mundial de la Pesca y la Acuicultura. Organización de las Naciones Unidas para la Agricultura y la Alimentación. Departamento de Pesca. Roma.

GEO Panamá. 2004. Informe del Estado del Ambiente de la República de Panamá 2004. 125 p.

Groombridge, B., 1992. Global Biodiversity: Status of the Earth's living resources. [Biodiversidad global: Estado de los recursos vivientes de la Tierra]. Report compiled by the Wold Conservation Monitoring Centre. Chapman and Hall, London

Jensen, J. R. 2005. Introductory Digital Image Processing. A Remote Sensing Perspectiva. **13**, 495 – 500.

Jimenez, B. & K. Aparicio. 2004. Humedales de la Bahía de Panamá. Sociedad Audubon de Panamá, BirdLife Internacional y Fundación Natura. 185 p.

Johnson, T.H., and A.J Stattersfield. 1990. A Global Review of Island Endemic Birds. The Ibis, **132**:167-180.

Kattan, G. H., 2002. Fragmentación: patrones y mecanismos de extinción de especies. En: M.R. Guariguata, G.H. Kattan (Eds.), Ecología y conservación de bosques Neotropicales. Pp.561-590. Libro Universitario Regional (EULAC-GTZ), Cartago, Costa Rica.

Lindsay-Poland, J., 2003. Emperadores de la Jungla. La Historia Escondida de los Estados Unidos en Panamá. Colección Agenda del Centenario. Instituto de Estudios Nacionales, Universidad de Panamá, **2,** 83 - 132

Luckman, A. J., A. C. Frery, C. C. F, Yanasse and G. B. Groom. 1997. Texture in airbone SAR imagery of tropical forest and its relationship to forest regeneration stage. International Journal of Remote Sensing. **18**: 1333-1349.

McNeely, J., A.J. Harrison and P. Dingwall. 1994. Protecting Nature. Regional Reviews of Protected Areas. UICN Gland, Suiza y Cambridge, UK. 402 p.

MICI – Ministerio de Comercio e Industrias, 1992. Estadística Pesquera 1981-1991. Panamá. **9,** 69**.**

Morán, R., 1996. The flora of Guadalupe Island, México. [La flora de la Isla de Guadalupe, México] San Francisco, California Academy of Sciences. *http://www.ine.gob.mx/dgoece/con_eco/conhc/isla_guadalupe.html*

Miller, K. 1980. Planificación de Parques Nacionales para el ecodesarrollo en Latinoamérica. Fundación para la Ecología y Protección del Medio Ambiente. España, **3,** 129 – 135.

Posner,J., C. Bussink, R. J. Hijmans, R. Delgado, H. Willet, P. Zorogastúa y J.de la Cruz. 2002. Priorizando Áreas para la Conservación de Suelos en la Microcuenca La Encañada. Documento de Trabajo. Centro Internacional de la Papa (CIP) y El Consorcio para el Desarrollo Sostenible de la Ecorregión Andina (CONDESAN), Lima, Perú. 31 p.

Rignot, E., W. A. Salas, and D. I., 1997. Mapping deforestation and secondary growth in Rondonia, Brazil, using imaging radar and thematic mapper data. Remote Sensing of Enviorment. **59**: 167-179.

Saunders, D.A., Hobbs, R.J.,and Margules, C.R., 1991. Biological Consecuences of Ecosystem Fragmentation: a Review. Conservation Biology, **5**:18-32.

Steadman, D.W., 1997. Human Caused Extinctions of Birds. In: M.L. Reaka-Kudla, W.E. Wilson, and W.O. Wilson. (Eds.), Biodiversity II: Understanding and Protecting our Biological Resources. pp.139-161. Joseph Henry Press, Washington D.C.

Tershy, B.R. and D.A. Croll., 1994. Avoiding the problems of fragmentation by conserving natural fragments: the benefits of restoring and protecting small islands. Abstracts, Society for Conservation Biology Annual Meeting. [Cómo evitar los problemas de fragmentación conservando los fragmentos naturales: ventajas de restaurar y proteger islas pequeñas] Guadalajara, Mexico. June 7-11.

Tershy, B. and D. Breese., 1997. Human perturbations and conservation strategies on San Pedro Mártir Island, Gulf of California, México. [Perturbaciones humanas y estrategias de conservación en la Isla de Pedro Mártir, Golfo de California, México] Environmental Conservation **24**:161-170.

UICN/BID 1993. Parques y Progreso, UICN. Cambridge, UK. 258 p.

Windevoxhel, N. J., J. J. Rodríguez and E. J. Laman. 1998. Situación del Manejo Integrado de Zonas Costeras en Centroamérica; Experiencias del Programa de Conservación Humedales y Zonas Costeras de UICN para la región. Conservación de Humedales y Zonas Costeras para Mesoamérica de UICN. 31 p.

Whittaker, R.J., 1998. Island Biogeography: Ecology, Evolution and Conservation. Oxford University Press. 118 p.

APPENDIX 1. Land Use of Bayoneta Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	59.49	22.06	26.94	9.99	22.06	8.18
Humid Forest of Low Terrain with little intervention	46.08	17.09	140.12	51.97	26.24	9.73
Intervened Forest	103.39	38.35	73.90	27.41	86.91	32.23
Brushwood - Stuble		0.00	7.65	2.84	88.54	32.84
Paddocks, Grasslands, and Farming Areas	40.00	14.83	0.86	0.32	24.97	9.26
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	20.67	7.67	20.16	7.48	20.90	7.75
Total	269.63	100.00	269.63	100.00	269.63	100.00

APPENDIX 2. Land Use of Bolaños Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove		0.00		0.00	0.37	1.70
Humid Forest of Low Terrain with little intervention	15.51	71.44	16.58	76.34	4.63	21.32
Intervened Forest	3.87	17.83	1.29	5.94	7.59	34.94
Brushwood - Stuble		0.00	0.27	1.24	4.13	19.01
Paddocks, Grasslands, and Farming Areas	1.62	7.47	0.05	0.23	0.37	1.70
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	0.71	3.25	3.53	16.25	4.63	21.32
Total	21.72	100.00	21.72	100.00	21.72	100.00

APPENDIX 3. Land Use of Casaya Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	61.88	21.62	25.93	9.04	20.55	7.18
Humid Forest of Low Terrain with little intervention	55.42	19.37	101.49	35.62	41.68	14.56
Intervened Forest	68.10	23.80	111.22	42.26	71.75	25.07
Brushwood - Stuble		0.00	20.64	7.20	82.70	28.90
Paddocks, Grasslands, and Farming Areas	65.25	22.80	3.24	1.13	44.02	15.38
Populated Areas	0.32	0.11	0.85	0.30	0.68	0.24
Beaches - Barren Land	35.19	12.30	22.80	4.46	24.78	8.66
Total	286.17	100.00	286.17	100.00	286.17	100.00

APPENDIX 4. Land Use of Caña Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	59.13	11.62	30.02	5.90	16.95	3.33
Humid Forest of Low Terrain with little intervention	336.20	66.05	242.58	47.66	92.62	18.20
Intervened Forest	85.83	16.86	191.09	37.54	197.42	38.79
Brushwood - Stuble		0.00	18.92	3.72	118.32	23.25
Paddocks, Grasslands, and Farming Areas	6.68	1.31	4.99	0.98	63.12	12.40
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	21.14	4.15	21.39	4.20	20.54	4.04
Total	508.98	100.00	508.98	100.00	508.98	100.00

APPENDIX 5. Land Use of Contadora Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	4.60	3.85	2.76	2.31	0.68	0.57
Humid Forest of Low Terrain with little intervention		0.00		0.00		0.00
Intervened Forest	33.96	28.44	48.89	40.94	24.05	20.14
Brushwood - Stuble	10.69	8.95	8.31	6.96	3.36	2.82
Paddocks, Grasslands, and Farming Areas	61.34	51.37	39.68	33.23	51.09	42.79
Populated Areas	0.65	0.54	2.27	1.90	21.92	18.36
Beaches - Barren Land	8.16	6.83	17.49	14.65	18.30	15.32
Total	119.40	100.00	119.40	100.00	119.40	100.00

APPENDIX 6. Land Use of Chapera Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	14.80	7.94	8.23	4.42	4.30	2.31
Humid Forest of Low Terrain with little intervention	57.65	30.95	93.29	50.07	42.11	22.60
Intervened Forest	82.53	44.30	67.72	36.35	93.11	49.98
Brushwood - Stuble	1.23	0.66	3.03	1.63	27.09	14.54
Paddocks, Grasslands, and Farming Areas	23.49	12.61	3.49	1.87	8.33	4.47
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	6.59	3.54	10.56	5.67	11.37	6.11
Total	186.31	100.00	186.31	100.00	186.31	100.00

APPENDIX 7. Land Use of Galera Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	1.59	6.82	0.45	1.92	0.05	0.23
Humid Forest of Low Terrain with little intervention	9.71	41.76	7.31	31.45	4.64	19.95
Intervened Forest	3.78	16.24	8.16	35.09	7.28	31.31
Brushwood - Stuble		0.00	0.09	0.39	3.30	14.19
Paddocks, Grasslands, and Farming Areas	1.53	6.58	0.17	0.74	0.62	2.68
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	6.65	28.60	7.07	30.40	7.36	31.65
Total	23.25	100.00	23.25	100.00	23.25	100.00

APPENDIX 8. Land Use of Gibraleon Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	15.47	13.77	9.08	8.09	11.85	10.54
Humid Forest of Low Terrain with little intervention	39.00	34.71	57.54	51.22	18.69	16.63
Intervened Forest	42.36	37.70	28.65	25.50	31.45	28.00
Brushwood - Stuble		0.00	0.50	0.45	31.58	28.11
Paddocks, Grasslands, and Farming Areas	1.48	1.32	2.56	2.28	4.55	4.05
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	14.04	12.50	14.01	12.47	14.23	12.67
Total	112.35	100.00	112.35	100.00	112.35	100.00

APPENDIX 9. Land Use of Mina Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	48.78	49.53	44.47	45.15	15.02	15.25
Humid Forest of Low Terrain with little intervention	7.76	7.88	20.78	21.10	16.21	16.46
Intervened Forest	23.59	23.95	22.45	22.79	40.94	41.57
Brushwood - Stuble		0.00	0.15	0.15	13.21	13.41
Paddocks, Grasslands, and Farming Areas	7.59	7.71		0.00	2.83	2.88
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	10.77	10.94	10.64	10.80	10.28	10.44
Total	98.49	100.00	98.49	100.00	98.49	100.00

APPENDIX 10. Land Use of Mogo Mogo Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	48.78	49.53	44.47	45.15	15.02	15.25
Humid Forest of Low Terrain with little intervention	7.76	7.88	20.78	21.10	16.21	16.46
Intervened Forest	23.59	23.95	22.45	22.79	40.94	41.57
Brushwood - Stuble		0.00	0.15	0.15	13.21	13.41
Paddocks, Grasslands, and Farming Areas	7.59	7.71		0.00	2.83	2.88
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	10.77	10.94	10.64	10.80	10.28	10.44
Total	98.49	100.00	98.49	100.00	98.49	100.00

APPENDIX 11. Land Use of Pacheca Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove		0.00		0.00	0.16	0.23
Humid Forest of Low Terrain with little intervention	13.22	18.39	7.02	9.77	4.18	5.81
Intervened Forest	22.33	31.07	43.48	60.49	36.06	50.16
Brushwood - Stuble	10.85	15.10	13.00	18.09	18.56	25.82
Paddocks, Grasslands, and Farming Areas	17.69	24.61	0.54	0.75	5.14	7.16
Populated Areas		0.00	0.00	0.00		0.00
Beaches - Barren Land	7.79	10.84	7.84	10.91	7.77	10.81
Total	71.88	100.00	71.88	100.00	71.89	100.00

APPENDIX 12. Land Use of Pedro González Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	32.26	2.21	11.38	0.78	31.71	2.17
Humid Forest of Low Terrain with little intervention	545.70	37.31	352.60	24.11	156.09	10.67
Intervened Forest	590.70	40.39	673.49	46.05	405.91	27.75
Brushwood - Stuble	7.14	0.49	349.95	23.93	548.95	37.53
Paddocks, Grasslands, and Farming Areas	259.43	17.74	46.44	3.18	287.97	19.69
Populated Areas	2.23	0.15	3.51	0.24	6.47	0.44
Beaches - Barren Land	25.18	1.72	25.25	1.73	25.52	1.74
Total	1462.63	100.00	1462.63	100.00	1462.63	100.00

APPENDIX 13. Land Use of Pericote Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	1.72	6.01	7.91	27.64	2.51	8.77
Humid Forest of Low Terrain with little intervention	9.47	33.08	4.12	14.39	4.13	14.43
Intervened Forest	12.32	43.03	9.45	33.00	1.63	5.69
Brushwood - Stuble		0.00	1.98	6.92	12.78	44.64
Paddocks, Grasslands, and Farming Areas	0.67	2.34	0.85	2.97	3.10	10.83
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	4.45	15.54	4.32	15.09	4.48	15.65
Total	28.63	100.00	28.63	100.00	28.63	100.00

APPENDIX 14. Land Use of Puerco Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	8.74	13.73	9.81	31.12	7.56	11.87
Humid Forest of Low Terrain with little intervention	46.96	84.76	15.70	24.66	4.69	7.36
Intervened Forest	0.32	0.51	20.14	31.63	29.49	46.32
Brushwood - Stuble		0.00	0.81	1.27	8.96	14.08
Paddocks, Grasslands, and Farming Areas	0.31	0.49	10.18	0.28	5.81	9.13
Populated Areas		0.00		0.00	0.00	0.00
Beaches - Barren Land	7.33	0.51	7.03	11.04	7.16	11.25
Total	63.67	100.00	63.67	100.00	63.67	100.00

APPENDIX 15. Land Use of El Rey Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	2288.22	9.57	1563.85	6.54	1356.34	5.67
Humid Forest of Low Terrain with little intervention	16793.83	70.20	9148.06	38.24	7779.36	32.52
Intervened Forest	3389.02	14.17	7756.99	32.43	7664.95	32.04
Brushwood - Stuble	116.00	0.48	4542.32	18.99	5176.62	21.64
Paddocks, Grasslands, and Farming Areas	1116.21	4.67	685.35	2.86	1720.65	7.19
Populated Areas	23.22	0.10	29.87	0.12	28.39	0.12
Beaches - Barren Land	195.72	0.82	195.79	0.82	195.91	0.82
Total	23922.22	100.00	23922.22	100.00	23922.22	100.00

APPENDIX 16. Land Use of Saboga Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	3.15	1.07	2.70	0.92	7.51	2.55
Humid Forest of Low Terrain with little intervention	139.85	47.56	76.66	26.07	80.76	27.46
Intervened Forest	90.93	30.92	154.44	52.52	94.67	32.19
Brushwood - Stuble		0.00	36.40	12.38	54.83	18.64
Paddocks, Grasslands, and Farming Areas	50.04	17.02	7.26	2.47	38.92	13.24
Populated Areas		0.00	6.03	2.05	6.52	2.22
Beaches - Barren Land	10.10	3.43	10.59	3.60	10.86	3.69
Total	294.07	100.00	294.07	100.00	294.07	100.00

APPENDIX 17. Land Use of San José Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	105.97	2.41	85.06	1.93	68.72	1.56
Humid Forest of Low Terrain with little intervention	3885.95	88.30	3246.82	73.78	3208.65	72.91
Intervened Forest	245.58	5.58	876.97	19.93	725.10	16.48
Brushwood - Stuble	7.57	0.17	75.00	1.70	260.73	5.92
Paddocks, Grasslands, and Farming Areas	82.27	1.87	53.64	1.22	66.68	1.52
Populated Areas	14.80	0.34	9.42	0.21	10.73	0.24
Beaches - Barren Land	58.76	1.34	53.99	1.23	60.29	1.37
Total	4400.90	100.00	4400.90	100.00	4400.90	100.00

APPENDIX 18. Land Use of San Telmo Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	4.43	2.73	2.00	1.23	6.91	4.26
Humid Forest of Low Terrain with little intervention	102.06	62.83	104.47	64.32	72.46	44.61
Intervened Forest	35.76	22.01	26.38	16.24	39.19	24.13
Brushwood - Stuble		0.00	12.31	7.58	22.38	13.78
Paddocks, Grasslands, and Farming Areas	3.54	2.18	0.18	0.11	4.75	2.93
Populated Areas		0.00	0.12	0.08	0.06	0.04
Beaches - Barren Land	16.64	10.24	16.96	10.44	16.68	10.27
Total	162.43	100.00	162.43	100.00	162.43	100.00

APPENDIX 19. Land Use of Señora Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove		0.00		0.00	0.61	2.12
Humid Forest of Low Terrain with little intervention	5.85	20.29	5.38	18.65	2.06	7.14
Intervened Forest	18.55	64.35	19.06	66.09	10.60	36.75
Brushwood - Stuble		0.00	0.27	0.94	8.85	30.69
Paddocks, Grasslands, and Farming Areas		0.00		0.00	2.05	7.11
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	4.43	15.37	4.13	14.32	4.67	16.19
Total	28.83	100.00	28.84	100.00	28.84	100.00

APPENDIX 20. Land Use of Vivienda Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	2.53	9.23	1.51	5.49	1.52	5.55
Humid Forest of Low Terrain with little intervention	10.25	37.41	16.75	61.14	7.50	27.37
Intervened Forest	9.90	36.14	5.08	18.52	9.62	35.11
Brushwood - Stuble		0.00	0.40	1.45	3.82	13.94
Paddocks, Grasslands, and Farming Areas	0.92	3.36	0.50	1.83	1.71	6.24
Populated Areas		0.00		0.00		0.00
Beaches - Barren Land	3.80	13.87	3.17	11.57	3.23	11.79
Total	27.40	100.00	27.40	100.00	27.40	100.00

APPENDIX 21. Land Use of Viveros Island

Class	1974		1986		2000	
	Surface (ha)	%	Surface (ha)	%	Surface (ha)	%
Mangrove	136.36	21.66	60.58	9.62	71.29	11.33
Humid Forest of Low Terrain with little intervention	234.01	37.18	200.01	31.77	159.86	25.40
Intervened Forest	165.87	26.35	266.18	42.29	243.34	38.66
Brushwood - Stuble		0.00	45.32	7.20	77.53	12.32
Paddocks, Grasslands, and Farming Areas	40.90	6.50	2.50	0.40	22.46	3.57
Populated Areas		0.00		0.00	0.06	0.01
Beaches - Barren Land	52.34	8.31	54.87	8.72	54.92	8.72
Total	629.47	100.00	629.47	100.00	629.47	100.00

APPENDIX 22 Propose natural reserve areas within the archipelago Las Perlas, Panama.