Political Ecology, Ecological Economics, Landscape Change and Management of Cerro El Roble Nature Sanctuary in Central Chile

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ABSTRACT

Habitat destruction, climate change, overexploitation, and pollution are forcing the biological diversity of our planet towards a mass extinction, the first ever caused by human activity. This imminent threat raises an urgent need to create protected areas that sustain the Earth's remaining species. However, the creation of protected areas generates social conflict, changes in land use from production to conservation, and raises a number of complex management issues that need to be resolved in order to maintain existing species diversity and ecosystem services.

I have studied the processes, conflicts, and outcomes related to the creation of the Cerro El Roble Nature Sanctuary, a conservation area located 47 Km northwest of Santiago, Chile's capital city. The creation of the 998.1 hectares Cerro El Roble Nature Sanctuary in 2000 produced social conflict within the nearby community of Caleu (pop. 430). We conducted an in-depth, interdisciplinary study of the consequences of establishing the Nature Sanctuary by collecting data using focus groups, surveys, extensive interviews, field observations, and remote sensing satellite imagery. We focused on the social conflict, the ecological economics of ecosystem use, the state of the El Roble hill ecosystem, and a sustainable management plan for the Sanctuary.

The conflict surrounding the creation of the Cerro El Roble Nature Sanctuary was complex, having different levels and domains that emerged primarily because of the power struggle and divergent views between the ancestral, less educated locals, and the richer, more educated newcomers. As documented in this study, following the creation of the Sanctuary, there was a significant reduction ($p<0.05$) in the use of ecosystem services by the community of Caleu. However, as a result, the local people, especially older "Calegüanos", lost a range of valuable resources that supplemented and sustained their daily lives, and that, consequently, led to further impoverishment.

The analyses of long-term changes in the Cerro El Roble landscape, using a series of Landsat satellite images taken between 1975 and 2012, indicated that the core oak forest has been declining in area and increasing in fragmentation for

at least the past 38 years. Local weather records that cover the same period show no significant change in average precipitation. However, there is been an increase of 1.2 degree C° in average temperature in the area, double than world temperature increase in the same period. On-site observations and a number of related studies support the hypothesis that the deterioration of El Roble hill ecosystem has resulted primarily from anthropogenic disturbance and likely for indirect global warming effects. While the establishment of the sanctuary has helped to reduce these perturbations, at current rates of change the core oak forest will be reduced from 120-140 hectares in 1975 to just 10-15 hectares of increasingly fragmented habitat by 2050.

Finally, state-of-the-art, science-based approaches to the management and conservation of ecological reserves are reviewed with the aim of crafting a new management strategy for the Cerro El Roble Nature Sanctuary that replaces the current, inadequate plan. The plan proposed here lays the foundation for realizing the sustainable use of the sanctuary, and will promote the recovery of the centrally important oak forest.

1. INTRODUCTION

1.1. Background

1.1.1. Socio-Environmental Conflict

The drastic diminution of biodiversity through deforestation, change in land use and pollution, among other factors, along with increasing demand for ecosystem services and natural resources by a overpopulated planet, has placed humanity on a course towards self-destruction. Conservation and protection of natural areas are the most effective, near-term strategies that will play a crucial role in mitigating ongoing damage to the environment, and eventually restoring the sustainable use of the Earth's ecosystems.

However, establishing new, or expanding existing, protected areas often creates conflict between groups that favor and those that oppose changing the status of a given area of land. The conflicts do not arise from contraposition between preservation goals and economic growth interests. Rather, they originate from debates over a specific set of policies for sustainable development, that is acceptable to the majority of the stakeholders involved.

Some stakeholders, often local residents, expect to continue exercising what they regard as their legitimate rights of use of their shared land. They fear and oppose having their long held privileges, and in some cases livelihood, taken away through outside conservation policies. These fears among the local community are sometimes validated and reinforced in situations where there are strong information asymmetries arising from differences in educational level, social status, economic power, and political influence among locals and newcomers. Such conflicts are increasingly common in conservation efforts as the stock of usable, non-degraded lands decreases, and the opposing interests of stakeholders are exacerbated. The resulting tensions between incumbent locals versus outside elites may result in social and political restructuring,

exacerbating the sense of loss and deprivation among long-term residents who are no longer permitted to extract ecosystem services that have traditionally improved their quality of life.

1.1.2. Ecosystem Services

This study focuses on the uses, economics, management and sustainability of protected ecosystems and the services they provide. Ecosystems and biodiversity are the building blocks of the natural world. Ecosystems are complex systems that encompass the interaction of both biotic and abiotic elements of a given area, while biodiversity is the biological diversity of organisms, genes and ecosystems in nature.

Ecosystems, through their complex functioning, produce ecosystem services. These services are beneficial to natural systems themselves. They include the cycle of nutrients, such as Nitrogen, that are essential for life, the maintenance of clean air and water, the production of organic soils, the pollination of plants, and the primary productivity that sustains the biosphere. However, their various uses by humans and their central importance to the sustainability of our existence are often overlooked. Ecosystem services can be utilized directly by human beings for their own welfare, or they can provide benefits to humans that arise indirectly from ecosystem functions. Ecosystem function is defined as the ability of components and natural processes to provide goods and services that meet human needs, directly or indirectly.

Ecosystem functions become services when human values are involved, making the concept of ecosystem goods or services inherently anthropocentric. Virtually all definitions of ecosystem services coincide in that the defined services are fundamental to supporting all living organisms within the Earth's biosphere, including human social systems and the economy.

1.1.3. Caleu and Hill El Roble

The community of Caleu (pop. 431 inhabitants, 2012) is located 75 km northeast of Santiago City, Chile's capital city, in the vicinity of the city of Runge and to the north of the town of Til-til. Caleu is composed of three villages: La Capilla, Lo Marin and Espinalillo. Caleu has a communitarian organization that is very unusual and rare elsewhere in Chile, especially in the central or southern regions. In this type of social system, each person owns a ranch received by heritage, and have the right to use any common lands owned by the community with regard to all the beneficial goods and services those land provide.

Caleu's climate is classified as Mediterranean and is highly seasonal, having cold and rainy winters with summers that are dry and hot. Rains are variable in occurrence and duration, and greatly affected by the El Niño Southern Oscillation (ENSO). Sometimes due to the area's elevation (900-2200 m.), precipitation is in the form of snow, which can reach the lowest parts of the watershed. As a result of fog that flows inland from the nearby Pacific coast (80 km) the weather can also be very humid.

Hill El Roble (elevation 2,222 m) is the highest peak of Chile's Coastal Mountain Range. The name of the hill[1] derivates from the high-elevation resident specie of white oak, *Nothofagus macrocarpa*. This is the northern-most population of white oak forest in Chile, and it is endemic to this country. The western side of the hill belongs to La Campana National Park. The eastern side of the hill is historically common land belonging to people who live permanently in Caleu, and as such cannot be subdivided or sold.

Due to the long-standing use of the ecosystem services (see chapters 3, 4 and 5) of El Roble hill, its dry, Mediterranean forest has deteriorated. As discussed in chapter 5, several anthropogenic-based disturbances appear to be the cause of the ongoing degradation of El Roble hill, including tree cutting for timber, collection of firewood, soil extraction for sale, charcoal production, introduction of European rabbits, cattle grazing, and silver and gold mining.

[1] Roble in Spanish translates Oak in English.

A complex socio-ecological situation, reviewed in detail in chapters 3 and 4, developed in this community when a group of concerned people who owned vacation homes in Caleu petitioned the government to declare El Roble hill a Nature Sanctuary. It was declared a Nature Sanctuary in 2000, and, as a result making use of the hill for any activities other than recreation was forbidden by law. The new laws thus denied the residents the long-standing extraction of ecosystem services on their common land.

1.1.4. Management of the Cerro El Roble Nature Sanctuary

When El Roble hill became a Nature Sanctuary, several offices and departments within the Chilean government attempted to develop a participatory management plan to protect the sanctuary and enforce the new, legalized restrictions of the use of the hill. Unfortunately, this plan was based on disconnected, and in some cases misguided efforts, and has failed to meet its objectives. With the aim of constructing a new, more effective plan for the sustainable management of Cerro El Roble Nature Sanctuary, best practices in ecosystem management, community-based resource management and ecosystem stewardship will be reviewed in chapter 6, and a number of conservation recommendations proposed for the future management.

1.2. Statement of Purpose

The research discussed below has multiple goals by carrying out a holistic, multidisciplinary study of the current and future status of Cerro El Roble Nature Sanctuary, taking into account social, political, economic and environmental aspects of the problem.

The first goal was to understand economic, political, and social aspects of the conflict produced in the community of Caleu when El Roble hill was declared a Nature Sanctuary. The second goal was to understand the current state of the El Roble hill, from ecological, climatological and socio-political points of view, and doing so, construct a holistic, integrated set of recommendations, to help the

community better manage and protect their common land and ensure the future sustainability of the Cerro El Roble Nature Sanctuary.

To accomplish these goals, this study draws upon the concepts and techniques of ecological economics to investigate how the uses of the ecosystem services by the community, and how those uses changed after the hill became a Nature Sanctuary. The study also employs the principles and procedures of political ecology to research the socio-environmental conflict and the dynamics that developed between local Calegüanos and the more affluent, part time residents who were mainly from Santiago.

Finally, remote sensing was employed to reveal long-term ecological changes in the El Roble hill, in particular the Santiago White Oak forest, and inform a science-based plan for the management of the sanctuary.

1.3. Importance and Broader Impact

In general, there is a distinct lack of cross-discipline studies taking a holistic view of the impact, both ecological and sociological, of creating protected areas, not only in Chile, but also in many other parts of the world. This is especially true for private sanctuaries, such as El Roble hill. This study analyzes how changes in conservation policies impact: (1) social conflicts; (2) use of ecosystem services; (3) environmental degradation; and (4) management of protected areas. It focuses on changes in behavior reflected in the annual usage of 19 ecosystem services as they relate to explanatory variables, such as distance, age, policy, and education level, and it allows for a better understanding of the usage of select direct ecosystem services by people in rural areas where most ecological reserves are located.

The research presented here provides an important case study concerning how changes in the laws regulating long-standing patterns of ecosystem exploitation affected a local community that was dependent in many ways on extracting those services. It is also important to determine the impact

that the new environmental regulations and management strategies have on the recovery of the ecosystem degraded by human perturbations.

Caleu and El Roble hill are a unique case in that the land constituting the Nature Sanctuary belongs to the surrounding community, just as it did before the sanctuary was created. This study thus provides insight into the issues and outcomes inherent in local ownership and management of protected lands, and a detailed analysis of the social changes produced within the community of land owners.

The results of this research also make an important contribution to understanding the complex issues involved in successful efforts to preserve an ecosystem that is part of the Mediterranean forest biome. The Mediterranean biome contains an extraordinary diversity of species and their habitats, and, while covering less that 2% of the Earth's surface, contains over 10% of all known plant species. The biome is threatened by human activities in all areas where it occurs, specially including central Chile.

1.4. Organization of the Study

The results of this study are discussed in five interrelated chapters, plus an introductory chapter and a multidisciplinary conclusions chapter.

Chapter 2 presents an overview of the biogeography and climate of central Chile, a description of the Mediterranean biome, basic information concerning the community of Caleu and El Roble hill, and a discussion of the ecosystem services that El Roble hill could potentially supply.

Chapter 3 provides an extended description of Caleu's history and an analysis from the perspective of political ecology of the socio-environmental conflict derived from the creation of Cerro El Roble Nature Sanctuary.

Chapter 4 presents the results of detailed surveys with local residents concerning the frequency with which they extracted ecosystem services and the type of service utilized before and after the Nature Sanctuary was established. Statistical analysis of the survey data are discussed that result in a better

understanding of the factors influencing the community's utilization of ecosystem services.

Chapter 5 utilized data from Landsat satellite images to document the long-term degradation of the El Roble hill landscape. Climate data are also analyzed to determine the extent and influence of climate change on the El Roble forest. The effects of anthropogenic disturbances are discussed that provide the basis for future conservation efforts.

Chapter 6 summarize the scientific foundation for ecosystem management, discusses optimal strategies for protecting natural areas, including community-based management and ecosystem stewardship, and provides recommendation for improving the future management and sustainable use of the Cerro El Roble Nature Sanctuary.

Chapter 7 discusses the study's conclusions and presents a holistic model of the environmental system model of the situations of the El Roble hill and Caleu, that attempts to connect and integrate the various components of the research.

2. THE STUDY AREA: CALEU AND HILL EL ROBLE

2.1. Introduction

This chapter contains a literature review of the biogeoclimatic topography of Chile, with special focus on Mediterranean biome, followed by a detailed description of the community of Caleu and the El Roble hill.

Chile is a long and narrow country that extends in essentially a straight line from 18 degrees to 56 degrees south latitude along the Pacific border of South America. Because its unique geography, Chile, contains within its borders seven major climates: Desert, Alpine Tundra, Glaciers, Humid-Tropical (Easter Island), Oceanic (in the extreme south) and Mediterranean (in central Chile). Chile's continental climates includes "Desert" (Atacama Desert and Patagonia Desert), "Semi-Arid" (the boundary between Atacama Desert and Chilean Matorral), "Mediterranean" (in central Chile), "Temperate Oceanic" (the Valdivian Rain Forest), "Sub-polar Oceanic" (the Magellan Sub-Polar Forest), and "Alpine Tundra", (the Andean Dry Puna).

Due to its elongated geography, which starts north of the southern tropic and ends north of the Antarctic circle, Chile contains several biogeoclimatic regions, from the extreme North (Atacama Dessert) to the extreme South (Patagonia and Antarctic), (Figure 2.1). The research discussed here concerns Chile's central Mediterranean biome. The following is a review of climate and topography of this biome with the aim of providing a better understanding of its unique relictual vegetation, and the importance of the Santiago white oak (*Nothofagus macrocarpa*) forest.

2.2. Bioclimatic Geography of Chile

Bioclimatic patterns in Chile can be understood using the concept of bioclimatic belt (*piso bioclimático*), which are also referred to as temperature belt (*piso*

termoclimático), and vegetation belt (*piso vegetacional*). The bioclimatic belt is correlated with temperature regimes and vegetation belt is based on vegetation types as which are also indicators of climate regimes. Using these two concepts, it can be identified the relationships between temperature and rainfall with the major vegetation types of each region of Chile (Amigo & Ramirez, 1998).

Following Rivas-Martinez (1993) classification, a bioclimatic zoning of Chile can be done defined based on the five "macro-bio-climates" of the world: Tropical, Mediterranean, Temperate, Boreal and Polar. Each macro-bio-climate is divided into belts (hottest to coldest) based on temperature regimes[2]. Finally, each macro-bio-climate can also be subdivided into rainfall regimes[3].

2.3. Overview of the Mediterranean Biome

Mediterranean biome exists on five zones (Fig. 2.2): America (California and Chile), Africa (South Africa), Oceania (New Zealand and Australia), and the land surrounded the Mediterranean sea. All these regions are distinguished by their high diversity of plants and high levels of endemism, which are more greater than the tropical flora of Africa and Asia combined (Underwood et al, 2009) to be the main factors underlying the elevated species richness and high endemism of the Mediterranean biome.

Most conservation assessments classify the Mediterranean biome as a top priority for biodiversity conservation. It follows that better understanding of the Mediterranean biome and the threats to its existence, is urgently needed (Underwood et al, 2009).

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2 The prefixes used to designate these belts from hottest to coldest are: Infra-, Thermo-, Meso-, Supra-, Oro-, and Cryoro-. With some exceptions for Boreal (includes Tundral, Cryodesertic and Pergelid; and for Polar only with three belts: Tundral, Cryodesertic and Pergelid).

3 Ultraperarid, Perarid, Arid, Semiarid, Dry, Subhumid, Humid, Perhumid, and Ultraperhumid.

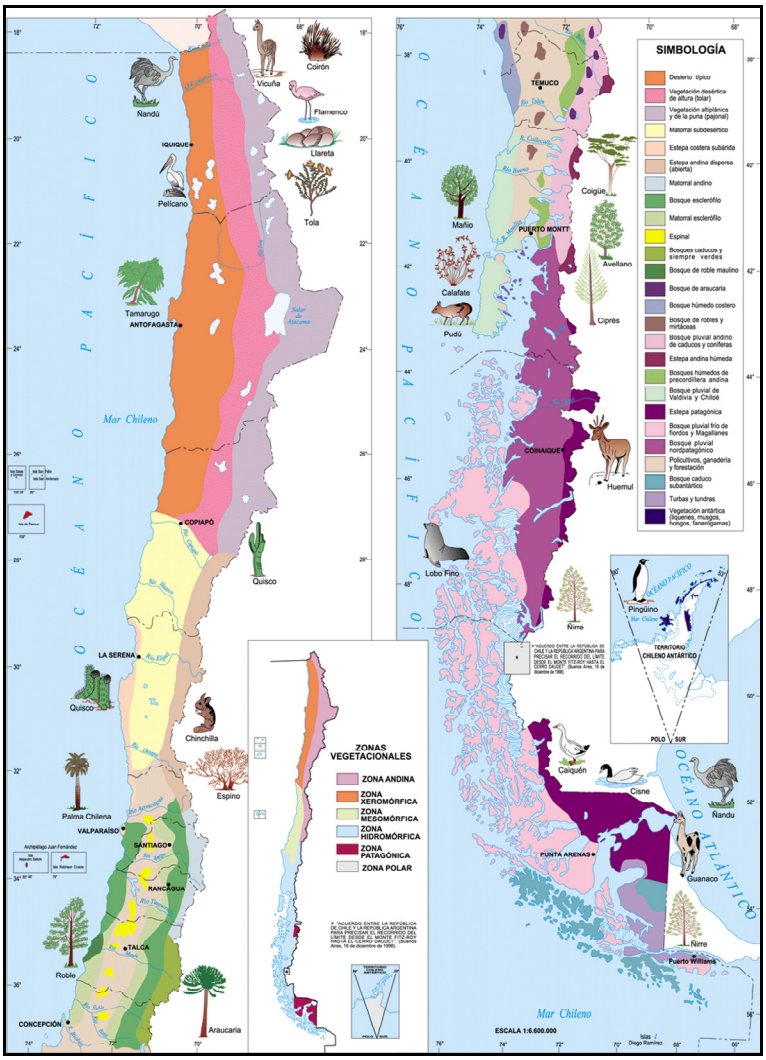

Figure 2.1. Chile's biogeographical and vegetational zones (Source: accessed on 5/13/2012 http://www.educarchile.cl).

The level of the threats varies among the five Mediterranean areas. In Chile and California Plant extinction are correlated with scale and duration of western colonization. "New world" Mediterranean biomes experienced the rapid introduction of hundred of alien species from Europe and growing disturbances from human settlers who also introduced domesticated herbivores such cattle, sheep and goats as well as European rabbits and hares.

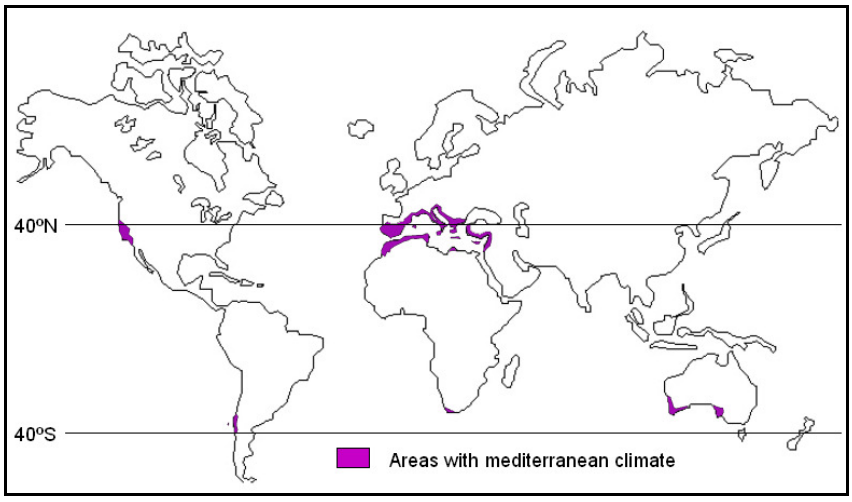

Figure 2.2. Distribution of areas with Mediterranean biome. (Source: accessed on 5/13/2012 http://en.wikipedia.org/wiki/Mediterranean_climate).

The mild climate of the Mediterranean biome also made it favorable for human settlements, resulting in high percentage of conversion to agriculture, rural, urban, or other human uses (Rundel, 1981). Plants from Europe's Mediterranean biome had coevolved with humans and herbivores for thousands of years and easily outcompeted many of Chile's Mediterranean plants species (Underwood et al, 2009). Currently, threats to Mediterranean biome are related to population density and growth of urban areas (Rouget et al. 2003), expansion of agriculture (le Houerou, 1981), and conversion of wilderness for tourism development (Paskoff & Martinez, 1999).

Mediterranean biome is predicted to undergo major changes in biodiversity by 2100 because the biome is particularly sensitive to land use change and in some areas climate change (Underwood et al, 2009). Projected changes due to global warming include greater than 80% range reduction in 66% of the endemic plant taxa in California by 2100, and 51-65% reduction in the ranges of endemic taxa in South Africa by 2050 (Klausmeyer & Shaw, 2009). Regional climate model prediction for central Chile through 2050 under scenario A2 of the IPCC[4] (regional expansion in economic development, no reduction in emissions) indicate temperature increases and reduced in the vegetation to

[4] Intergovernmental Panel on Climate Change.

grassland and matorral. The rest of the biome should experience little change in climate and vegetational structure (Armesto et al. 2007).

There are similarities and differences among the five regions of the world with Mediterranean biome. There are “affinities” and “dissimilarities”, generally speaking, physiographic, climatic, physiognomic, and phenomenological, and convergences in patterns of land use. The closest similarities are between California and Chile, and between Australia and South Africa.

The California-Chile Complex

The California-Chile complex is characterized by young orogenic systems with important volcanic and seismic areas having a similar terrain configuration: coastal ranges; a central valley bordered on the east by high mountains; and an expected general resemblance due to the fact that both regions are placed at the same parallel, 40° south and north. Chile and California show a homologous arrangement, however, in a poleward sequence. The effect of the Humboldt Current and California Current and the fact that both areas show “the most typical west coast” Mediterranean climate make them even more similar. The origins of communities of plants and animals are formed by a mixture of temperate and tropical elements in Chile, similar to those in California. There is also evidence of convergent evolution among plants of those two Mediterranean biomes.

Chile and California biomes are not identical, as Di Castri et al. (1981) explain, there are 20 detectable differences between both. The main of those differences are related to geographic characteristics, vegetation and climate. California is at higher latitude than Chile; Chile has a greater isolation effect, including greater biogeographical isolation. Chilean vegetation is more open and stratified, the disposition of ecosystems is like a mosaic, and also this area has greater coverage of grasses and weedy annuals, with wider distribution and diversity. Chilean Matorral has a structure with multiple layers including trees, shrubs and grasses. California has a well-developed coniferous and montane

forest because of some summer rainfall in the mountains; this not happen in Chile, with the exception of some *Autrocedrus chilensis*. Chile has a widespread "replacement" of forest systems from native to *Pinus radiata* and Eucalyptus spp. that is minor in California. California chaparral does not evolve towards sclerophyllous forest and does not have the ability to grow renewals without fire. Chile's climate is rainier than California's, variations of temperature are less and humidity is higher. Arid and humid periods happen a month later in California than in Chile (Di Castri et al, 1981).

2.4. Mediterranean Biome in Central Chile

Central Chile is divisible into three physiographic regions: Coastal Mountain Range, Andean Mountain Range and Central Valley. Both were formed in Precambrian and Cretaceous from crystalline rocks uplifted during the Tertiary. The highest pick is El Roble hill with 2,222 m in elevation. The soils in the coastal range are high in organic materials, which makes them especially prone to erosion when loss of plant cover occurs. These soils were produced during the Jurassic age from a highly weathered metamorphic parental material (Armesto et al. 2007). The Central valley of Chile is a structural basin filled with sediments from the erosion of the Andes to the east and the Coastal Range to the west.

In Chile, the Mediterranean biome is limited to a narrow band of 1,000 km. long in central part of the country that ranges from 30° to 36° south latitude (Arroyo et al. 1999). This biome represents a transition from the Atacama desert to the north, one of the driest in the world, to a mixed of deciduous-evergreen temperate forest, the Maulino forest, in the south. Physiognomically, the Mediterranean biome in central Chile is a heterogeneous vegetational mosaic with three major vegetation types: xerophytes (summer-deciduous shrubs and succulents), mesic communities (evergreen sclerophyllous trees), and forest (winter-deciduous trees).

This area is currently classified as one of 200 hotspots to conserve global biodiversity due to the richness of its terrestrial flora (Arroyo et al, 1999).

Accordingly, numerous studies that involves the Mediterranean biome in South America have addressed "the causes of such high floristic richness, the nature of current threats and the future of its conservation" (Armesto et al. 2007). In general, the landscape of central Chile has been changed forever by the plantations of monocultures of *Pinus radiata* and *Eucaliptus spp*. Exotics grasses have found fertile grounds in central Chile, with more than 400 taxa recorded of invading species recorded. The original landscape of central Chile was also transformed by the introduction of goats, cattle, and rabbits, which are major predator of seedlings and hence severely limit regeneration (Fuentes, 1995).

2.4.1. Climate and Topography

The Mediterranean biome is characterized by a climate with four distinct seasons: dry summers, cold, rainy winters, and a spring and fall with mild temperatures. Typical of Mediterranean biomes, precipitation in Central Chile is characterized by cold winter rains and dry summers. The climate is extremely variable with spring-summer droughts that can last for up to 6 months. Annual precipitation within Chile's Mediterranean biome varies from less than 200 mm to 700 mm per year. The climatic regime is driven by seasonal changes in strength and latitude of the southern anticyclone from the Pacific Ocean; with high atmospheric pressure around 40° south latitude in the pacific coast (Rundel et al, 1981). During Chile's summer season, the high pressure point occupies a wide latitudinal range. Which blocks the westerly flow of humid air masses from the Pacific Ocean. As a consequence, central Chile is usually left completely dry from December through April.

The El Niño Southern Oscillation (ENSO) is an extremely important component forcing the variation in precipitation between years. In general, ENSO increases rainfall in the Mediterranean zone and decreases upwelling, thus making the anticyclone weaker. During La Niña years, the opposite occurs. Extremely dry conditions develop "causing long droughts with major ecological consequences" (Rundel et al, 1981).The main difference between the climate of

the Mediterranean biome in Chile, compared with other parts of the world, is the complete absence of rain during Chile's summer. Moreover, the Andes Cordillera produces a rain shadow effect, which keeps hyper-arid conditions in the Atacama Desert. Another unique feature of Chile's Mediterranean biome is the extra input of water to the coastal range vegetation due to condensation and fog-zone of moist air arriving from the nearby coast (Rundel et al, 1981).

2.4.2. History of the Mediterranean Area in Chile

Between 15 and 8 millions years ago, the final uplift of the Precordillera, the lower sections of the Andes Mountains, completely cutoff the east-west flow of air from the tropics. This resulted in a single rainy season, the winter, typical of the Chilean Mediterranean climate.

Another important characteristic is the desiccation of the climate due to the cold Humboldt Current; the current pattern stabilized and the ice sheets in Antarctica expanded, thus enhancing the cooling of the proto-Humboldt Current. Due to this scenario, the major determinant of species survival during the Quaternary was the ability to tolerate seasonal desiccation, as seasonal droughts became more frequent and intense during the interglacial period (Villagran, 1995).

2.4.3. Mediterranean Vegetation Types

Heterogeneity of the natural environment results in high floristic richness and diversity of plant communities. Andean uplift may also contribute because added opportunities for colonization and differentiation of the local "alpine" floras. The vegetation types in the Mediterranean biome in central Chile are: relict coastal forest (Olivillo-forest and Nothofagus-forest); Sclerophyllous matorral shrublands, and thornscrub; *Acacia caven* savanna; Chilean Palm forest; Swamp forest; Coastal Matorral; and Andean montane woodland.

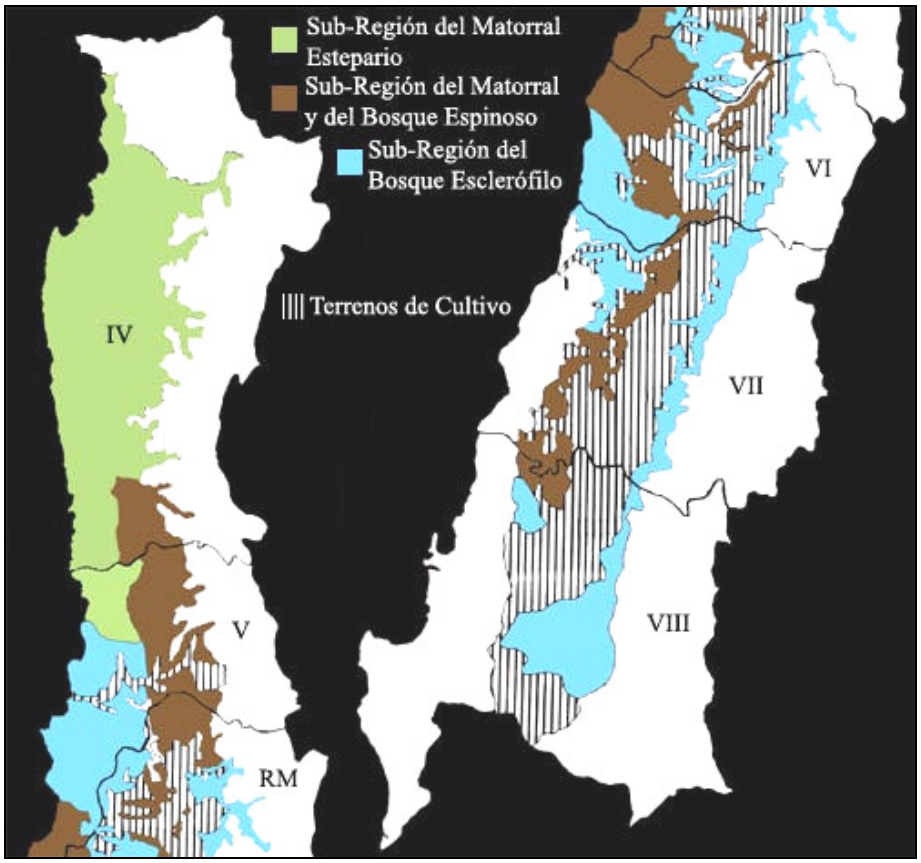

Figure 2.3. Chile's Mediterranean forest, Matorral and Sclerophyllous forest. (Source: accessed on 5/13/2012 http://www.florachilena.cl/Regiones_Vegetales/Bosque Esclerofilo/Matorral y Bosque Esclerofilo.htm).

2.4.4. Relict Vegetation

During the Tertiary, Nothofagus forest –it is been hypothesized– occurred in the present coastal zone between Valparaíso and Coquimbo, and later along the Andean Cordillera (Rundel, 1981). During the last glacial period, continuous glacial ice extended southward from an area north of Santiago through the Andes to Tierra del Fuego. Central Chile vegetation zones are localize to 500 m of the last major glacial advance, which ended 12,000 years ago, that was followed by a trend of warming climate (Vuilleumier, 1971). Current distribution of relicts includes Nothofagus and some related "hygrophilous forest species in central Chile gives evidence of the northern advance of cool-temperature vegetation, during Pleistocene" (Rundel, 1981). Surviving in special areas with microclimatic favorable conditions, those relicts survived including a diversity of typical species of the Valdivian forest in the southern of Chile.

Nothofagus forest is best developed, in the north of Chile's central area, in the south- or southeast- facing slopes at especially high elevations, like in La Campana, El Roble, and Campanita hills. Aside of *Nothofagus obliqua,* other species in these forests include *Lomatia obliqua*, *L. dentata* and *Viola portalesia*.

The Nothofagus Forest

Nothofagaceae is distributed in the Mediterranean biome's most southern limit, next to the temperate rainforest region. However, these remnants are small fragmental populations found only above 1,000 m in the highest peaks of the coastal range, for example in La Campana, El Roble and Cantillana hills. (Armesto et al, 2007). Chile's northernmost population of Nothofagus are in these three areas and are isolated of the continuous distribution of *Nothofagus obliqua* in the central depression as well as Andean foothills in south-central Chile, (Donoso, 1993). The northern populations of *Nothofagus obliqua* are remnants "from a more continuous distribution at lower elevation during the glacial advances" (Villagran, 1990). During the last glacial period, cooler and wetter climate could have helped the Equatorward expansion of the Nothofagus woodlands in central Chile (Rundel, 1981).

2.4.5. Anthropogenic Perturbation of Mediterranean Biome

Chile's Central Mediterranean area is smaller compared to other Mediterranean climate regions which could have been caused by a more insidious human impact in Chile compared to that of California (Arroyo et al, 1995). Several factors associated with long periods of human settlement influenced strongly the vegetation dynamics and plant communities' distribution.

Climatic trends are the most common factor impacting the establishment of shrublands into open lands. Other several anthropogenic conditions can also produce lost of matorral shrubs and tree, the most important of which are human-caused fires.

Another factor of anthropogenic impact in the Mediterranean biome is the introduction of exotic plants and animals to new habitats. The original landscape of central Chile was deeply transformed by the introduction of goats and rabbits, which are the major predators of seedlings, limiting regeneration (Fuentes, 1995). Also, natural herbivores, such as rodents, have less likely impact on vegetation because of population control by their natural predators, currently reduced in numbers (Jaksic, 1997). Even more, the landscape of central Chile has been changed forever by the plantations of monocultures of *Pinus radiata* and *Eucaliptus spp*. Exotic grasses have found fertile grounds in central Chile, with more than 400 taxa of exotic grass species recorded.

The openings on vegetation due to all the anthropogenic factors described before has increased the amount of runoff, producing massive losses of organic soil and nutrients to downstream and the Pacific ocean. Any perturbation maybe intensified by the extreme variability of precipitation in the Mediterranean biome. The loss of stature of sclerophyllous vegetation can be critical especially in the coastal range. It is thought that a long history of chronic perturbation in the vegetation of the coastal range could have then disrupted the normal hydrologic cycle over many years with a likely negative feedback effect on plant recovery and tree regeneration, causing even more desertification and loss of forest.

2.4.6. Conservation and Restoration of the Mediterranean Biome

The conservation of Mediterranean biome is no different than the majority of hotspots with the exception that this one has a long history of human occupation, farming, industry and residency (Armesto, 1998).

Less than 5% of the protected areas in Chile are placed within this climate, which contains about 50% of the vascular plant species endemic to Chile (Arroyo, 1995). It is estimated that 80% of the ecosystems that are included in the Mediterranean biome are either threatened or endangered. Restoration programs in the Mediterranean biome should be favored over the vast extensions of land that are getting exotic plantation in the coastal areas. Restoration efforts

must consider the need to exclude exotic herbivores, such as cattle, goats and rabbits.

2.5. Caleu

The community of Caleu is located 75 km to the northeast of Santiago, in the vicinity of Runge and to the northwest of Til-Til (Fig. 2.4). Caleu is composed of four settlements: El Peralillo, Espinalillo, La Capilla and Lo Marin. But only three of those are villages: La Capilla de Caleu, Lo Marin, and Espinalillo (Fig. 2.5).

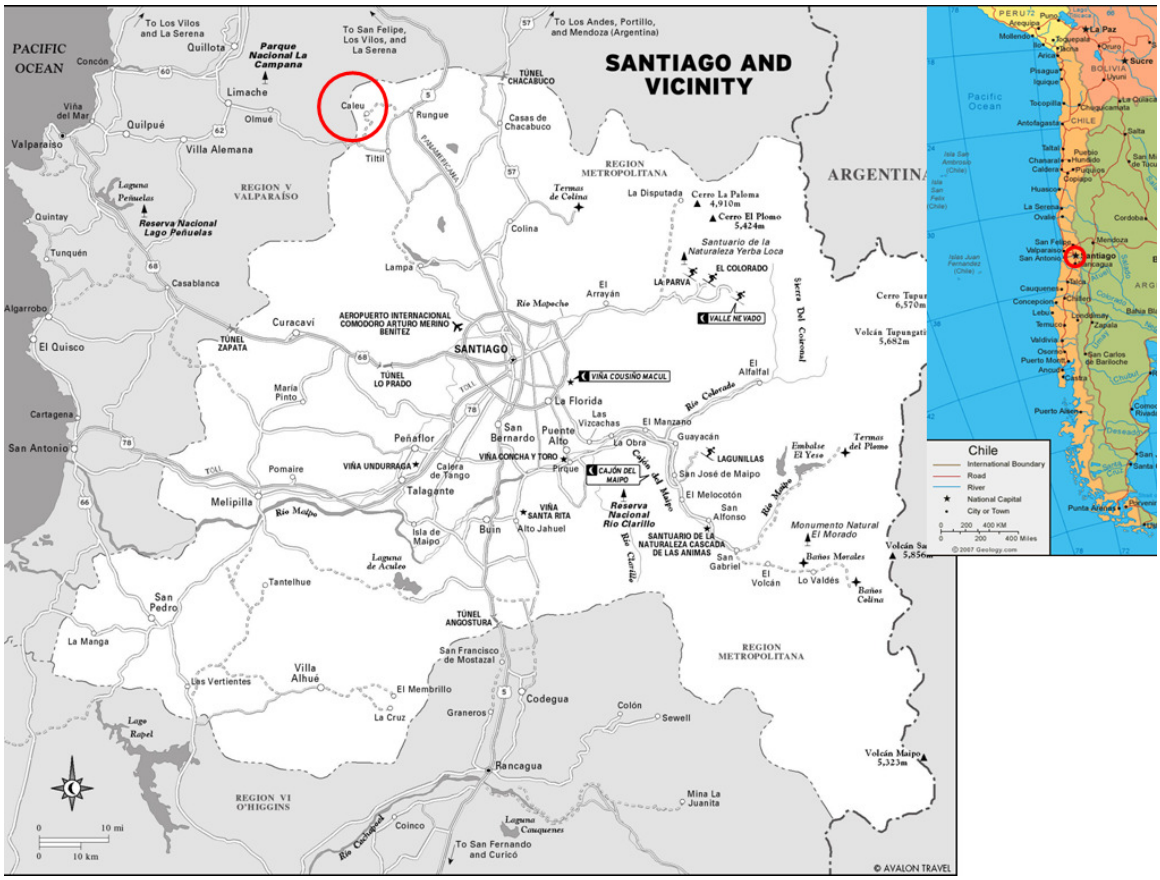

Figure 2.4. In the right side Chile with the Metropolitan Region highlighted in red. The central map shows the Metropolitan Region and Santiago with Caleu highlighted in red. (Source: accessed on 5/13/2012 http://www.moon.com/files/map-images/chl_01_Santiago-and-Vicinity.jpg and http://planetolog.com/maps/map-country/big/geo/chile-map.gif).

Caleu is characterized by a Mediterranean climate, with cold and rainy winters, and summers that are dry and hot. The rains are variable in occurrence and duration. Sometimes due to the elevation, precipitation is in the form of

snow, which can reach the lowest places in the watershed. In general, the area is relatively sunny but, as a result of fog coming in from the coast, the humidity is often high (Moreira, 1999).

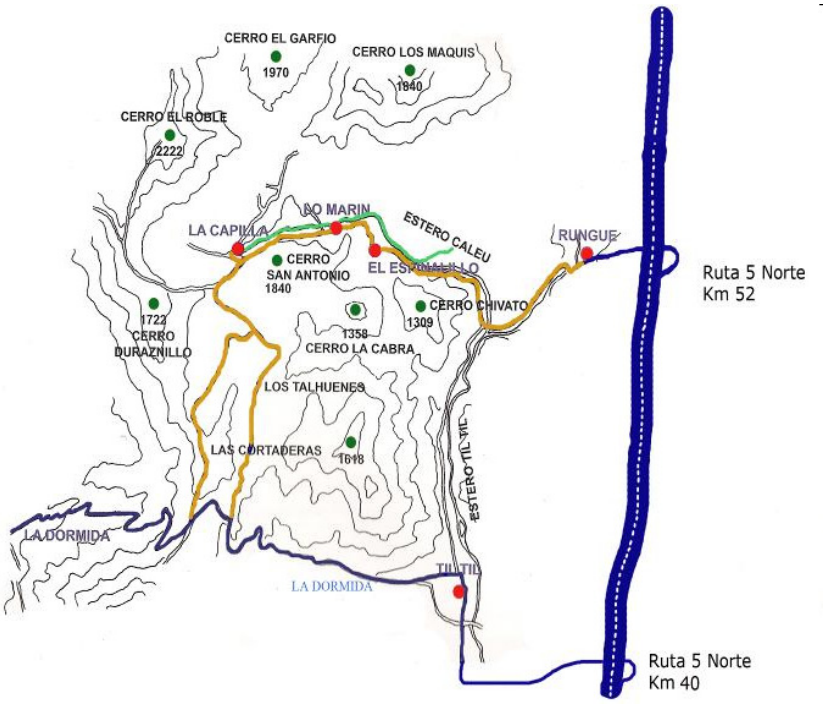

Figure 2.5. In this detailed map, it is shown the three villages of Caleu (La Capilla, Lo Marin and Espinalillo) and the proximity to the El Roble hill. (Source: accessed 5/13/2012 http://www4.biblioredes.cl/avalancha.cl).

An interesting characteristic of Caleu is that more than half of the houses in the locality are vacational homes. Of the total number of houses (316), only 154 are occupied all year (Fig. 2.6), and 189 are in use only during vacation times or weekends (Table 2.1).

Table 2.1. The villages, number of habitants, and number of houses in each village for the locality of Caleu are shown. Vacation-homes are 189 in the overall Caleu, no details available (Source: INE, 2010).

Locality	Village	Men	Women	Total habitants	Houses
Caleu	Espinalillo	39	32	71	65
Caleu	La Capilla	130	117	247	166
Caleu	Lo Marin	64	49	113	85
		233	**198**	**431**	**316**

Caleu has a communitarian organization that is very unusual and difficult to find elsewhere in the country, especially in the central and southern areas. In

this institutional organization, each person owns a ranch received by heritage and has rights to the common land with all its uses, habitats, and services. “La Agrupación de Comuneros La Capilla de Caleu” (the Association of the Owners of the Common Land “La Capilla” of Caleu) has the responsibility of managing this common land and also supporting culture and education in the community.

Figure 2.6. The main street in Lo Marin is shown.

The communitarian organization of Caleu that comes from the previous centuries when Caleu was an estancia. This kind of organization is very unusual and difficult to find, especially in the center or south of Chile. This type of organization is based on each person owning a ranch acquired through heritage (hijuela), along with the right to the common land for all its uses. This person is called a Comunero, which means “someone who owns right over a common land”. This common area should be managed in such a way that produces benefits for all in the community as it can be read in the Law Decree of 1936 (Moreira, 1999). In this Law Decree, there is a donation of more than 5,000 ha. to approximately 135 families for use as common land.

The Association of Comuneros La Capilla of Caleu (ACCC) is a long-standing organization created January 23, 1966. It is a nonprofit organization that

manages El Roble hill. This organization, despite its name, includes people from the villages of La Capilla, Lo Marin, and Espinalillo. The ACCC has the responsibility of managing the common land and encouraging culture and education in the community. In addition, it maintains medical services for the community, carries out economic initiatives, and helps to standardize the property deeds (Moreira, 1999).

2.6. Hill El Roble

Hill El Roble (elevation 2,222 m) is the highest peak of Chile's Coastal Mountain Range. The name of the hill comes from the high-elevation Santiago white oak species *Nothofagus macrocarpa*. Hill El Roble is the northernmost population of Santiago white oak in Chile. The western side of the hill belongs to the National Park La Campana. The hill cannot be sold or split, because it is common land belonging to the permanent residents of Caleu.

Figure 2.7. Cerro El Roble Nature Sanctuary.

Hill El Roble (Figure 2.5), next to the locality of Caleu, has an area of 998.6 ha. and an elevation ranging from 1450 m to 2222 m. It is situated in the

northwest of the Priority Area for Conservation, also called El Roble. At its peak, there is an *Entel* rebroadcasting antenna connected with the valley by a restricted access ferry cable cart. At the end of the valley is the Caleu stream, which is supplied by the different gullies emerging on the El Roble hill watershed. The Caleu stream runs into the valley towards the east, flowing to the basin of the Til-til stream (Moreira, 1999).

The more important characteristics of the El Roble hill are related to its vegetation, flora and fauna. The vegetation of El Roble hill is composed by Laurifolious forest (canelo, *Drimys winteri* – chequen, *Luma chequen*), sclerophyllous forest (quillay, *Quillaja saponaria* – litre, *Lithraea caustica*), sclerophyllous shrubland (romerillo *Baccharis linearis* and duraznillo, *Colliguaja integerrima* –guindillo, *Guindilia trinervis*), thorny shrubland of chagualillo, *Eryngium paniculatum* with Chilean Palm (*Jubaea chilensis*), and deciduous Santiago white oak forest (*Nothofagus macrocarpa*). The flora consists of 73 species, 10 of which are classified as vulnerable, one as rare, and one as endemic. The fauna of the area includes 75 species of birds, 22 species of mammals, 12 species of reptiles, and 6 species of amphibians (Donoso, 2007).

The flora of the area of Caleu, and in particular of El Roble hill, is very rich and biodiverse and many of the plants are endemic to Chile. This makes El Roble hill a unique place in Chile's Metropolitan Region because it is the only area containing the natural vegetation of central Chile. Among the trees are oaks, canelos (*Drimys winteri*), peumos (*Cryptocarya alba*), quillayes (*Quillaja saponaria*) and maitenes (*Maytenus boaria*). Among the scrubs, there are litre (*Lithraea caustica*), espino (*Acacia caven*), palhuen (*Adesmia confusa*), tralhuen (*Talguenea quinquinervia*), and romerillo (*Baccharis linearis*). Among the succulent plants of the dry, rocky areas are the columnar cactus (quiscos) and chaguales (*Puya alpestris*). Finally, among the evergreen herbs with beautiful flowers is macaya (*Placea ornata*), which lives above 1,000 meters and has white flowers with purple lines. Its range is limited to the three hills of El Roble, La Dormida and La Campana. The añañuca (*Rhodophiala tiltilensis*). which has

large, red flowers, is locally present over an extended area, but its range is still limited to the Caleu area (Donoso, 2007).

The El Roble hill is also important because it is the only area in Chile that has remnants of the oak and sclerophyllous forest from the central and northern regions of the country; moreover, due to the concentration of populated centers and the consequent human impact, the fauna in the Metropolitan Region is greatly deteriorated (Donoso, 2007).

Common private land at El Roble belongs to the people of Caleu (primarily the older people). In the past, there was considerable overexploitation of natural resources, including mining of gold and silver. It was because of the mining that in 1997 the ACCC, together with people from Santiago, who owned vacation homes in the area, requested that El Roble hill be classified as a Nature Sanctuary by the Minister of Education (MINEDUC). The request was granted and the sanctuary was created on June 27, 2000. In 2003, Corporacion Nacional Forestal (CONAF[5]) and Comision Nacional del Medio Ambiente (CONAMA[6]) initiated a project that in 2005, after 12 community-based workshops, produced the Participatory Management Plan.

Not all the Comuneros agreed with this petition. As a result, problems arose between the people who supported the Nature Sanctuary and those who wanted to keep El Roble hill as it was before and continue to use its ecosystem services (as defined in section 1.1.2). Before the establishment of the Nature Sanctuary, people used El Roble hill to extract a variety of resources ranging from Digüeñes (a kind of edible fungi) to snow (to sell and make ice cream). Since the area is now a Nature Sanctuary, it is prohibited to extract any ecosystem services from El Roble hill, and the only use allowed is recreational. Since 2005, many of the activities that previously were part of the residents' income and normal patterns of subsistence living have been prohibited. One of the many consequences is that people residing around El Roble hill want to

[5] CONAF: National Corporation of Forest (private-governmental organization)
[6] CONAMA: National Commission for the Environment.

increase tourism because they see it as a possible source of income that could offset the loss of resources provided by the ecosystems in the hill.

2.7. Diagnostic of the Status of the Santiago's White Oak Forest in El Roble

The genus *Nothofagus* has some of the biogeography element most characteristic to the forest in the southern area of the southern hemisphere. However, the El Roble hill is located at 33° 07' latitude S 71° 00' longitude W.

A study[7] of demographic characteristics of the *Nothofagus macrocarpa* on the El Roble hill, in 1982, showed that the growth rates are higher for the exposition W-SW, with more humidity, and lower elevation.

It also showed that an important proportion of the *Nothofagus macrocarpa* had been cut, producing new renewals, and the ages of those renewals were calculated. The distribution of ages histogram showed a distribution skewed to the right from the year 30 and on. This can be classified as a distribution of a population stationary state of development. Also, the authors highlighted the total absence of young individuals (<20 years) and the absolutely lack of renewals. The model developed by Golowash et al. (1982) shows us a forecast that the population could be in state of growth with no development.

The lack of new renewals of Santiago white oak in the El Roble hill could be an effect of multiple causes, among them: (1) climatic change; (2) indiscriminate cutting of trees; together with (3) mining exploitation and their consequences for the forest (Golowash et al., 1982).

The plants of this species are unable to develop under their own shadow; therefore, it is very significant that renewals were not found in the numerous opening areas due to human activities (Golowash et al., 1982). The cyclical distribution of age structure of the population of *Nothofagus macrocarpa* in the El Roble hill can be happening due to a pattern of cyclic "aridness" (Golowash et al., 1982).

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[7] Golowash et al. (1982).

2.8. Potential Ecosystem Services

A large number of ecosystem services are produced by El Roble hill. These can be related to the hill as a water supply, provider of other ecosystem services such as medicinal plants, timber, and firewood, or a source of recreation (Table 2.2 according to the Millennium Ecosystem Assessment categories for ecosystem services). These ecosystem services involve the whole spectrum of production and consumption for the natural area El Roble hill. However, the level of specification is more general, relative to those that are in direct use for the people in the El Roble hill.

Table 2.2. Potential Ecosystem Services for the El Roble hill based on MA, (2005) and De Groot et al (2002).

Ecosystem Services		
MA categories	Ecosystem Services identified using MA	Ecosystem Services identified using De Groot et al (2002)
Supportive	Soil formation Primary production	Net primary production Soil formation
Regulating	Water regulation Pollination	Water regulation Soil retention Nutrient regulation Pollination
Provisioning	Fresh Water Food Fuel wood Fiber Biochemicals Genetic resources	Water Supply Food Raw material Medicinal resources Genetic resources
Cultural	Recreation and ecotourism Aesthetic Educational Sense of place	Recreation Aesthetic Science and education Historic and spiritual information

2.9. References

Amigo J, Ramirez C. 1998. A bioclimatic classification of Chile: Woodland communities in temperate zone. Plant Ecology 136:9-26.

Armesto JJ, Arroyo MTK, Hinojosa LF. 2007. The Mediterranean Environment. In Veblen, Young, Orme, editors. The physical geography of South America. Oxford University Press. UK.

Arroyo MTK, Rozzi R, Simonetti JA, Salaberry M. 1999. Central Chile. in Mittermeier RA, Myers N, Mittermeier CG, editors. Hotspots. Earth's biologically riches and most endangered terrestrial Ecoregions. CEMEX. Mexico City. Pages 161-171.

Arroyo MTK, Cavierres L, Marticorena C, Muñoz-Schick. 1995. Convergence in the Mediterranean floras in central Chile and California: Insights from comparative biogeography, in Arroyo MTK, Zedler PH, Fox MD, editors. Ecology and Biogeography of Mediterranean Ecosystems in Chile, California and Australia. Springer-Verlag Press. New York. Pages:43-88

Bolund P, Hunhammar S. 1999. Ecosystem services in urban areas. Ecological Economics 29: 293-301.

Castri di F, Goodall DW, Specht RL. 1981. Ecosystems of the World 11. Mediterranean-type shrublands. Elsevier, Amsterdam.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature, Vol. 387: 253-260.

Daily GC, editor. 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press. Washington D.C.

Daly HE, Farley J. 2004. Ecological Economics: Principles and Applications. Island Press. Washington, D.C.

De Groot RS, Wilson MA, Boumans RMJ. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393-408.

Fuentes ER, Muñoz. 1995. The human role in changing landscapes in central Chile: Implications for intercontinental comparisons. In Ecology and Biogeography of Mediterranean Ecosystems in Chile, California, and Australia. MTK Arroyo, PH Zedler, and M D Fox, editors. Springer-Verlag, New York.

Golowash J, MK Arroyo, Villagran C, Armesto JJ. 1982. Características democráticas de una población de *Nothofagus oblique* (Mirb.) Blume Var. *Macrocarpa* DC. En el cerro el Roble (33° Lat. S) en Chile. Bol. Mus. Nac. Hist. Nat. Chile 39: 37-44.

INE, 2010. Instituto Nacional de Estadísticas, Chile. Required data online system. [Accessed on August, 2010 http://encina.ine.cl/suru].

Jaksic FM. 1997. Ecología de Vertebrados de Chile. Ediciones Universidad Católica de Chile. Santiago.

Klausmeyer KR, Shaw MR. 2009. Climate change, habitat loss, protected areas and the climate adaptation potential of species in Mediterranean ecosystems worldwide. PLoS ONE 4(7): e6392. DOI:10.1371/journal.pone.0006392

le Houerou HN. 1981. Impact of man and his animals on Mediterranean vegetation. Mediterranean-type shrublands. Di Castri F, Goodall DW, Specht RL, editors. Elsevier. Amsterdam. Pages: 479-521.

Noss, RF. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology. Volume 4, Issue 4 (December): 355–364. DOI: 10.1111/j.1523-1739.1990.tb00309.x

Paskoff R, Martinez H. 1999. Ecosystem and legal framework for coastal management in central Chile. Ocean and Coastal Management, 42: 105-117.

PASOLAC, (Programa para la Agricultura Sostenible en Laderas de América Central). 2000. Pago por Servicios Ambientales: conceptos y principios. Pérez AC, Barzev R, Herlant P, editores. Costa Rica.

Rivas-Martinez S. 1993. Bases para una nueva clasificación bioclimática de la Tierra. Folia Geobotanica Matritensis 10.

Rouget M, Richardson DDM, Cowling RM, Lloyd JW, Lombard AT. 2003. Current patterns of habitat transformation and future threats to biodiversity in terrestrial ecosystem of the Cape Floristic Region, South Africa. Biological Conservation. 112: 63-85.

Rundel, PW. 1981. The matorral zone of central Chile. Di Castri F, Goodall DW, Spencht RL, editors. Mediterranean-type shrublands. Elsevier. Amsterdam. Pages: 175-201.

Tansley AG. 1935. The use and abuse of vegetational concepts and terms. Ecology, Vol. 16, No. 3 (July):284-307.

Underwood EC, Viers JH, Klausmeyer KR, Cox RL, Shaw MR. 2009. Threats and biodiversity in the Mediterranean biome. Diversity and Distributions, (15): 188–197. DOI: 10.1111/j.1472-4642.2008.00518.x

Villagran C. 1995. Quaternary history of the Mediterranean vegetation of Chile. Arroyo MTK, Zedler PH, Fox MD, editors. Ecology and Biogeography of Mediterranean Ecosystems in Chile, California and Australia. Springer Verlag. Berlin. Pages: 3-20

Villagran C. 1990. Glacial climates and their effects on the history of vegetation of Chile. A synthesis based on palynological evidence from Isla De Chiloe. Review of Paleobotany and Palynology 65: 17-24.

3. CERRO EL ROBLE NATURE SANCTUARY: A POLITICAL ECOLOGY PERSPECTIVE

3.1. Introduction

This chapter examines the history of land use in Caleu, the social context in which the Cerro[8] El Roble Nature Sanctuary was created, and the effects of the conservation efforts on the residents of Caleu.

The main research questions addressed in this chapter are:

(1) How and why did the El Roble hill become a Nature Sanctuary?

(2) How did the creation of the Nature Sanctuary affect the residents of Caleu?
More specifically, what conflicts were generated, and did these conflicts affect the relationships between the long-time residents and relative newcomers to the community?

To answer these questions, I analyze data collected through qualitative interviews with full-time (permanent) and part-time (vacationing) residents of Caleu, as well as secondary sources. To interpret this data, I use concepts from the field of political ecology. First, I apply the conservation and control thesis (Robbins, 2004), which indicates that efforts of environmental conservation sometimes have pernicious side effects that can lead to an overall failure of the project. Second, I advance the environmental conflict thesis (Robbins, 2004), which states that environmental conflicts can often be generated by preexisting tensions and struggles along gender, class, and race lines.

[8] I called *El Roble hill*, when I address the hill called El Roble. When the El Roble hill became a Nature Sanctuary I called it *Cerro El Roble*, because that is the official name of the sanctuary.

I begin with a discussion of my theoretical framework and research methods. Then I discuss the history of the community of Caleu until the mid-20th century, followed by an analysis of the land conflict in Caleu that brought about the creation of the Nature Sanctuary Cerro El Roble. Finally, I offer an assessment of the Sanctuary's effects on the community.

3.2. Political Ecology of Nature Conservation

This chapter contributes to the social science literature that examines the political dynamics and social consequences of nature preserves. Theoretical insights from the field of political ecology are particularly relevant to the case of the Cerro El Roble Nature Sanctuary. Political ecology addresses the interactions and changes of the social and natural systems, with explicit consideration of relations of power. Following the political ecology hypothesis of Robbins (2004), environmental problems result from social inequalities that lead to an unequal distribution and control of natural resources. This perspective contrasts with explanations of the causes of environmental problems offered in areas like ecology or economics, which tend to look into explanations like (1) overpopulation and/or (2) not utilizing the right technology. Political ecology offers a critical perspective on nature conservation projects like the Cerro el Roble Nature Sanctuary by examining the social forces that lead to the creation of protected areas, such as natural sanctuaries, and by investigating the social consequences of particular conservation strategies.

What drives the creation of protected areas? As Molotoch, Hopkins and O'Neill explain (cited in Bates and Rudel, 2000), social elites generally shape the planning of land use. However, the process of creating a protected area is always triggered by a threat, even if the nation recognizes the importance of environmental protection. In the case of forest protection, these threats usually start with (1) a rapid and increasing deforestation rate, or (2) when countries have small amounts of forest or endangered species and there is the potential threat that one or more may disappear. Rapid deforestation, small amounts of

forest, or endangered species are used as tools by social movements to create political pressure in order to create protected areas. The majority of these threats come from companies, politicians, and landowners who look to extract natural resources and produce agricultural landscapes to create wealth (Bates and Rudel, 2000).

In the 1990s, conservation strategies came under scrutiny due to criticisms related to the social injustice that may be involved. Research on the social consequences of nature conservation and preservation projects indicates that such projects frequently deepen social inequalities by taking control of natural resources and ecosystem services away from long-time residents (McNeely and Miller, 1984; McNeely 1993; Adams and Hulme 2001; Adams and Hutton, 2007). There are two general approaches to biodiversity conservation through the creation of protected areas. On one side, *exclusionary* preservation of protected areas protects by restricting the human presence or use of the place, and, on the other side, *inclusionary* protected areas integrate human inhabitants of the forest into plans for reserve management. The exclusionary conservation and the inclusionary conservation approaches have been analyzed and contrasted with each other by activists and scientists. Most of the time, this analysis involves criticism of the exclusionary approach for its unequal and sometimes coercive methods of biodiversity conservation. The protection of these areas produces restrictions over the use of natural resources and ecosystem services from the forest. In most cases, this development cuts poor rural communities off from the ecosystem services of the area under protection (Bates and Rudel, 2000). In the long run, long-time local residents are left without the means to replace the income or subsidy that the ecosystem services were providing them. Critiques of conservation strategies formed the basis for two main perspectives in political ecology: the *conservation and control thesis* and the *environmental conflict thesis*, each summarized by Robbins (2004).

The *environmental conflict thesis* indicates that state authorities, private firms, and social elites have made natural resources increasingly scarce, through the enclosure or appropriation of land and other resources, and this has

increased the appearance of conflict between social groups (frequently along the lines of gender, class, or ethnicity). The environmental conflict thesis is based on three main observations. The first is that societies are marked by divisions of labor and differential access to productive resources. For this reason, the creation of protected areas brings different consequences to different groups, potentially creating conflicts and struggles. The second observation is that "property" is a complex group of rights that is historically contingent (Robbins, 2004). If there is a change in the property rights of a land, this will have as a consequence a change in ownership identity: some groups that held ownership in the past, may not feel the same respect and deference from the other groups as before.

Finally, the history of international development has been rooted in specific assumptions about class of the people affected by development strategies, often resulting in poorly produced policies with uneven results (Robbins, 2004). Assumptions about the local residents' outlook, behavior, and interests reflect the social imaginaries of the planners or social elites, which may include false assumptions that locals are greedy and ignorant people just because they are classified in poor or lower classes. Social conflict may develop with the creation of protected areas, due to changes in the structure of social systems, the change in ownership identity, and the false assumption that locals are greedy (because they keep using ecosystem services and natural resources at the cost to society and future generations) and ignorant (because they are considered to be poor or lower class).

The *conservation and control thesis* suggests that the implementation of preservation and conservation projects frequently takes control of natural resources and ecosystem services away from local producers. Robbins (2004) argues that control of resources, ecosystem services, and the landscape have been taken away from the locals who "produce" through the actions of preserving nature, without community participation, for the enjoyment of tourists ("consumers"). During this process, the attempt to preserve the environment had disabled local systems of livelihood, production, and in some cases also the

socio-political organization. Moreover, some studies (Ostrom, 1990; Sivaramakrishnan, 1998) demonstrated that where local production practices have historically been productive (and relatively benign in some cases), they have been characterized as unsustainable by state authorities and other players in the battle for controlling the ecosystems. Robbins (2004) summarizes four main critiques of conservation projects, which are the basic pillars supporting the conservation and control thesis.

First, Robbins (2004) indicates that conservation is frequently a form of hegemonic governmentality,[9] meaning that rule is self-imposed by individuals through social institutions that enforce rules (what people can or cannot do), norms, and expectations (what goals and behaviors are considered socially desirable), and aesthetics and ethics (what ecological results are appropriate). The history of conservation clearly has some elements of coercive statecraft, such as territorializing conservation space, and controlling surrounding communities is a basic and principal objective in the history of environmental conservation. The majority of the efforts are centered on extending the discretionary conservation power (of the state) by causing individuals and social groups to "internalize" the coercive actions of the government, creating self-enforcing coercion.

Second, Robbins (2004) argues that conservation projects can lead to the disintegration of the moral economy—the traditional environmental management strategies and rules that defined natural resource extraction without strong state intervention or individual property rights. The imposition of new conservation regimes tends to lead to violations of traditional constraints on ecosystem uses.

Third, Robbins (2004) critiques the built character of "natural wilderness." The idea of untouched and undisturbed nature has almost no empirical support in environmental history or in the contemporary world. However, this construct is usually used to move human communities out of the environmental history of a place, leaving it easier to produce a market for tourists.

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[9] The term "governmentality", coined by Foucault (1991), is used in Bryant (2002).

Fourth, Robbins (2004) observes that the territorialization and spatial bounding of conservation units into discrete, mappable units is problematic because bounded spaces and territories typical of contemporary conservation (like fenced polygons) do not match the ecosystem functions and materials and energy flows of the diverse natural elements. The development of a protected area involves the division of territory, landscape, resources, and ecosystem services. It also involves putting boundaries around those divisions and limiting the set of uses for the new protected area.

The environmental conflict thesis and the conservation and control thesis above presented are not only relevant, but also in the case of the community of Caleu, illustrate both theories very well. The first main question of this study (how and why did the El Roble hill become a Nature Sanctuary?) is explained by the conservation and control theory, and the second main group of questions (how did the creation of the Nature Sanctuary affect the residents of Caleu? What conflicts were generated? Did these conflicts affect the relationships between the long-time residents and relative newcomers to the community?) are explained by the environmental conflict theory.

3.3. Methodology

3.3.1. Gathering Data

The methodology used in this study consisted of interviews to members of the community and a focus group of assembled local residents to obtain basic information of their ecosystem services use. The first survey was used to measure changes in ecosystem services use before and after El Roble hill was designated a Nature Sanctuary. The methodology used was designed to address the research questions.

The field work was separated in 3 stages: (1) exploratory focus group; (2) surveys; and (3) in-depth interviews.

(1) Exploratory focus group. A focus group was developed to collect multiple viewpoints about the relationship of Caleu with the hill and how the

residents used it before and after the sanctuary was created. The focus group was conducted in a relaxed atmosphere and each person was able to voice her opinion. The focus group served to gather opinions regarding their use of the land before and after the creation of the Nature Sanctuary. The information obtained from the focus group was used to build a questionnaire incorporating the different activities that the people of Caleu used to do, or now do, on the hill.

The focus group was organized to coincide with the of the local women's "clay workshop", thus overcoming their resistance to participate in a time-consuming focus group. The participants were women from the three villages: La Capilla, Lo Marin and Espinalillo, representing wide range of age distribution. The questions asked were broad matters and open ended, with the goal of not influencing the respondents. For example: "Tell me about Caleu. What do people live from in Caleu? What kind of activities are most common and why?" Duration of the focus group was 38 minutes.

(2) The main survey and the complementary survey. The survey was applied across the community of Caleu. Its main objective was to understand the relationship between the people of Caleu and El Roble hill. People were asked how and how often they used hill before and after it was turned into a Nature Sanctuary. Residents were also asked about the importance and significance of the hill to them, along with other questions about level and quality of life of each household. The goal is to compare ecosystem use before and after the Nature Sanctuary was established and to learn how this change in usage had affected the income and / or quality of life of the people of Caleu.

A team was formed in order to carry out the surveys and prepared through a one hour long training session designed to explain the social and economic context of Caleu. Also, it was explained the way of life and general level of education of its population and, using a map, explained the geography and landscape of the locality. The team was paid per day of work (not per number of surveys completed), thus avoiding rushing to complete questionnaires or pressuring the interviewees for answers. The survey was taken over 5 days spread across two weeks to accommodate a holiday. The survey was conducted

first in La Capilla, then in Lo Marin, and finally in Espinalillo. On the last day, the team came back to go over non-respondents in all three places. There were 3 types of responses to the survey: (1) don't open the door (approximate 50-55 households), (2) open the door and don't want to do the survey (approximate 7-12 households), and (3) open the door and answer the survey (92 households).

Of the 316 houses in Caleu, 154 were occupied all year; 92 of those answered the survey. There was a percentage of people who refused to answer the survey likely because being an isolated and small rural community, and it seems they do not trust people from the capital city.

The complementary survey was carried out in the same fashion as the main survey (same team and same strategy of action).

(3) The in-depth interviews. The methodology used consisted of semi-structured interviews conducted by the researcher to obtain information from the local residents (newcomers and Calegüanos) about the recent history of Caleu and its conflicts. 25 interviews were conducted, their length ranging between 30 minutes and 3 hours, depending on the interviewee's answers. There was no time restriction for each interview; the interviewee could speak at length as much as she or he needed. Interviewees were contacted using the snowball method, having in the beginning only three or four contacts (key individuals in the community), who provided contact information of other high-profile[10] people in Caleu. Each interview was recorded using digital voice recorders and extensive notes were taken.

The snow-ball reference methodology allowed identification of high-profile individuals throughout the first 20th interviews; after that, the names referred by the interviewees started to repeat. The sample assembled was representative for the objective of the interviews: to collect the history of Caleu, its key actors, their activities and their interaction patterns with each other. A potential shortcoming of the process conducted is that the sample assembled (Table A, Appendix 4) was such that different groups had different relative sizes among

[10] High-profile is consider a person who, if Calegüano, plays an active role in the community politics or social events. If not Calegüano (Newcomer), then participates actively in social meetings and activities.

them; thus, the interviews were such that not all groups had the same size. Therefore, it is reasonable to suspect that smaller groups were underrepresented.

3.3.2. Analyzing Data

The analysis of the focus group data included the following processes: (1) transcription onto paper; (2) identifying changes in activities, behavior, and civility (conflicts and fights); and finally (3) identifying potential causes for the observed phenomena.

The survey responses were assembled in Excel Microsoft Office and then the statistical computations were made in R-Studio and STATA®.

The gathering and analysis of the data of the interviews included (1) digitally recording the interviews, (2) taking written notes of the most important topics covered during the interview and (3) transcribing into Microsoft Word documents the most important facts related to those relevant topics for each interview, including the timing of the information. The transcribed interviews were highlighted in those sections that contain the most relevant information for the purposes of this research.

3.3.3. Conceptualizing The Data

This study classified the residents into four separate groups:

(1) Newcomer no-Comuneros: People who bought parcelas without rights to the common land.

(2) Newcomer Comuneros: People who bought parcelas with rights to the common land.

(3) Long-time resident Comuneros: Calegüanos who have hijuelas and rights to the common land.

(4) Long-time resident no-Comuneros: Calegüanos who have parcelas and

do not have rights to the common land.

The fourth group is very small, does not have independent identity, and is important as a category but not as a social group. The first three groups and their relative influences are shown in Figure 3. Also, the local Comuneros can be further classified by their respective villages: the long-time residents of La Capilla, the long-time residents of Lo Marin, and the long-time residents of Espinalillo. Therefore, local Comuneros is a heterogeneous group, in contrast to the more homogeneous, in terms of education and wealth, newcomers groups.

3.4. Early History of Caleu

To understand the history of land use in Caleu, I interviewed several long-time residents and asked them to relate their knowledge of the history of their villages. I spoke to three residents whose families had been in Caleu since the time of Spanish conquest. Their oral histories are the basis of most of this section.

Around the middle of the 16th century, colonizers from Spain arrived in Chile. These Spanish colonizers divided the indigenous, Chilean native population through *encomiendas*[11], and they divided up the Chilean land for themselves —sending commodities such as gold, slaves, and agricultural products back to the Spanish crown. The governors and the *cabildo*[12] gave away huge extensions of land with unclear boundaries, which eventually turned into *estancias*[13]. In the coastal mountain range in the central zone of Chile, there were some very important estancias, for example, Til-Til, Las Palmas, San Pedro, and El Almendral. In addition, the estancia of Caleu eventually became what is now known as the locality of Caleu (Moreira, 1999).

The relevance of those estancias rested in the gold, silver, and copper mines that were in the area. In fact, each estancia owner was given the title “High Major of Mines.” They supervised the extraction of the minerals for the Spanish

[11] Encomienda: a type of slavery that the Spanish people “encomenderos” have with the indigenous people.
[12] Town Council
[13] Estancia: is a Spanish term describing a large rural land with similarities to the English term ranch.

crown. The crown could change the ownership of those estancias if the current owners were not exploiting the land to the satisfaction of the crown. After their extraction, the raw materials were transported to Spain.

In 1724, Captain Salvador de Leyba and Mr. Francisco Hidalgo and his parents and grandparents got the rights to the land called Garfio and the estancia of Caleu:

> "As owners for decades of the pasture, hillocks and mountainous areas that make up the hill [mountain] called Garfias as accessory to the estancia of Caleu, to Capitan Salvador de Leyba and Don Francisco Hidalgo and their parents and their grandparents"[14]

In this settlement and the surrounding territories, there were gold mines. Due to this gold, there was constantly infighting among the owners of the estancias who wanted to take ownership of these lucrative mines. Around 1750, Miguel Allende and Francisco Astorga got a mining concession in Caleu. They worked there, became rich, and brought in more miners and started a community in the valley of Caleu (Moreira, 1999).

In 1803, there were already problems and legal disputes between the Astorga family and the Leyba family about the village of Caleu. The village's growth was due mainly to the attraction of the chapel, which was built at the beginning of 1600. Even today, the main locality of Caleu is called La Capilla ("the chapel") (Moreira, 1999).

During the independence war in the 19th century, the mining activities were greatly reduced. After the defeat of the Spanish army in the Chacabuco battle, some soldiers escaped to the coastal mountain range seeking safety from the Chilean army and a better life. One of those places was Caleu (Moreira, 1999).

Since 1900, Calegüanos (or people from Caleu) have made their living from the extraction of natural resources. During all this time, there have been

[14] Own Translation, Archivo de la Real Audiencia año 1724 No 3565, volumen 2313 (Cited in Barahona et at. 2004).

many ecosystem services[15] used by the community. Several of the Calegüanos I interviewed –Ms. G, Long-time Resident Comunero (6/28/11); Mr. I, Long-time Resident Comunero (6/30/11); Mr. K, Long-time Resident Comunero (7/04/11)-- said that the most relevant ecosystem service was the production and extraction of ice during the winter in order to sell it to nearby localities during the summer. Three other important activities that had a high impact on the forests of Caleu, especially surrounding the El Roble hill, were the extraction of timber and firewood, and the production of charcoal, mainly from white oak trees. Also, there were other ecosystem services with less impact for the ecosystem, such as hunting rabbits, collecting mushrooms, and extraction of medicinal plants, Ms. F, Newcomer Comunera (6/28/11)[16] and Mr. E, Long-time Resident Comunero (6/27/11)[17].

> The first three families who arrived to Caleu were the Astorga, the Leyba and the Allende; my family was one of them. In the beginning of the 1900s, the main activities were producing charcoal and some people had fruit trees. Mr. J, Newcomer Comunero (7/04/11).

Eventually, people started to move from some of these activities to other tasks that paid better and were less physically demanding, for example, growing fruit trees on their hijuelas. Later on, and mainly due to agricultural infestations, many Calegüanos again changed how they made their living by becoming

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[15] Ecosystem services are the services to humans that are produced by nature through ecosystem functions like primary productivity or microclimatic regulation. As we will see in detail in chapter 4.

[16] "The activity of men in Caleu always was extractive and very intense with a huge degradation, when Caleu was formed was because mine activities… After the independence in the battle of Chacabuco, the Spanish people hided here… The land here is really bad quality, it is classified as category 6 or 7, only for forestry proposes, and therefore the agriculture is only for survival. There were only pear trees, and some apple trees, but that was it. This happen around 1940s and 1950s. Before 1940, there was the snow-based ice-producing activities, during 1900s until 1930s. The people made ice on the hill and they brought it down on mules to the train station of Llay-Llay… It was a very hard and sacrificed work, the people usually got sick in the knees and bones because the cold, making the ice… Also, the activities of producing charcoal and extracting firewood was very intense and very exploitative… There were more than 100 burners (hornillas) to produce white oak charcoal…"

[17] "Because we are here in Espinalillo, we are far away from the El Roble hill, therefore we don't use it as the people of Lo Marin and La Capilla do. But all of us: La Capilla, Lo Marin, and Espinalillo, used to use 'the paths' (trails) to going to the Fifth Region, especially by horse, or to go to use the paths to bring the cows. The only resources that existed here were firewood and charcoal, even more, there were used for livelihood. The life was very hard…There was some raising of cows, but there were exploitation because there were survival needs, but every locality used their closed hills, therefore there was not overexploitation".

pirquineros (a pirquinero is generally an independent, artisanal "micro-miner", who extracts very small daily amounts of minerals).

> There was always mining on a microscale, pirquineros. There used to be lots of gold here. Still there are mines of copper in Caleu – there are 2 mines currently working—but not in El Roble hill, in La Cabra hill or El Chivato hill. In El Roble hill used to be a mine called Los Cristales, it was closed, the owner was Mr. Quijano, but it was closed after the hill became a Nature Sanctuary, but always there were micro-miners (pirquineros). Mr. B, Newcomer Comunero, (6/21/11).
>
> …The mine activities were not very successful either, there were always attempts of micro-mining; however, the veins are really small… there were only pirquineros in groups of 3 or 4 persons... Ms. F, Newcomer Comunera (6/28/11).

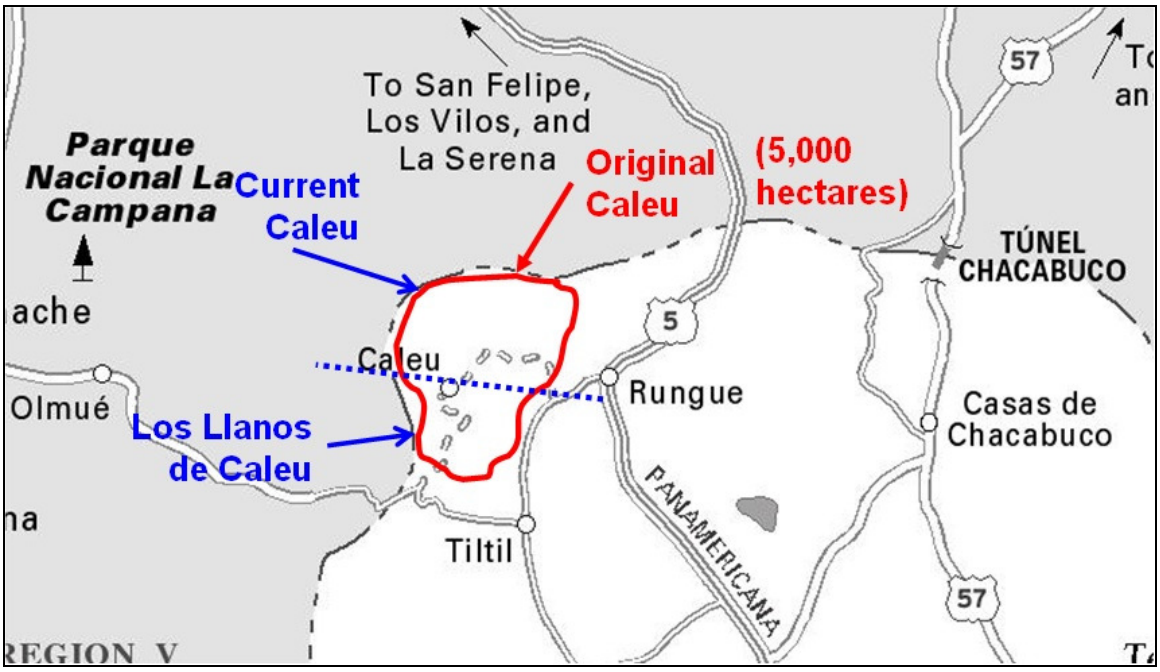

Figure 3.1. It shown in red the approximate limits of the original Caleu, which was divided into two localities: Caleu (which includes La Capilla, Lo Marin and Espinalillo) and Los Llanos de Caleu (a separate locality). In Blue, the approximate limits where these two localities were divided. (Source: accessed on 5/13/2012 http://www.moon.com/files/map-images/chl_01_Santiago-and-Vicinity.jpg).

3.5. Common Land in Caleu

Today, there are two types of land in Caleu. The private land is divided into hijuelas or *parcelas*[18], where Calegüanos and Newcomers have their houses. Also, there is a common land, which belongs to all the people who inherit it or the people who bought rights to the common land when they bought their parcelas. This common land is ruled by the Comuneros[19] through ACCC[20]. This institution has a directive that rules and organizes all the matters related to the common land in Caleu. But, due to the political isolation of Caleu for such a long time, this association also rules over the *neighbors meeting* in La Capilla, Lo Marin, and Espinalillo —the neighbors meetings are the most basic political institution in Chile.

> The Comuneros Association of Caleu has as principal goal management of the common land of 3,500 hectares… The neighbors meeting takes care of the issues of the parcelas, and private land[21]. Mr. B, Newcomer Comunero (6/21/11)

These land tenure arrangements originated in 1935, when the government ruled by President Carlos Ibañez del Campo legally gave 5,000 hectares[22] of land to the families who lived there for several generations. To do this, they needed to legalize their land title deeds. Unfortunately, the people did not follow the proper paperwork, so, in 1956 the government intervened and ultimately divided Caleu into two separate communities: Caleu[23] and El Llano de Caleu. The latter community, El Llano de Caleu, turned into a different community with their own directive and their own common land, while Caleu's 125 families held rights to their *hijuelas*[24] and to 3,500 hectares of common land. Due to isolation

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[18] Parcela: Small portion of land that has been purchased, expropriated or awarded.
[19] Comunero: person who owns the common land existent in the community by heritage and have right to use it.
[20] Association of Caleu (also known as Comuneros Association of La Capilla of Caleu).
[21] When Mr. B said "…and the private land" he refers to the common land, which is private because it belong to the comuneros only.
[22] One hectare corresponds to 10,000 square meters or 107,640 Square Feet.
[23] From this point in the dissertation, when I use the word "Caleu," I am specifically referring to the "new" Caleu that was formed after the 1956 split.
[24] Hijuela: A large farm in a rural area that is created by the division of a bigger piece of inheritable land.

from the central government in Santiago, most of the 125 families in Caleu once again did not complete the paperwork process to legalize their properties and their rights to the common land. As of this writing, there are still families in Caleu that have not signed the legal paperwork. Mr. B[25], Newcomer Comunero (6/21/11) and Ms. F[26], Newcomer Comunera (6/28/11).

> In 1967, it was formed the Association of Comuneros of Caleu to organize the land better, because in 1935 were given 'the hills' for be registered by "Tierras y Colonizacion"[27] . However, in 1935 the people did not complete the paperwork, and in 1957 –if I am not remembering it wrong—the Government took the land back from 'particular' persons and gave it back to the community for themselves to organize it, and in 1967 it was formed the Association Capilla de Caleu… The Llanos de Caleu is today a different association, but before it was everything together (all Caleu)… because The Llanos de Caleu were separated because there was a hill in between both communities. So, the Association of la Capilla de Caleu was given 3,500 hectares, while to the Association of the Llanos de Caleu was given 2,500 hectares, the total given was around 6,000 hectares. Mr. E, Long-time Resident Comunero, (6/27/11).

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[25] "In 1935 Caleu was formalized, in the government of Carlos Ibañez del Campo gave this territory to the Comuneros who lived in that time, there were approximate 152 families… and Carlos Ibañez del Campo said 'I will give you 5,000 hectares and the limits will be where delimiting the waters'. With time, this got smaller… Now there are only 3,500 hectares".

[26] "In 1935, the common land was in the hands of the Fisco (the Treasury), and only the parcelas were given to the people. The community complained, so the Fisco gave the common land to the same people who got the parcelas, then the Government asked them to register in the Conservador de Bienes Raices (Institution that belongs to Bienes Nacionales, "National Goods"), but the people did not do the paperwork. So in 1957 was given officially the common land to the same people of 1935 and the heirs of the people who died, and then was registered in the Conservador de Bienes Raices the common land for approximate 160 persons, heirs and 3 institutions —The Church, the Policy and the Cemetery of Caleu— …and the problem was that heirs still not keep doing the effective possession…"

[27] The old name for "National Goods" (Bienes Nacionales): the Government organization that takes care of legalizing the goods, for example land, apartments or houses.

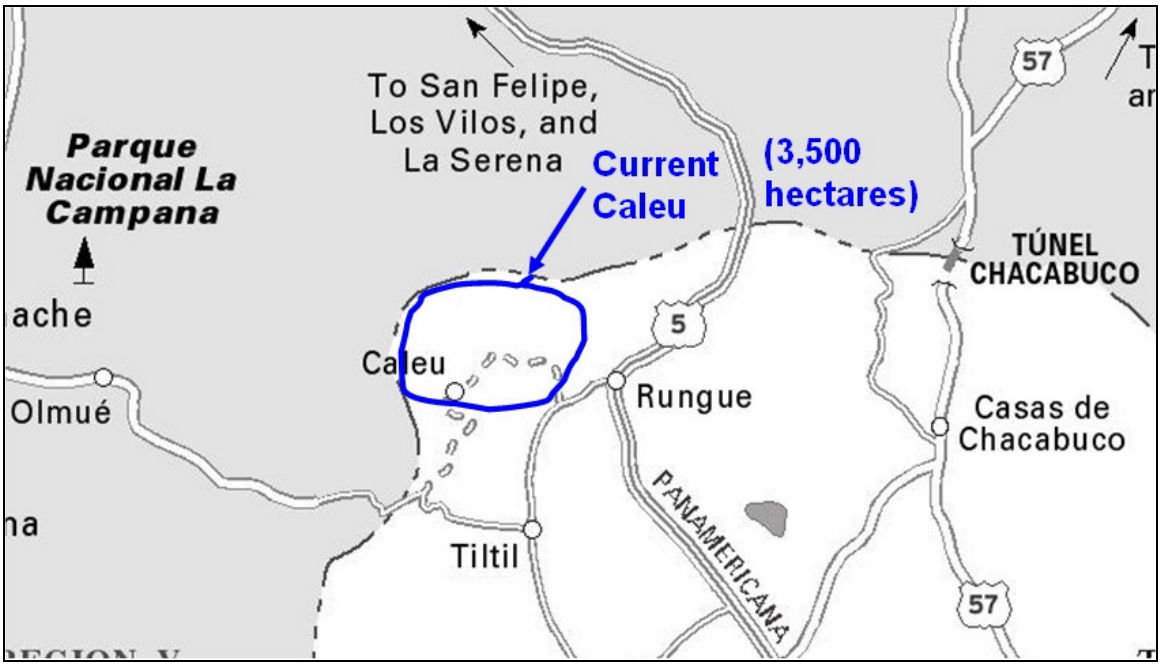

Figure 3.2. It shown in blue the current Caleu locality, which include the villages of La Capilla, Lo Marin and Espinalillo. (Source: accessed on 5/13/2012 http://www.moon.com/files/map-images/chl_01_Santiago-and-Vicinity.jpg).

3.6. Newcomers to Caleu

During the economic crisis and the political repression of the 1980s, some of the Calegüanos were forced, due to lack of money, to begin a process of dividing their hijuelas into parcelas ranging from 0.5 to approximately six hectares. They sold this land to wealthy people from Santiago and other places. These "Newcomers" were looking for a quiet place to stay during the summer and weekends. With the arrival of the Newcomers to Caleu, the Calegüanos' way of life changed forever.

Due to their previous isolation, Calegüanos were not used to dealing with an urban, more educated, wealthier, and more powerful people. Because of that, even if the Newcomers were recognized to have land in Caleu (parcelas), they were not recognized to have rights to the common land by the people from Caleu. Therefore, they were not recognized as Comuneros.

> The Association has the responsibility to take care of the common land and the Nature Sanctuary and also to take care of the health and education of the Comuneros… There are approximately 280

> members of the Association… There are three categories of members, 'active member', who has voice, vote, and the right to belong to the directory, but s/he needs to be Comunero, that is the requirement, only the heirs are legitimate owners of the common land. The owners of parcelas, who arrive in Caleu and buy a piece of land, they can be only 'cooperative members', who only have voice. The third category is the honorary member, who gave relevant services to the Association, and has only voice. Mr. P, Long-time Resident Comunero, (7/11/11).

When the Newcomers wanted to participate in the directive of the ACCC —because Newcomers purchased parcelas with rights to the common land— lots of distrust arose from the Calegüanos towards the Newcomers. The Calegüanos believed at the beginning that the Newcomers wanted to take control over the association. While there is no proof for that claim, it is clear that the Newcomers wanted to participate actively in the most important political institution of the whole area.

> …They bought the parcelas with rights to the common land…the buyers, outsiders [Newcomers] were against asphalting the roads, they were against new things, new technology… Always it had has a very distinguished mark among the natives (Calegüanos Comuneros), the descendents of the original community with the people who arrived later, the buyers of properties, and for different reasons they turned into Comuneros. It is very, very big the difference between these two groups because in that time, the Association was directed by the Newcomers Comuneros and not the Comuneros by heritage… Also, the problem of the road, the local people wanted the road to be paved, but the Newcomers did not want asphalt and they were opposed. This conflict lasted at least 8 months, but everything vanished with the fraud of the real state agency. The newcomers were against the development because that meant that more people would come to Caleu and

> they wanted the peace and tranquility of Caleu. Mr. D, Newcomer No-Comunero (6/22/11).
>
> With the arrival of the buyers [Newcomers], Caleu has lost lots of tradition, customs, the respect of the water schedule use… The Newcomers Comuneros have been getting into the Association, they did not manage water in the most correct way. Parcela owners and residents are getting inside the Association of Comuneros often… Mr. L, Long-time Resident, Comunero, living in Santiago, (7/05/11).

During the 1980s and also at the beginning of 1990s more and more newcomers came to Caleu to buy a piece of land and build a house for weekend and summer use. Because of this, more and more Calegüanos started to work for them in construction (building houses, swimming pools, etc.) or as guards for protecting the property when the owners were not there, or as gardeners or cleaning women. At the end of the 1990s, this type of work was the most common in Caleu.

> There were changes in the social aspect: the inequality found a place to stay because now, there are two different social classes very differentiated, Calegüanos and the Newcomers… and the Newcomers are from a higher economic level and that produced inequality in Caleu… Mr. M, Newcomer, No-Comunero (7/11/11).
>
> Here all the people work by seasons, they clean parcelas, maintain gardens, they are construction workers, watchmen of vacational parcelas, but all the jobs are for a season, there are not stable jobs, those are the only entrance because the fruits do not sell… usually is lost. Ms. N, Long-time resident Comunera, (7/21/11).
>
> Almost everyone from Caleu used to lived from the El Roble hill, now they are parcela-workers, although some are pensioned… Ms. C, Long-time resident Comunera, (6/22/11).

3.7. Creation of the Nature Sanctuary

Efforts to create a Nature Sanctuary in Caleu began in response to the efforts of a lawyer called Hector Morales to obtain land in the community. Morales[28] took interest in the informal situation of the ownership of the land in Caleu. At this point the story is unclear[29], how he managed to have the total trust of some of the Calegüanos, to make them sign blank papers, in order to inscribe those lands in their names. What the Calegüanos did not know is that he was inscribing those lands on his own name.

> Hector Morales Espinoza inscribed all the hills of Caleu (3,500 hectares), he did contact with Comuneros of Lo Marin, and he offered things to people to steal the Rights to the common land, if they had willingness to give him a small piece of land, he looked for how to cheat to people in Caleu… We got an injunction to stop the taking of land by Hector 'The Tick' Morales, who already had registered to take rights "for possession", he had already begin the process. The Civil Court of Colina was formed in Caleu. And that interviewed around 30 people and issued arrest warrants for the two lawyers of Hector Morales and himself. Mr. E, Long-time Resident Comunero, (6/27/11).
>
> The assignation of the common land was a year after the formal assignation of their hijuelas and parcelas from the government, but not all the people did register their lands, the government office never gave the deed. In 1957, the government gave the deed to the Calegüanos who still were alive and to their heirs in the other case. However, no one of them registered the land (effective possession)

[28] Nickname: El Garrapata ("The Tick").
[29] I could not get any answer about this point from long-time residents; newcomers did not know how this happened.

when the old Comuneros died. Ms. F[30], Newcomer Comunera, (6/28/11).

When these actions took a more nefarious direction, the newcomers did notice what was happening and organized themselves to help. And they did help. They stopped Morales in the very end of the process in National Goods (Bienes Nacionales), the institution which legalizes the real state assets (like land, houses, apartments, etc.) in Chile. The process to stop him was long and tedious. This group of newcomers obtained in Santiago the legal resolution (Decreto Ley, DL) that rules the organization and allocation of land in Caleu and they did the necessary paperwork in order that DL was taken into account.

> In 1993, 'The Tick' requested the change of administrative status of Caleu community, (trying to enforce law decree DL15, to single out communities throughout Chile). [Because of that] it was request [by the social elite] to solve that the Ministry of National Goods, and the Minister gives the response that it cannot be changed the status of the community and Caleu because this was created by Decree 1502 of 3 July 1935…During 1936 the Decree of common land of 1935 is corrected… [Nevertheless] "The tick" present himself as president of the Lo Marin Community in process of creation… it is presented a document by "the tick" saying 'The undersigned Comuneros of Marin request to form the community of The Marin', but the document did not have any signature at all. The request was accepted without any signature. In top of that, the letter to 'Contraloria General de la Republica' with impugnation an administrative fault was made using the wrong format… 'Contraloria General de la Republica' sent in 1995 a letter saying that it is rejected the request done by Hector Morales. Due to the

[30] During the 1980s, Hector Morales Espinosa had 10 possessions effective to name a few heirs and left the rest of the family with nothing, then bought land returned to them at ridiculous prices or simply not paid. Then he created the 'Real Estate The Oak', (buying and selling subdivisions), along with several Calegüanos who put their right they had to the common to its contribution to the estate, with the ultimate aim of the common field was divided, parceled and sold. It was then that the concern of the sanctuary began from part of the social elite of Caleu, the Calegüanos never had the idea to make a sanctuary.

> DL153 of 1932 and some other articles of civil code. A lawyer from Ministry of National Good who needed to make an inform to 'Contraloria General de la Republica', and this office gave us [to the Newcomers] the reason that the community cannot be divided. Because this fact Hector Morales was infuriated by this fact. Ms. R, Newcomer Comunera (7/25/11).

When Hector Morales knew what happened, he tried something unexpected. He tried the same strategy to obtain, illegally, the common land of the Calegüanos. In order to do this, he created a different Comuneros Association in the locality of Lo Marin, expecting that it would give him the rights over the El Roble hill and in this way be able to divide that land into parcelas, sell them and obtain economic gains from it.

> Hector Morales was making sign blank documents to an important group of illiterate Calegüanos [due to the lack of officially registration of the land]…There are several corrections of the Decree between 1935 and 1957. Only some people registered in the 'Conservador de Bienes Raíces'. Ms. R, Newcomer, Comunera (7/25/11).

Once again, a small and well-organized group of newcomers tried to stop him, this time in the General Comptroller Office of the Republic (Contraloria General de la Republica), because given the Decreto Ley[31] (DL) 1502 of July 3 of 1935, it was forbidden by law to divide the community of Caleu into its localities: La Capilla, Lo Marin and Espinalillo. Therefore, the new association was illegal. This documentation was presented to the General Comptroller Office of the Republic which sided in favor of the position of the newcomers.

> The common land was not register either in 'Conservador de Bienes Raíces' in 1957, together with those heirs also are buyers registered. Legally is owner of a land who have registered that land, it can be by heritage or through a purchase. And it is a mistake the

[31] Decreto Ley is a normative with status of law, created by the President or executive power without intervention or previous approval of the Parlament or Congress.

> Calegüanos do not let us participate in the ACCC. Ms. R, Newcomer Comunera (7/25/11).

This group of newcomers was very worried about other people trying to take over by force the common land and the hill with it; divided it to make their own parcelas, or take it over by any other means and then sell the land. Also, around the same time, a man named Mr Quijano began attempts to extract mineral resources in the hill.

> The mine 'The Crystals' owned by Mr. Quijano was closed, because it was in the hill, it was closed after it turned into a Nature Sanctuary. They wanted to re-open but it was already Cerro El Roble Nature Sanctuary. They were only pirquineros. Mr. B, Newcomer Comunero, (6/21/11).

Mr. Quijano thought there was gold and copper in the hill, and he tried to excavate it for some time bringing some heavy machinery, which eroded and degraded part of the hill.

In response to both of these threats, a group of newcomers to Caleu decided to organize themselves. They met in Santiago and hired a group of lawyers in order to present a petition to the Education Ministry to make El Roble hill a Nature Sanctuary, protected by legislation from being threatened again by people who only wanted to take advantage of the legal status of the land. This petition was supported by Ricardo Lagos, one of the vacation-home-owners and a powerful politician who in March of 2000 became President of the Republic. The government authorities helped in the process and in a very short period of time, in year 2000, the El Roble hill was turned into a Nature Sanctuary thus joining another 39 areas along the country that had this status already. The Nature Sanctuary status is a protection category given by Decreto Exento[32] (DE) 229 of the Ministry of Education, because of the hill's unique flora and vegetation. The Cerro El Roble Nature Sanctuary is situated between Til-Til and Llay-Llay at

[32] Decreto Exento is a Supreme Decree, a type of administrative action that usually comes from the executive. A Presidential or Supreme Decree has a statutory regulatory content, making it less than a law hierarchically. Also, it is not under the control of General Finance Office of the Republic (Contraloría General de la República).

kilometer 61 of Route 5 North. The petition was accepted, the hill became a Nature Sanctuary, and the owners that used to use ecosystem services from the area were incapacitated to develop any activity other than recreation, which created a socio-environmental conflict among groups (D.E. 229).

Newcomers led the effort to create the Nature Sanctuary, leaving long-time residents uninformed about the process. The newcomers group, who were mobilized, had the goal to "save" the El Roble hill from people. The Capilla's local people did not have too much information about what was happening; because of that, they did not take actions. The Lo Marin's local people were convinced that Hector Morales wanted the best for them and actually wanted to help him. And Espinalillo's people are geographically farther away from the hill and from the other two localities, and therefore they did not have an important role in the conflict.

> There was a Mr. Morales who wanted to take all the hill for himself, and he made a real state institution, this arrived to ears of the President of the Republic of that time, and he helped with the bureaucracy and paperwork for the creation of the sanctuary. Mr. B, Newcomer Comunero, (6/21/11).
>
> There was a crazy person [Hector Morales] who divided the common land and we noticed after the paperwork was already in the Ministry of National Goods… In one office of that institution told me that everything is done, and there is not much to do about it… We did derogate the decree to divide the community… Hector Morales lost the subdivision of the land, but he managed to keep one property… that finally ended up selling it. Mr. I, Long-time Resident Comunero, (6/30/11).

This process increased tensions between newcomers and long-time residents. Since the 1990s, all types of residents of Caleu have experienced conflict over the use of natural resources. In this case, newcomers have more economic power and more political power at the nation-state level (bureaucrats) and long-time residents have only more political power in the Association of

Comuneros. This produces tension between newcomers and long-time residents. This tension is possible to observe, as the conservation and control theory (Robbins, 2004), as explained in the literature review above.

> I participate in the meetings… but there were lots of people [Calegüanos] there that were not in agreement [with the Sanctuary] because they were getting a supply of the humus from the forest, they were not in agreement because those were incomes they had… Even making charcoal in the properties was also forbidden… there was a small group of Comuneros that were not in agreement with the Sanctuary…it was just at the same time, that in this period there were many people from outside [of Caleu], then they mobilized connections because they are influential people… Those influential people mobilized and acted over the Comuneros to make the sanctuary… this is the conflict between the Calegüanos and the Newcomers, and it was never solved…people with political power walked over the Comuneros. Ms. C, Long-time Resident Comunera (6/22/11).

> The elderly people were more affected by the creation of the sanctuary. The elder people felt no respect towards them… Mr. K, Long-time Resident Comunero, (7/04/11).

> When a group of Comuneros newcomers attempted to make the Sanctuary, there were lots of people who opposed to it, because they could not use the hill anymore… Mr. D, Newcomer No-Comunero (6/22/11).

However, a part of the population in Caleu still kept using some ecosystem services of the El Roble hill in order to extract a variety of basic elements to survive such as firewood, rabbits, timber, and medicinal plants (see chapter 4).

> …rabbit hunting is forbidden inside the predios[33], because when you fire a gun you can cause damage in the rubber hose for irrigation, that is why fire gun was forbidden… However, there is hunting with lasso (snare), the resources are used not only for Comuneros but also they are used for people who are not Comuneros. Mr. B, Newcomer Comunero, (6/21/11).

There was a extreme confusion among the long-time residents comuneros, about El Roble hill turned in a sanctuary and the funding for project that the Newcomers were carrying on for the Cerro El Roble Nature Sanctuary.

> …with the money of the project paid by the government were built two representation offices of the Association of Comuneros in Lo Marin and Espinalillo. And, there were installed plasma TVs he bought heaters for the people, and other things like that… residents assign to the newcomers the change in status of the sanctuary, but it begun by actions of CONAMA… Mr. M, Newcomer No-Comunero (7/11/11).

And this confusion and misinformation turned into confrontational opinions among the groups in the community of Caleu.

> They must be not very happy with us, but we are who give them jobs and who solve the problems here. Ms. R, Newcomer Comunera, (7/25/11).

The steps of the social process occurred in Caleu from the point where there were conflicts over the land until the point where there were social impacts that produced changes in social relations can be explained in eight steps:

(1) The process of turning the hill into a Nature Sanctuary, led by elite Newcomers, was done mainly to deny Mr. Morales and Mr. Quijano further opportunity to take over the land and natural resources of the hill, as Mr. E (6/27/11), Mr. W (8/09/11) and Ms. R (7/25/11) said.

[33] Piece of land, could be a parcela or a hijuela.

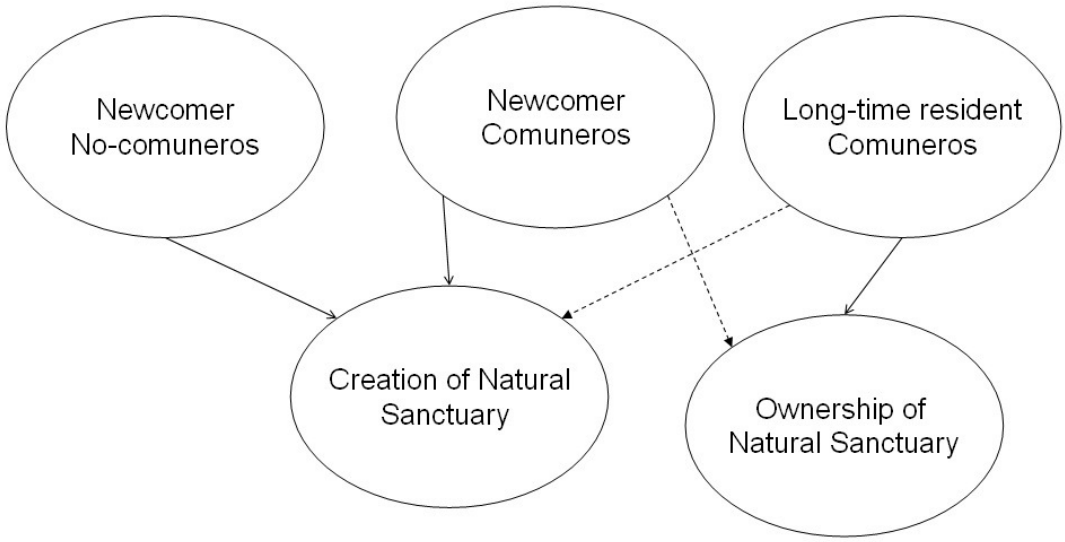

Figure 3.3. Model of the relationships among the three main socio-political groups in Caleu. The full arrows represent strong influence while dotted arrow represent weak influence.

Because of this, the Newcomers kept the process mostly as a secret from the locals, thus preventing them from informing the other parties. This secret maneuvering diminished the possibility of any form of legal action designed to stop the process of turning the hill into a Nature Sanctuary. This is the description of the process of the sanctuary's formation, which most of the Newcomers interviewed explicitly told me or implied during the interviews.

(2) For the long-time residents, the process of knowing, understanding, and behaving according to the rules of the new Nature Sanctuary, starts when the Nature Sanctuary is approved by the Comuneros Association of Caleu in a meeting that –one of the interviewees said—had no more than 20-30 Comuneros present.

(3) Over the course of the months after the establishment of the Nature Sanctuary, people overheard rumors and became interested in attending the monthly meetings of the Comuneros Association of Caleu, where they became aware that El Roble hill had become Cerro El Roble Nature Sanctuary.

(4) Long-time Residents have the right to be Comuneros because they are heirs of long-time Calegüanos, however many of them are not registered in the association and do not pay the fee; therefore, they are not officially considered Comuneros who have voice and vote in the meetings. These people gained

knowledge of the change in status of the hill to Nature Sanctuary by street rumors instead of an official statement or meeting. This explains why some people surveyed indicated different years for the official change in status of the hill, ranging from 1998 to 2006. This discrepancy shows confusion due to lack of transparency in the information given to the majority of the long-time residents of Caleu.

> Lots of people felt walked over when the Cerro El Roble Nature Sanctuary was imposed to us, the people did not understand what was happening until CONAF[34] arrived to Caleu. There were so many people angry with what happened: the ones who cut and collect firewood, the ones who took rock for construction, among others. Approximately 70 to 80% of them fell in isolation from the Participatory management plan, because they were against it… the management plan was made more with residents than Comuneros Calegüanos because they isolated themselves. But the residents and Newcomers were in agreement and participated… there were no voting or election neither public debate or organized complains, the conflict still is not solved. Ms. F, Newcomer Comunera, (6/28/11).

(5) Upon becoming aware of the law creating the Nature Sanctuary, residents stopped using the ecosystem services[35] of El Roble hill. The reason why they stopped using these services is unclear since there is no record of anyone getting a fee/ticket or being arrested by the police for infringement. Therefore, it is complex to state that they were afraid of constraints imposed by the law, or concerned of the social stigma.

> Comuneros used to participate sometimes in the meetings of ACCC, the older Comuneros and the Newcomers. Some people owning parcelas used to participate in the meetings, but everyone

[34] CONAF, Corporacion Nacional Forestal, Board of National Forest. The government office in charge of the public protected areas like National Parks, or Natural Reserves, among others. (which manage the SNASPE, State Public Protected Areas in Chile).
[35] See Chapter 4.

needed to comply with the change because it is said it was voted in the ACCC Assembly. Ms. O Long-time Resident Comunera, (7/21/11).

(6) The creation of the Nature Sanctuary put social pressure on the locals in the villages that compose Caleu. They seem to have developed new social norms of behavior even among those not afraid of social stigma. Some locals stated in the data collected in the surveys that some of them still collect, mostly at night, a minimum amount of humus and mushrooms, a behavior resulting from social penalties and stigma.

(7) Changes in behavior resulting from changes in the law or the perceived social stigma triggered changes in the activities supporting the livelihood of the residents. Most of the old people –as stated in the survey— asked for government pensions. People who did not qualify for welfare benefits or were not old enough, turned to the Newcomers for jobs. This made many locals financially dependent on the Newcomers.

> "The people earned their money here in Caleu working in parcelas of Newcomers. As subordinated employers, gardener, worker, everything. Clean, irrigate, maintain the place… and they pay the minimum salary. This is the only thing that left, but the young people study and leave. Ms. O, Long-time Resident Comunera (7/21/11)
>
> The people of Caleu constitute an extremely poor community with many unmet basic needs, the Nature Sanctuary was thought of as an input of economic resources for the people… There is an imbalance in the wealth, and the poorer are the Calegüanos, especially elder people, who will not be able to get the benefits of the hill. Mr. E, Long-time Resident Comunero (6/27/11).

(8) The dependency that the change in activities to survive produced, also affected the way social groups related to each other and modifying social relations in Caleu. This is appreciated in the bad impression that Newcomers have of the Long-time residents:

> "The persons of Caleu are really primitive people, in the sense that they do not manage concepts the way the rest of Chilean society manages them. For example they do not have clarity about the concept of environment, and they do not have clarity about the current concept of nature. For them the hill is only a source of economic resources… We need to take into account that Caleu today is not an isolated locality, as was completely isolated for many years –centuries—, it was really difficult to get there… also Caleu was not completely incorporated into the country until the 1900s because it was not connected to the rest of the country, even the Church had not presence in the place… Mr. M, Newcomer No-Comunero, (7/11/11).

The Locals distrust and share the bad opinion of the Newcomers:

> Before we could cut dried branches (and the white oak was pruned); now, the oaks do not have strength for producing Digueñes[36]… all the young people emigrate from here… now they are job-workers (before we did not have bosses because there were sales) now there are more than 100 parcelas of vacation homes. Ms. O, Long-time Resident Comunera (7/21/11).

The community stopped using the hill (supported by survey results on chapter 4). However, it is not possible to know if this behavior was enforced by the social stigma or they actually internalized the idea of conservation of the oak white forest in El Roble hill.

In summary, the creation of the Nature Sanctuary was a non-democratic process, fewer than 30 Comuneros of the Comuneros Association of Caleu were informed of its creation, a small fraction of the estimated 200 or more active members. During the process, there was an intentionally restricted and confusing flow of information controlled by the social elite, starting from the official process and throughout the posterior years. This information restriction was justified by

[36] A type of edible mushroom that only grows in white oak forest.

the Newcomers because of the need to keep Hector Morales unaware of the strategy[37]. The resulting social impact affected most of the Long-time Residents, leaving them with a feeling of social injustice, paralyzing any actions in response given that the Residents perceived that everything was already done, and there were no means to go back to the old ways of doing things.

> They never asked to me if I wanted the hill in our common land turned into a Nature Sanctuary, and I am not in agreement with that decision… Lots of people in Caleu felt they were walked over… Ms. F, Newcomer Comunera, (6/28/11).

A few years after the creation of the Nature Sanctuary, there was a government (CONAF) attempt to empower the long-time residents to improve their role in the management of the Nature Sanctuary. The one-year long workshop, for approximately 30 people once a month, also attempted to shift power back to the locals. During the workshop, experts talked about protected areas, ecology, management and their relationship with the community. However, this attempt failed, mainly due to the distrust and feeling of injustice among the long-time residents. The ultimate goal was empowering the residents with knowledge for managing the Nature Sanctuary in an environmentally and economically sustainable way. This goal failed because long-time residents distrusted outsiders and did not share the same approach to managing the Nature Sanctuary. The newcomers perceived the Calegüanos as not being capable of considering the facts surrounding ecosystem services over an extended timescale, meaningful to the long lasting potential of the sanctuary for tourism purposes.

3.8. Discussion: Political Ecology of Caleu

The recent history of Caleu tells us about a community composed of three villages that lived over many decades from the land in a hunting-gathering like social and economic structure, politically isolated from governmental institutions

[37] Interview with Ms. R, Newcomer Comunero, (7/25/11).

in Santiago. During the 1980s, in part due to changes in the political and economic rules of the country, long-time resident Comuneros in Caleu started to sell part of their hijuelas to generate some income; the newcomers began to open Caleu politically and economically. The new openness produced several conflicts with some outsiders who wanted to take advantage of the land situation in Caleu, and triggered conflicts over land ownership. Finally, the only solution that the social elite was able to come up with was to pursue a transformation of part of the common land of the El Roble hill into a Nature Sanctuary in order to stop the frauds that some outsiders were trying to perpetrate. This change in the status of the hill deeply impacted the community of Caleu and their way of living.

These findings, in the context of the literature review, show how typical is this conflict between proponents of protected area versus locals; and explains why it is that it has generated such an extensive literature on the subject.

However, I could not find a single piece of research where a situation like that of Caleu was presented; that is a case in which the locals are not displaced, but still remain as owners of their land, without the rights to use it for consumptive ecosystem services, and yet, they still have the responsibility of taking care of the Nature Sanctuary.

Another angle of the same problem is that the protected area was not pushed by the government or international environmental organizations, but by the local social elite. This also produced a change in the social structure of the whole community.

Research literature shows there are three main factors that shape the way protected areas and its conflicts are created and solved. These are ecological, political and economic factors (Bates and Rudel, 2000). Ecological conditions in Caleu's case are represented by the deterioration of the forest on the mountain due to over-exploitation of ecosystem services with one important endangered species, the white oak. The Political factor is represented in the reasons why some people asked to have El Roble hill protected, and in the resistance of the long-term land owners to lose rights of use of the ecosystem services of the hill. The economic factor is represented by the well-being and

income lost by the land owners, who, as a result of the creation of the sanctuary, can no longer use it for economic activities.

Bates and Rudel's (2000) theory, discussed in the literature review, states that social movement pressure for establishment of protected areas is mainly done through the political strength, gained for some groups, that comes from perceiving threats to the wilderness. Often, these threats are originated by companies, politicians and landowners who look to extract natural resources and produce agricultural landscapes to create wealth.

The case of Caleu and Cerro El Roble Nature Sanctuary differs from this theoretical framework in that the creation of the protected area was first initiated in response to a threat to wilderness from a fraudulent lawyer trying to misappropriate lands, and not from threats initiated by politicians, companies or landowners. However, the first facilitating condition of the theory, the imminent threat to the forest that mobilizes activists to protect it followed by the creation of a sanctuary, did develop in Caleu when the average literacy and educational level of the population increased because of the arrival of the educated newcomers. The second facilitating condition of the theory does not exist, because it involves the need for the government to create a budget for administering the new park, and because in the Cerro El Roble Nature Sanctuary the land is private, this condition is not met.

In creating the Nature Sanctuary, the control of the El Roble hill was partially taken away from the Calegüanos. Prior to creating the Nature Sanctuary, the long-time residents produced goods for living through actions that did not protect the forest and the hill. However, during the process of making the hill a Nature Sanctuary, the social elite in Caleu, disrupted the local system of livelihood, production and socio-political organization.

Several additional concepts from political ecology are important to the case of the Cerro El Roble Nature Sanctuary. First is the concept of coercion (ability to persuade an unwilling person to do something by using force or threats) to enforce rules, norms, and expectations; however, coercion is understood to extend beyond simply enforcing conservation rules. Efforts center

on extending the discretionary conservation power (of the state) –in the particular case of Caleu, the discretionary conservation power of the social elite of Caleu— by hypothetically causing individuals and social groups to “internalize” the coercive missions of the social elite, creating self-enforcing coercion.

Additionally important is the concept of a moral economy. The traditional environmental management in Caleu, prior to the creation of Cerro El Roble Nature Sanctuary, was based on extraction of natural resources and ecosystem services as described in chapter 4. However, it seems even if there was not over exploitation, neither there was in place a management system to take care of the forest. With the integration of social capital, the various flows of materials and energy in ecosystems and the access to resources and ecosystem services of the hill changed. This disruption is the result of policy changes, like turning the hill into a Nature Sanctuary. This change in the environmental policy, applied to the El Roble hill, can lead to a breach of the traditional constraints on exploiting ecosystem services.

All the facts and analysis stated above, can be understood, as if coercive actions were taken towards territorializing conservation in the hill and controlling the surrounding community, not by the state, but by the social elite. These efforts attempt to expand the conservation power by making Calegüanos internalize (in a relaxed notion of the concept) coercive actions making them self-enforcing coercion towards the use of ecosystem services. This means that hypothetically Calegüanos are “internalizing” the notion that they cannot use anymore the ecosystem services of the hill, even if they still have rights over those lands, but more evidence is needed for support this statement.

When we observe the El Roble hill, we can see the characteristic nature of Mediterranean forest of white oaks giving refuge to an important number of birds and lizards, among other endemic animals. However, these forested lands and the complexity of the wilderness are not isolated; the hill is next to Caleu valley, where 3 villages are positioned: La Capilla, Lo Marin and Espinalillo.

The idea of a Nature Sanctuary involves the character of “wilderness”. The social elite and government wanted to impose an ideal on the Calegüanos, that

of the wilderness entailed in the white oak tree forest of El Roble hill. The question of "what is it that we want to conserve?" was formulated and answered by the social elite as that of a wilderness area that needs protection for purposes of restoration and conservation.

The social elite thought that because of the damage resulting from constant interaction with people, "the forest needed to be restored". However, the idea of an unperturbed land does not exist in reality. Therefore, the idea of an untouched white oak forest for the enjoyment of tourists exists only in the collective imaginary of the social elite of Caleu, the government, and other social elites who helped to transform the hill into Cerro El Roble Nature Sanctuary. As a consequence, Long-time Residents were separated from their forest and forced to see it as a wilderness, changing the way that Calegüanos interact with the hill[38].

The territorialization of the protected areas, like the forest in the El Roble hill turned into Cerro El Roble Nature Sanctuary is a discrete and mappable unit composed of 998.1 hectares. This process presents us with the problem that this type of practice is in disagreement with how nature, how ecosystem functions and how materials and energy flows work. There is a hidden social impact, because one more time, people are restrained not only in the use, but also in the way they see Nature surrounding them, and thus changing the way they see themselves and the identity of Caleu.

The creation of the Cerro El Roble Nature Sanctuary changed the structure of the social system, from two independent groups: Long-time Residents and Newcomers, each having their own structure and circle of individuals, to a relationship of dependency between them. The Long-time Residents turned into servants for the Newcomers[39].

Also, there was a change in the ownership identity, because even if they are still owners of the land of the Nature Sanctuary, they cannot use it, except for

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[38] From the main contrast in the interviews of Long-time Residents Comuneros and Newcomers (especially the social elite).
[39] See previous quotations of Ms. O (7/21/11).

recreational purposes. The restrictions over the use of the ecosystem services of the El Roble hill changed the type of livelihood of the long-time resident Comuneros in Caleu from nature-dependency to a wage labor-dependency on the Newcomers. This had as consequences, conflicts over the two social groups in Caleu, changing the social order in which these groups interact and relate to each other, and producing a break in the already delicate balance of powers in the locality. This is shown in Figure 3.4.

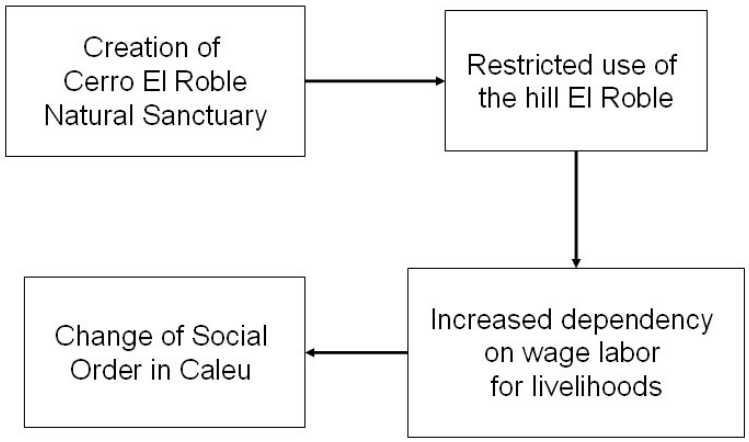


Figure 3.4. Shows the causality relationships between the creation of the Nature Sanctuary and the change in the Social order in Caleu.

The Long-time Residents had an identity as Comuneros and heirs of this common land over the decades. This can be seen especially in the interviews with the most elders of them. However, as Mr. I, Mr. K, Mr. P and Mr. Q emphasized, Long-time Residents do not feel the same way (with respect to the way they relate to the Newcomers) after the social elite –mainly from Santiago— changed the rights-to-use that the Long-time Resident Comuneros had over their own land. This impacted so deeply the way Long-time Resident Comuneros see themselves that changed their ownership identity, this means they still have the ownership of the common land that now is Cerro El Roble Nature Sanctuary, however they do not feel that the land belongs to them anymore. This somehow changed how these Long-time Resident Comuneros see themselves and the outlook for their own future generations.

The belief of the Newcomers that Long-time Resident Comuneros are people who do not care for their environment, for the land on the hill and for the forest is possible to argue as a false assumption, because it is possible to extract from the interviews with Mr. I, Mr. L and Mr. E that Long-time Residents (Comuneros or not) have concerns and somehow look after the forest and the hill, since for many decades that land was their source of ecosystem services and natural resources and thus they were committed to preserving it.

They might be more accurately accused of ignorance about some specifics of how the white oak forest works and its capacity for regeneration. Because it is possible to see in the interviews with Mr. I and Mr. K, that Long-time Resident Comuneros do care about the forest. However, they apparently do not share the “green” or “environmentalist” point of view of the Santiago social elite, of not being able to use some of those resources and ecosystem services at all.

The creation of the Cerro El Roble Nature Sanctuary also changed the social identities of the Long-time Resident Comuneros, especially in regard to job issues since the Long-time Residents moved from being hunters (mainly of rabbits), gatherers (of timber, firewood, mushrooms, medicinal plants among others) and farmers (of fruit trees, goats, cows), to being domestic employees, nannies, construction workers or gardeners working in the houses of the newcomers for a monthly salary.

The Long-time Resident Comuneros had a close relation to the land and to the hill in their ways of living which only depended on climate changes and other natural occurrences. Now, on the other hand, their connection with the land has been cut off and they now have an strong dependence with the willingness of the Newcomers for giving them jobs and for payment they receive –as the survey point out some Comuneros who work as a keeper of the parcelas of the Newcomers– receive an amazingly low salary for their services.

3.9. Conclusions

The conclusions of the study have shown that:

(1) Closed and isolated communities usually confront conflicts when they open politically and economically to the rest of the society.

(2) The case of Caleu shows how political and economic allocation of resources can result in an imbalance in the small communities, when they were isolated at length and social elites incorporate to them.

(3) The outsiders exerted political and economic power at the nation-state level, despite and against the preferences of Long-time Residents, who used the hill as a source of ecosystem services and natural resources.

(4) A profound implication is the fact that in the current times, even if the Long-time Resident Comuneros have the ownership of the common land, including the almost 1,000 hectares of the Nature Sanctuary, they actually depend more on paid salaries for work in the houses of the Newcomers.

3.10. References

Adams WM, Hulme D. 2001. Conservations and communities: changing narratives, policies and practices in African conservation. In African Wildlife and Livelihoods: The promise and performance of Community Conservation. Hulme D, Murphree M, editors. James Currey. London. Pages: 9-23.

Adams WM, Hutton J. 2007. People, parks and poverty: political ecology and biodiversity conservation. Conservation and Society Vol. 5 No. 2:147-183.

Barahona Meneses M, Hidalgo Ahumanda M, Vicencio Salinas M. 2004. Caleu. Tierra Amada. PRODEMU. Chile.

Bates D, Rudel TK. 2000. The political ecology of conserving Tropical Rain forest: a cross-national analysis. Society & Natural Resources: An International Journal Volume 13, Issue 7. Pages: 619-634.

Borgerhoff Mulder M, Coppolillo P. 2005. Conservation. Linking Ecology, Economics and Culture. Princeton University Press. Princeton.

Brosious JP, Tsing AL, Zerner C, editors. 2005. Communities and Conservation. Histories and politics of Community-Based natural resource Management. Altamira Press. Lanham, Maryland, USA.

Bryant RL. 2002. Non-governmental organizations and governmentality: 'consuming' biodiversity and indigenous people in the Philippines. Political Studies 50 (2): 268-292.

Robbins P. 2004. Political Ecology. Critical Introductions to Geography. Blackwell Publishing. UK.

McNeely JA, Miller RK, editors. 1984. National Parks Conservation and Development: The role of protected areas in Sustaining Society. Smithsonian Institute Press, Washington DC.

McNeely JA. 1993. Economic incentives for conserving biodiversity: Lessons from Africa. Ambio 22: 144-150.

Moreira Muñoz A. 1999. Caleu y el Cerro El Roble. Guia de Campo. CONAMA-FONDART. Chile.

Neumann RP. 1992. Political ecology of wildlife conservation in the Mt. Meru area of northeast Tanzania. Land Degradation & Rehabilitation 3(2): 85-98.

Ostrom E. 1990. Governing the Commons: The Evolution of institutions for Collective Action. Cambridge University Press.

Stevens S, editor. 1997. In conservation though cultural survival. Indigenous peoples and protected areas. The Guilford Press. Island Press. Washington D.C.

Sivaramakrishnan K. 1998. Comanaged forest in west Bengal: historical perspectives on community and control. Journal of Sustainable Forestry 7 (3/4): 23-49.

Whitesell E A. 1996. Local struggles over rain-forest conservation in Alaska and Amazonia. The Geographical Review 86(3): 414-436.

Zimmerer KS, Bassett TJ, editors. 2003. Political Ecology. An Integrative Approach to Geography and Environment-Development Studies. The Guilford Press. New York.

4. CHANGES IN THE USE OF ECOSYSTEM SERVICES IN THE HILL EL ROBLE IN CALEU, CHILE

4.1. Introduction

The functioning of ecosystems support all life on Earth, and provides services that sustain human's social and economic subsystems (Daly and Farley 2004). Ecosystem services could vary over a very broad range from the 'preservation of soil' that enables local agriculture to 'global-scale carbon sequestration' that controls greenhouse gasses. The growing pressure on ecosystem services from human population growth, expanding land use, and climate change is becoming of utmost importance, not only for the natural world but also for the continued viability of human society.

The Millennium Ecosystem Assessment (MA, 2005) recently documented the growing impact of human activities on ecosystem services. Of the 24 services measured, 14 are in decline and just four are increasing. Exacerbating this trend is the current deterioration of biodiversity. The degradation of ecosystem services and the associated loss of species diversity continue partly because both ecosystems and species are not adequately valued by economic markets. Ecosystem services fall into the category of public goods and therefore it is difficult to establish private prices for them. Ecosystem services are also affected by negative externalities not internalized in the production process. The adequate assessment of ecosystem services requires going beyond standard economic concepts and tools of valuation, and employs a holistic assessment of the economic, social, and biophysical measures of ecosystem services.

This study identifies the ecosystem services provided by El Roble hill (white oak hill), to the community of Caleu, Chile. The economic activities in Caleu are mainly stockbreeding and goat breeding, along with production of fruits. For many generations, another important and underappreciated

contribution to the local economy has been the utilization of ecosystem services provided by the El Roble hill and the surrounding area.

This chapter examines how the establishment of the Cerro El Roble Nature Sanctuary affected the use of ecosystem services by the people of Caleu. The research objective is to compare the use of ecosystem services before and after the establishment of the El Roble hill as a sanctuary, with the aim of understanding how a change in an environmental policy –the change in the status of a hill– affects a whole community in unanticipated ways.

4.2. Ecosystems and Ecosystem Services

Ecosystems can be defined as the joint product of biotic and abiotic elements and the complex relationships among them. The first definition in the literature was in 1935, when Tansley defined an ecosystem as the whole system –in a physics sense– including the organism-complex, as same as the total complex of physical factors which shape the environment of the biome (Tansley, 1935). Within any ecosystem (Figure 4.1), there is a constant flow of energy and nutrients between the organic and inorganic components. Because of this, ecosystems are the basic functional units of Nature. Over the years, the ecosystem concept has continued to be refined, but the basic concept of ecosystems as complex systems of relationships between living organisms and non-living physical elements has been maintained.

Noss (1990) described ecosystems as being a component of biodiversity having three basic attributes –composition, structure and function. Composition is related to the identity and variety of elements in a collection, and can include both species and genetic diversity. Structure is the pattern and physical organization of a system, which can include the physiognomy of vegetation, food web structure, and the spatial distribution of patches and other elements in the landscape. Function, on the other hand, involves ecological and evolutionary processes, such as energy and gene flow or nutrient cycling.

Scientific understanding of how ecosystems function is still in its early

stages and many gaps remain. One recent development is our understanding of the importance of ecosystem functions to human well-being. Ecosystems, through their complex functions, interactions and flows, produce ecosystem services. These services are emergent properties of the healthy functioning of ecosystems in nature. Ecosystem services have the potential to be used directly by humans for their own welfare (PASOLAC, 2000), or they provide benefits to human populations that arise directly or indirectly from ecosystem functions (Costanza et al, 1997; Bolund and Hunhammar, 1999). De Groot et al. (2002) defined ecosystem function as "the ability of components and natural processes to provide goods and services that meet human needs, directly or indirectly."

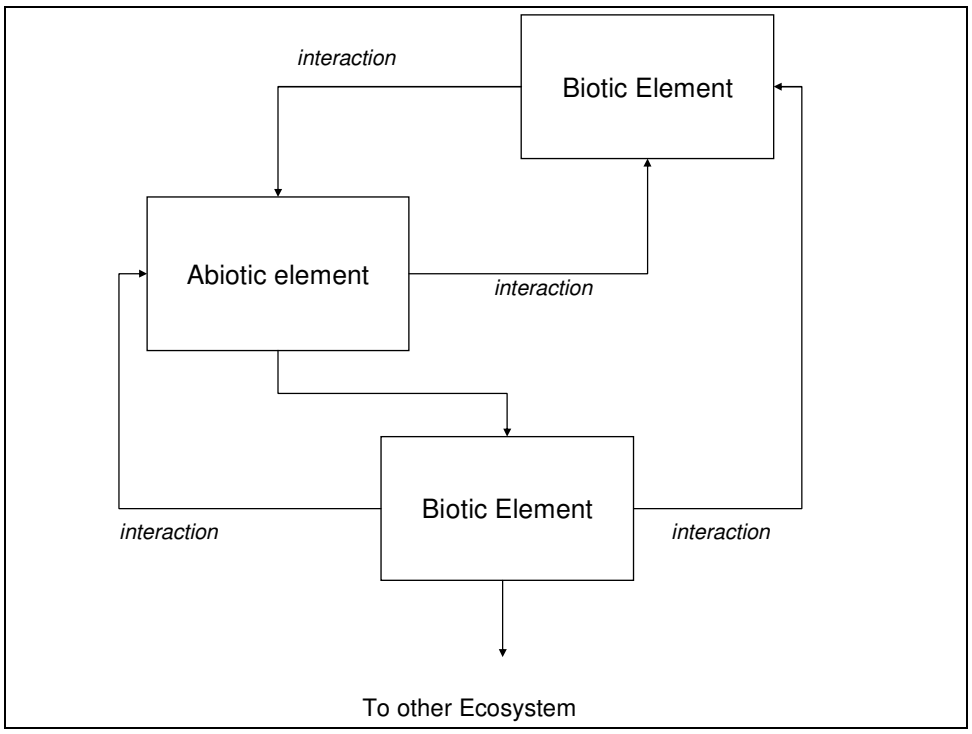


Figure 4.1. **The conceptualization of a model of an ecosystem.**

These functions become services when human values are involved. Thus, the concept of goods or services derived from ecosystems is inherently anthropocentric. Daly and Farley (2004) define ecosystem services as an ecosystem function that has value to humans. For Daily (1997), ecosystem services are the conditions and process through which natural ecosystems, and the species that make them up, sustain and fulfill human life. All these definitions

coincide in that ecosystem services are fundamental to supporting life on earth as well as the human social subsystem, including the economy.

The most ambitious attempt to date to assess the contributions of the natural world to human well being is the Millennium Ecosystem Assessment (MA) project (2005). In the MA the term "services" include tangible, as well as intangible, benefits for humans, which are sometimes called goods and services. In this study, ecosystem services include all goods, services and cultural values related to ecosystems. The MA classifies ecosystem services as provisioning, regulating, cultural, and supporting services (MA, 2005).

Table 4.1. Four types of ecosystem services integrated in MA framework (definition and examples included).

Type of service	Definition	Examples
Provisioning services	Products obtained from ecosystem	Food and fiber, fuel, genetic resources, biochemical, natural medicines and pharmaceuticals, ornamental resources and fresh water
Regulating services	Benefits obtained from the regulation of ecosystem process	Air quality maintenance, climate regulation, water regulation, erosion control, water purification and waste treatment, regulation of human disease, biological control, pollination, and storm protection
Cultural services	The non-material benefits people get from ecosystems though spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences	Cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism
Supporting services	Necessary for the production of all other ecosystem services. Their impacts on people are indirect or it is produced over very long periods of time.	Primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling and provisioning of habitat

The Millennium Ecosystem Assessment identified five key components of human well-being: needs for a good life, freedom and choice, health, good social relations, and personal security. Ecosystems are essential for human well being

through all of the services (Table 4.1). Ecosystem services have a strong impact on human well-being, based on the use of services to improve basic needs such as happiness, comfort, safety, and health. In this regard, some ecosystem services are similar to traded economic services in the market, like the ones everyone uses and pays the cost of. This connection between markets and ecosystem is further explored in section 4.5 below.

4.3. Why are Ecosystems Important?

Ecosystems through their complex functions produce ecosystem services; they are defined from the ecosystem functions that occur in the systems of nature. These functions have potential uses by humans. The possibilities or the potential to be used by humans for their own welfare. are ecosystem services and can be classified in a functional way, using categories of provisioning, regulating, cultural, and supporting services. (MA, 2005)

- Provisioning services are the products obtained from ecosystem and include: food and fiber; fuel; genetic resources; biochemical, natural medicines and pharmaceuticals; ornamental resources; and fresh water.
- Regulating services are benefits obtained from the regulation of ecosystem processes, including: air quality maintenance; climate regulation; water regulation; erosion control; water purification and waste treatment; regulation of human disease; biological control; pollination; and storm protection.
- Cultural services are non-material benefits that people get from ecosystems though spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. These services include cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism.
- Supporting services: are those that are necessary for the production of all other ecosystem services. Their impact on people are indirect or produced

over very long periods of time. They include primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling and provisioning of habitat.

The ecosystem services mentioned above have a strong relationship with the human well-being, and this was highlighted by the Millennium Ecosystem Assessment, through the five key components of human well-being, they are needs for a good life, freedom and choice, health, good social relations, and personal security. Human beings' quality of life can be improved by sustainable human interaction with nature with the support of appropriate instruments, institutions, organizations and technology.

4.4. Ecosystem Services are Under Critical Threat

The Economics of Ecosystems and Biodiversity (TEEB, 2008) project there is a diagnosis of the relationship between ecosystems and human welfare. At the core of this relationship is the fundamental necessity of healthy ecosystems for the growing population, consumption and production taking place around the globe. The resulting pressures on terrestrial and marine ecosystems are triggering rapid and non-linear changes and consequent critical transitions into less desirable state. Some of the greatest pressures arise for the growing demand for food, for biofuels, because of the increasing prices of food and energy. As a consequence, there is a rising demand for convert natural ecosystems into farmlands. However, humans have already converted 80% of the Earth's usable surface area to farm land or living space. At the same time, overexploitation of fisheries is occurring in every marine habitat on the planet. Recent estimates indicate that 80% of the world's fisheries have either collapsed or are in danger of collapse (TEEB, 2008).

The most delicate issue today is the supply of fresh water, because to the normal pressure of population grow, now is also being added climate change, which could accentuate water supply problems around the world including availability of fresh water in quantity and quality. Human health also is

increasingly at risk mainly because of disappearance of the biodiversity of plants around the world, which are the most important source of new medicines. The International Union for the Conservation of Nature (IUCN) estimates that 70% of all plants on the planet are in danger of extinction, together with 25% of mammals, 12% of birds, 30% of amphibians and 5% of reptiles (IUCN, 2010).

Gowdy (2009) states that “a consensus exist among conservation biologists that the earth is experiencing a loss of biodiversity on the scale of five major extinction episodes during the past 600 millions years of complex life on earth. It is not exaggeration to say that human activity within the past one hundred years has drastically altered the course of biological evolution”.

At present, ecosystems services and the future of human welfare on earth are facing five common challenges: (1) accelerating biodiversity loss; (2) incomplete knowledge and understanding of the scope and magnitude of the situation; (3) a decreasing time frame for action; (4) small changes in far away places can have enormous impact on the other side of the world; (5) the growing human population which in terms of its ecological footprint already needs 1.2 planets to support its activities, and by 2050 it will need the equivalent of 2 Earths; and (6) the fact that the poorest populations are going to suffer the most for our collective assault on ecosystem and their services.

The future of human civilization is dependent on maintaining in operational ecosystems and their services. However, our economic system was built on the false assumption that natural resources are essentially infinite. As a result, ecosystem services have being historically undervalued in the markets and traditional accounting systems.

4.5. Ecosystem Services are Undervalued by Markets

Ecosystem services have no active markets and no price, which results in no value in public policy decisions. The reasons explaining why ecosystem services not having prices are several and different depending on the specific service. The most common reason is that the ecosystem services are produced by nature as

a public common goods. Public common goods have two main characteristics: (1) they are “not-exclusive”, that is anyone can use them without paying regardless of ultimate or hidden costs; and (2) they are “non-rival”, that is the use by one person does not affect another person’s use.

Public goods can lead in the long run to the “tragedy of the commons”, referred to as such because, given a finite open resource –like most of the ecosystem services– providing open access to the resource creates an incentive for each individual to exploit the resource as quickly as possible before someone else can profit from it. Hardin's Tragedy of the Commons model predicts the eventual overexploitation or degradation of all natural resources (ecosystem services) used in common. However, his theory lack of all the complexity of social and political context plus the environmental conditions, factors which can produce very different results from the one Hardin predicts.

Hardin’s tragedy of the commons is typical when the ecosystem services are partially public goods, are not exclusive but are rival goods, therefore these services can be exhausted by the overuse. These situations are usually fixed by assignment of property rights over the resources or in this case over the ecosystem services. Another possibility is that the economy, through markets, gives some value (price) to the ecosystem services, but this price does not have all the information, and it is not accurate, and therefore the ecosystem service is under valued. A third case occurs when Nature is affected by negative externalities which produce damage and degradation. In many instances these externalities are not incorporated into prices and therefore the valuation is faulty as it lacks critical information. Finally, a situation can arise in which there is overuse of services that have a price, but the users of the resources do not suffer the consequences of this overuse, which can lead to depletion and degradation. This is another kind of negative externality.

In the following section I introduce a different analytical framework to study ecosystems and give valuation to them, called the Millennium Ecosystem Assessment, an approach stemming from the field of ecological economics.

4.6. Ecological Economics: The Millennium Ecosystem Assessment

This section focuses on (1) changes in use of ecosystem services (direct drivers of change in Figure 4.2), and (2) the seeking for direct causes of the change in use of ecosystem services (direct drivers of change). Finally, in conjunction with chapter 3 (indirect drivers of change), using the framework of the Millennium Ecosystem Assessment as a guidance, I present how the people of the community of Caleu changed the use and frequency of use of the identified ecosystem services, and I offer some hypotheses for direct causes of the use of said services.

The Millennium Ecosystem Assessment has as a goal establishing scientific basis for the implementation of projects to improve the conservation and sustainable use of the ecosystem. The Millennium Ecosystem Assessment was set out to assess the consequences of ecosystem change due to a human well-being.

The analytical framework in the Millennium Ecosystem Assessment project attempts to address the changes in factors that indirectly affect ecosystems –like population, technology and lifestyle– in Figure 4.2 this corresponds to the upper right white box. These changes can produce changes in factors directly affecting ecosystems –like the catch of fisheries or application of fertilizers– this is shown in the lower right white box in Figure 4.2. These directs drivers of change result in changes in ecosystems (lower left white box in Figure 4.2) which produces changes in ecosystem services and finally affects human well-being, shown in the upper left white box.

All these complex interactions can be produced in different scales and across scales. The scales are temporal and spatial; therefore, interactions occur at global, regional and local levels and over long, medium and short periods of time. Figure 4.2 misses some of the complexity of the interactions in the temporal and spatial domains. However, these interactions, including intra- and inter-elements in the framework of assessment. It is possible that actions can be taken almost in every point of interaction in order to respond to negative changes, or to

improve positive changes.

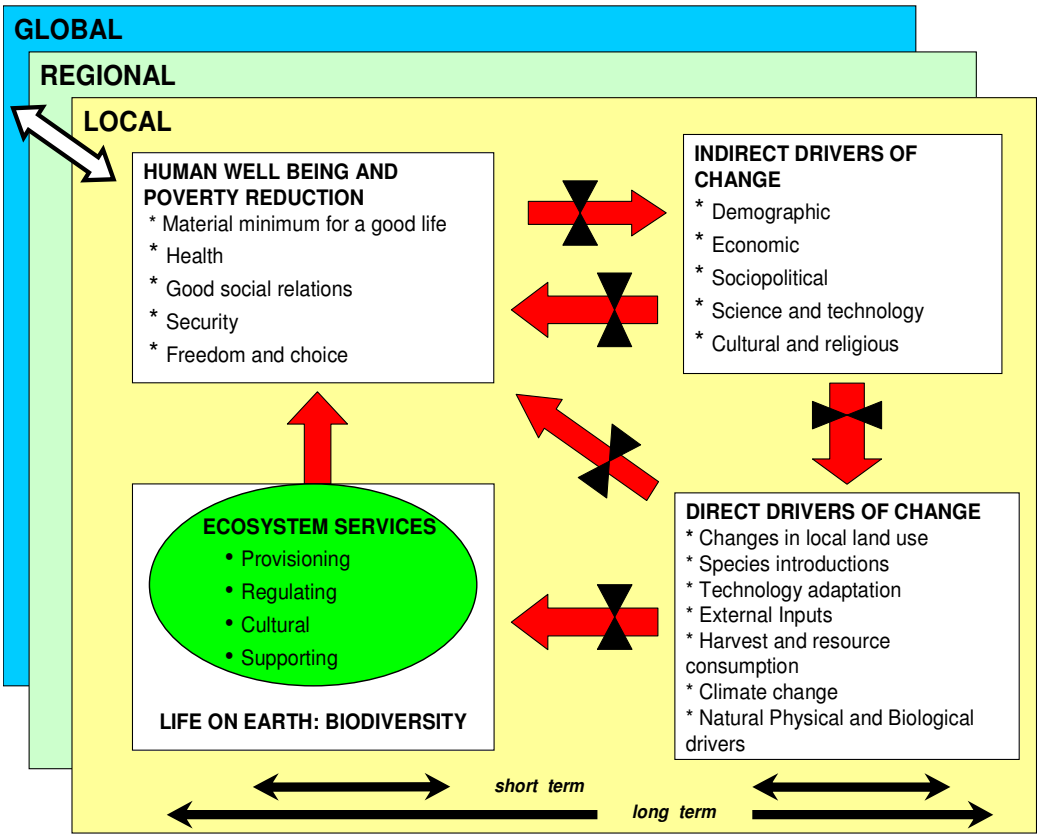


Figure 4.2. The sign ⧗ means possibilities of strategies and interventions. (Source: Millennium Ecosystem Assessment, 2007).

In this framework, human well-being and poverty are the primary focus of target issues of the assessment. This is because the framework is designed to assess the consequences of changes in ecosystems and in ecosystem services in particular to the human well-being. The underlying assumption is that the five main components of the human well-being –basic material needs for a good life, freedom and choice, health, good social relations, and personal security – are closely related to the status of the environment.

The assessment framework has three basic elements. (1) Condition and Trends, which involves the assessment of the current conditions and historical trends over the past 50 years. (2) Scenarios, which involves the assessment of the consequences of possible future changes in driving forces, extending out 50 to 100 years in some cases. And finally (3) Responses, which involves the

assessment of strengths and weaknesses of different response options, examine the strategy and intervention points. This step includes valuation (ecological, cultural and economic) and policies.

The preceding framework is an attempt to carry out, through an analytical approach, the Millennium Ecosystem Assessment. The overall analytical approach to be used to classify the goals has nine major tasks which are described in the Figure 4.3.

An essential issue to the design of successful interventions that improve positive and minimize negative impacts is the understanding of the factors that cause changes in ecosystems and their services.

Direct and indirect pathways between ecosystem change and human well being can be positive or negative. The indirect effects have a more complex web of causations that involves social, economic and political issues. The disadvantaged communities are generally the most vulnerable to adverse ecosystem changes. A driver is any human-induced or natural factor that indirectly or directly causes a change in an ecosystem. Direct drivers can undeniably influence ecosystem processes and therefore an be identified and measured in different degrees of depth and accuracy. On the other hand, indirect drivers operate more diffusely usually altering one or more direct drivers; its influence can be recognized by understanding its effects on direct drivers.

Decision makers influence some drivers and at the same time are influenced by them. The first type are endogenous drivers and the second are exogenous drivers. The decisions that affect these drivers and are affected by them are made in three organizational levels: (1) individual and small groups at local level, (2) public and private decision makers at municipal and national levels, (3) public and private decision makers at international level. The degree to which a driver is outside of the influence of a decision making process depends strongly on the temporal scale. This is because some factors can be exogenous in the short run, while being endogenous in the long run.

The temporal and spatial scales at which ecosystems are studied prove to be fundamental at the time of issuing conclusions and giving public policy advise.

Many environmental problems originate by the mismatch between the scale over which the ecological process occurs and the scale over which decisions are made. The choice of scale and boundaries of an assessment is not politically neutral, because it can implicitly give favor to certain groups, system of knowledge, types of information and modes of expression. Reflecting on political consequences of the scale and boundaries chosen is an important requisite to the analysis of decision and policy making processes at various levels.

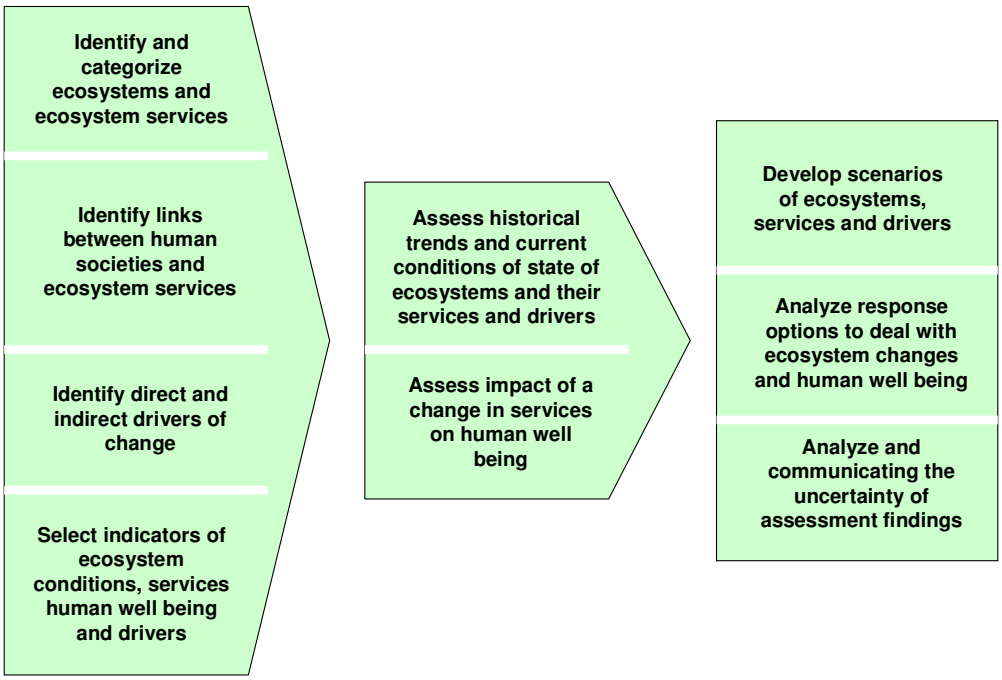


Figure 4.3. The analytical approach of Millennium Ecosystem Assessment and its main tasks. (Source: Millennium Ecosystem Assessment, 2007).

The specific scale in space and time of ecosystem processes and their services are usually more strongly expressed and observed, and have dominant drivers or consequences. Social, political and economic processes can be observed more clearly in some scales than others. Social organization has few discrete levels: households, community and nation that correspond to different and particular scale domains in time and space. A multi-scale approach that simultaneously uses larger and smaller scale assessments can help to identify important dynamics of the system under study.

The Millennium Ecosystem Assessment framework is a tool to develop assessments of ecosystems and in so doing provide better information accessible for decision-making and public policy. In the case of Caleu, this approach will be fundamental for the development of the recommendations section in chapter 6.

4.7. Ecological Economic: Ecosystem Services and Public Policy

Following the Millennium Ecosystem Assessment, interventions and decision-making processes are a fundamental point in order to carry out real changes in the actual status of the ecosystems and ecosystem services.

Decision-making processes and institutions work across spatial scales and organizational levels. These decision processes are value-based and combine political and technical elements at different levels and degrees. Decision making processes have some desirable properties, like equity, transparency, accountability, participation, and attention to vulnerability.

Strategies and interventions can help societies reach their goals of conservation and sustainable use of nature, including incorporating the value of ecosystems in decision making; thus guiding diffuse ecosystem benefits through decision making with focus on local interests, creating markets and property rights, delivering education and dispersing knowledge and investing to improve ecosystem services.

In order to accomplish these interventions, there are mechanisms that include conventions, laws, regulations, and enforcement; contracts, partnerships, and collaborations, and also private and public action.

Decision-making processes combine identification of the problems, analysis of the problems, identification of the policy options, policy choices, policy implementation, and monitoring and evaluating in an iterative way.

Policies at every level and scale need to be adaptative and flexible in order to acquire experiential lessons, and hedge against risks in order to account for uncertainties. However, there are trade-offs between the responsiveness and

the stability of the policy environment that need to be considered.

Social and environmental innovation, technological advance and economic development can be supported by subsides. However, at the same time, subsides can result in social losses and inefficient markets and distortions. Subsides can be removed to avoid a distortion, or reformed, or even created to promote environmentally friendly uses of nature. Also, subsides can be replaced using private resources to maintain acceptable cash flows and certain good practices.

Due to the fact that most of the ecosystem services are public goods, establishing correct prices seems impossible. This is fixable by producing appropriate policies –rewarding the preservation and penalizing the destruction– and creating the appropriate markets –mainly agreement markets.

Payments for ecosystem services (PES) are payments for a service coming from an ecosystem likely to secure that service (UNEP/IUCN, 2007). These payments are especially important when land cannot be purchased for preservation or is located where protected areas cannot be created. A characteristic for the success of the PES is a combination of introduction of protective legislation and conservation incentives.

Polluter pays principle is broadly used in order to address the degradation of ecosystem services through the use of damages valuation. In these cases the polluter should pay costs of clean up and restoration projects. This principle can also be extended to agreements or compliance markets. In this way, the cost of the externalities can be captured, securitized and capped for trading among polluters.

In order to promote the creation of successful new markets, markets need not only appropriate institutional infrastructure, but also the correct incentives, financing and governance. The creation of markets is a good alternative, because they are flexible and usually cost-effective. However, due to the difficulty of finding the right price, ecosystem service markets can be imperfect; or even the transaction costs can be bigger than the potential gains.

Safeguarding and extending protected areas should be done in interaction

with the local communities. The economics of ecosystem services must be such that shares its value with those communities.

Actually, protected area networks are incomplete and suffer from being under threat due to lack of funding and political support. Valuation processes need to be a point of better understanding and should help in informing about policy choices made during creation and maintenance of protected areas.

Usually local governments and communities try to reach economic development by seeking to attract more people and businesses through construction and infrastructure developments. These practices show incoherence with the notion of safeguarding ecosystem services, and need to be corrected though participation in the revenues from the protected areas. Tax transfers between central and local governments can provide the tool for reaching this goal.

A better understanding of the economics of ecosystem services in the context of protected areas requires focusing on the creation of cash flows, gaining political support, improving policy making and improving governance structure.

Finally, for a successful environmental management, it is necessary to measure specific parameters of nature, including ecosystem services, and explicitly accounting for their degradation in the National Accounts. One important step in that direction was the conference “Beyond GDP” in Brussels, where the consensus was that it is necessary to add environmental and social measurements to the existing GDP metrics (Beyond GDP, 2007).

In conclusion, there is still a big and unmet need for research focused not only in the ecological aspects of how ecosystems function, but also in the economic aspects where there is a need to develop a new methodology that can capture the real complexity of the relationship between humans and ecosystem services.

4.8. Methodology

The methodology used in this study consisted of interviews and a focus group in order to obtain basic information about ecosystem use by local residents. A survey was used to measure changes in ecosystem services usage before and after the El Roble hill was designated as a Nature Sanctuary.

The first step was focused on recollecting information about the place. The methodology was designed to respond the research question: How did the change in use of ecosystem services affect the people of Caleu? To address this, the work was separated into 3 stages: interviews, focus group, and survey.

4.8.1. The Interviews

Two interviews were made with the goal of obtaining knowledge about Caleu and the relationship of its people with El Roble hill. In the first interview, I obtained basic information about the history of Caleu and the relationship its people have with the Cerro El Roble Nature Sanctuary. In the second interview, I learned about the uses of the ecosystem services of El Roble hill. All the information obtained in the interviews was used in the process of developing the questions for the survey.

4.8.2. The Focus Group

A focus group was developed in order to collect multiple viewpoints about the relationship of Caleu with the hill and how the residents currently use it, by comparing it to how they used to use it. The focus group was conducted in a relaxed atmosphere and each person was able to openly give her opinion in the group. In this focus group, I obtained different opinions about the change in the behavior of the people from before the after the sanctuary was created. The information obtained in the focus group was useful and used in building the questionnaire. The questionnaire incorporated all the different activities that the people of Caleu used to do, or do at present on the El Roble hill.

4.8.3. The Main Survey and the Complementary Survey

The survey was applied across the community of Caleu. The main objective was to understand the relationship between the people of Caleu and the El Roble hill. People were asked how they use the El Roble hill and how often they use it, before and after the hill was turned into a Nature Sanctuary. Also, they were asked if the El Roble hill is important to them; among other questions about level and quality of life of the family. The goal is to compare ecosystem use before and after the Nature Sanctuary was established and learnt how the change in usage had affected the income and / or quality of life in the people of Caleu. A team was formed according to the methodology described in chapter 3 .

4.9. Results

The amount of information obtained was extensive. Among the responses, 19 ecosystem services were identified by the residents and newcomers surveyed. Data included on the ways ecosystem services were used decades to years before Cerro El Roble Nature Sanctuary was created, and on how they are used today. It also included questions regarding the frequency of these uses and its relation to their income, as well as other related variables.

Next, I present a list explaining each of the ecosystem services identified, including a 20th ecosystem service (water supply), which was identified during the interviews but not during the focus group or first survey. Several of the ecosystem services identified as in current use (Table 4.2) are or should be forbidden from use if it is not done in a sustainable way because over half of them damage the white oak forest ecosystem through overexploitation.

4.9.1. The Ecosystem Services

In the survey, information was obtained about uses of ecosystems services on the hill, as well as other basic household information. There were 19 ecosystem services found in use in Caleu before and after the establishment of the Nature

Sanctuary (Figures 4.4 and 4.5). The following list of the ecosystem services includes 19 services identified in the focus group and survey, including a 20th service identified *a posteriori* during the interviews:

1) Stockbreeding: the comuneros bring their cows to the hill to graze.
2) Goatbreeding: the comuneros bring their goats to the hill to graze.
3) Sandrock: the comuneros extract this type of rock for construction and for finishing houses and patios.
4) Timber: the comuneros collect timber used in construction.
5) Firewood: the comuneros collect firewood heating, cooking and even selling the rest to other communities.
6) Seeds: the comuneros collect seeds to sell.
7) Mushrooms: the comuneros collect *digueñes* from the white oaks to eat and sell to other communities.
8) Medicinal Plants: the comuneros from Caleu collect a wide number of medicinal herbs, among them: *vira-vira*, *oreganillo, hierba del platero, zarzaparrilla, bailahuen, tilo, menta* (mint).
9) Snow: the comuneros extract snow to sell to Rungue's community for making ice cream during the summer.
10) Humus: the comuneros extract the first layer of soil and fallen leaves in order to sell as top soil for gardens.
11) Bees: the comuneros and other residents keep honeycombs nearby the hill, the bees pollinate flowers and produce honey.
12) Rabbits: the comuneros hunt rabbits with snares.
13) Recreation: people walk on the road, run bikes and do hiking during good weather.
14) Gold and Silver: people used to conduct extractive mining activities for gold and silver. These activities have ended.
15) Charcoal: the comuneros produce coal from fallen trees and branches to use in heaters and to cook. They sell the remaining to other communities.
16) Chicken: people releases chickens to eat insects of the forest.
17) Eggs of wild birds: the comuneros extract Codorniz's eggs, mainly of quail,

for personal consumption.

18) Cristal Rock (quartz): several persons use quartz to make jewelry for sale to tourists.
19) Grass Extraction: the comuneros extracted grass for feeding animals during winter, this activity has ended.
20) Fresh water supply: the comuneros extract fresh water as a collective. They do not have estimates of use before and after the sanctuary.

As follow the Table 4.2 is a comparison between the ecosystem services used by the comuneros before (left column) and after (right column) the sanctuary was declared.

Table 4.2. Show the results in the histogram of all ecosystem services in use before and after the establishment of the Nature Sanctuary.

Ecosystem Services in use Before	Ecosystem Services in use After
Stockbreeding	Stockbreeding
Goatbreeding	Goatbreeding
Sandrock	Sandrock
Timber	Timber
Firewood	Firewood
Seeds	Seeds
Mushrooms	Mushrooms
Medicinal Plants	Medicinal Plants
Snow	Snow
Humus	Humus
Bees	Bees
Rabbits	Rabbits
Recreation	Recreation
Gold and Silver	---
Charcoal	Charcoal
---	Chicken
---	Codorniz's eggs
Crystal Rock	Crystal Rock
Grass Extraction	---

Most ecosystem services are related to the subsistence economy of the community, and for that reason they remained in use, albeit reduced, after the creation of the sanctuary. These services are all intensive with the sole exception of recreational activities. Figure 4.4 shows the 19 ecosystem services identified (does not include fresh water) based on the number of households that indicated

using them before and after the creation of the sanctuary.

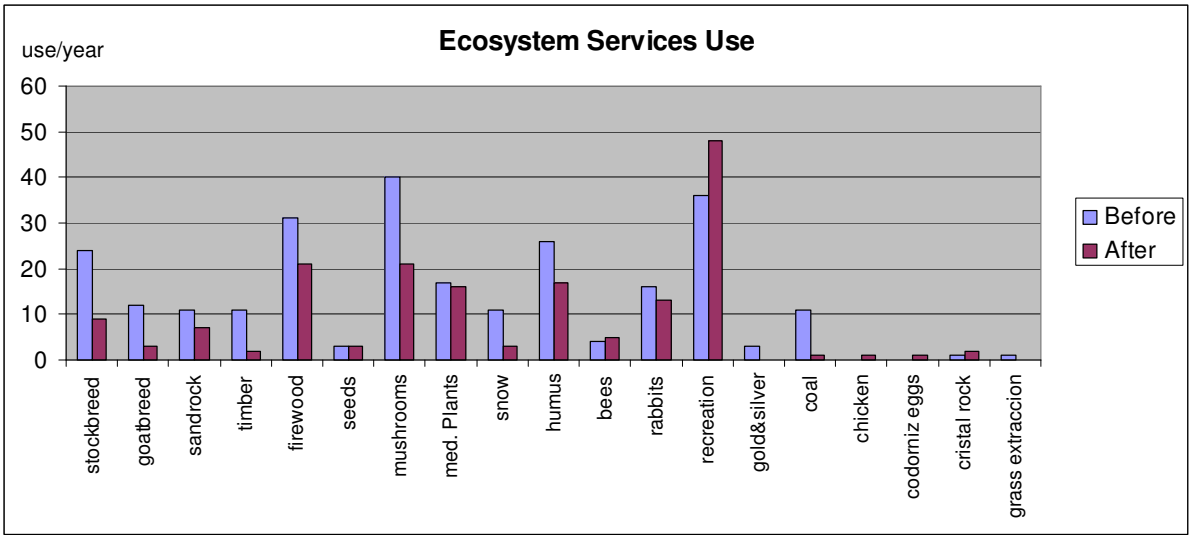


Figure 4.4. Number of households that use ecosystem services in the El Roble hill before and after been declared Nature Sanctuary.

The frequency of use data shows a pattern of reducing use of ecosystem services after the creation of the Nature Sanctuary. It is observed that stockbreeding, goatbreeding, mushrooms and humus, among others, substantially reduced frequency of use (Figure 4.5).

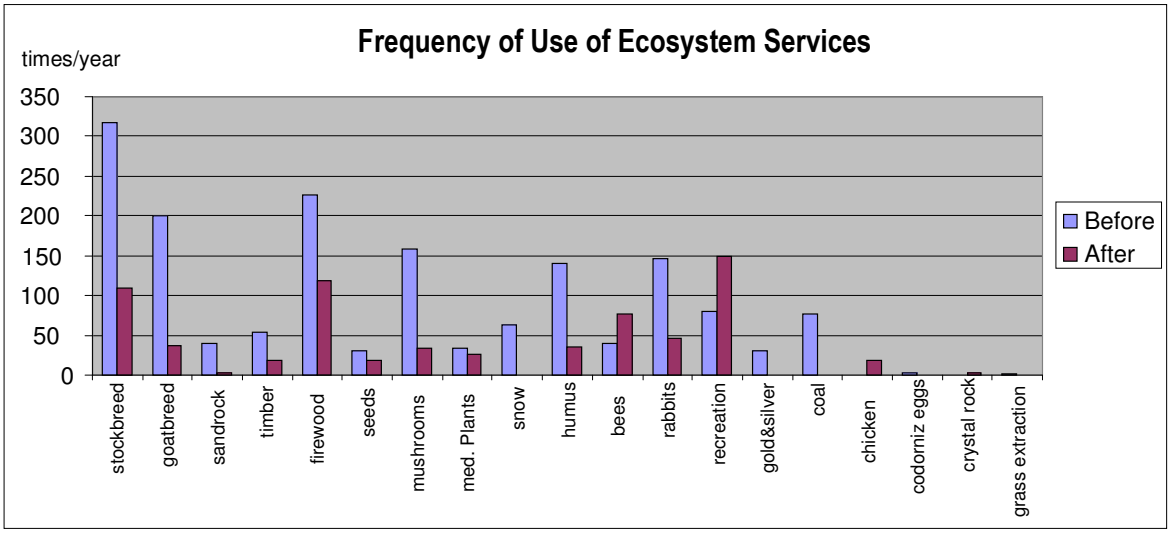


Figure 4.5. Show the frequency of use of ecosystem services per household in a year, before and after El Roble hill was declared Nature Sanctuary.

All the ecosystem services reduced their frequency of use, with the exception of recreation uses and bee-keeping, which increased their use after

the creation of the sanctuary.

A paired t-test was developed to test for changes in the use of ecosystem services before and after the change in the status of the hill. The same test was done for the frequency of use as the following table shows:

Table 4.3. Paired t test for the Use of Ecosystem Services.

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf Interval]	
Serv. Before	92	2.804348	.2783127	2.669482	2.251514	3.357182
Serv. After	92	1.880435	.0272248	1.98811	1.468709	2.292161
Diff.	92	.923913	.2459581	2.359147	.43534875	1.412479

```
    mean(diff) = mean(ServBefore - ServAfter)                     t =   3.7564
Ho: mean(diff) = 0                              degrees of freedom =       91

Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
Pr(T < t) = 0.9998         Pr(|T| > |t|) = 0.0003          Pr(T > t) = 0.0002
```

There is a significant change in the total use of ecosystem services before and after the El Roble hill was declared a Nature Sanctuary. The use of ecosystem services diminishes with the exception of recreation which had an increase, as is expected.

Table 4.4. Paired t test for the Frequency of Use of Ecosystem Services.

Variable	Obs	Mean	Std. Err.	Std. Dev	[95% Conf. Interval]	
Freq. Serv.	86	341.6988	55.74743	516.9804	230.858	452.5397
Freq. Serv.	86	148.3895	33.06897	306.669	82.63957	214.1395
Diff	86	193.3093	54.69585	507.2284	84.5593	302.0593

```
    mean(diff) = mean(FrecServBefore - FrecServAfter)             t =   3.5343
Ho: mean(diff) = 0                              degrees of freedom =       85

Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
Pr(T < t) = 0.9997         Pr(|T| > |t|) = 0.0007          Pr(T > t) = 0.0003
```

There is a significant change in the frequency of the total use of ecosystem services before and after El Roble hill was declared a Nature Sanctuary. Tables 4.3 and 4.4 show that the average frequency of use of ecosystem services has a mean value difference that is statistically significant before and after the Nature Sanctuary was established.

4.9.2. The Analysis

The majority of the members of the community of Caleu – which includes 3 villages, La Capilla, Lo Marin and Espinalillo– use ecosystem services for their basic survival needs before and after the El Roble hill was declared Nature Sanctuary.

Establishing the prediction model, there are three fundamental stages: (1) selection of the variables, (2) estimation of the coefficients of the variables selected and (3) validation of the model. Ideally, this validation stage should be done using different observation datasets; however, in most practical situations, these three stages are performed using the same sample data.

Indeed, it is often difficult to have separate samples for the various stages of modeling because the dataset available to the researcher are frequently too small to use only part of it to establish the regression model leaving the remaining for its validation, which is precisely the case of the Caleu's dataset. Sometimes, even the number of predictors is higher than the number of observations.

The goals of this study are (1) to compare the use of ecosystem services before and after the establishment of the hill as a Nature Sanctuary, and (2) to identify other effects from those associated to the change in conservation policy of El Roble hill. The first objective was demonstrated in two t-tests developed, the first test for use of ecosystem services and the second test for frequency of use. The second objective, however, it is more difficult to develop and needs a series of regressions which will be presented below. Three series of regressions were made utilizing the use of ecosystem services and the frequency of use data. There were computed using OLS[40] with linear regressions and robust results.

For the first group of regressions, a series of 6 models were considered where the use of ecosystem services was explained by age of the household, education of the household in years, policy for the change of the hill from

[40] Ordinary Least Squared.

common land to Nature Sanctuary, gender of the household, total income in the house, village of the household, the number of years living in Caleu and increase in income, which is defined by the use of a given ecosystem service as increasing or not the household income.

Table 4.5. Summarize the variables used in the models.

Variable	Obs	Mean	Std. Dev.	Min	Max
Sum_use	184	2.342	2.392	0	11
Sum_freq	184	254.579	430.027	0	2190
Age	182	51.923	17.549	18	86
Education	184	8.717	4.497	0	17
Policy	184	0.500	0.501	0	1
Gender	184	0.5109	0.501	0	1
Total_income	174	306310.3	340827.7	30000	2500000
Village	184	1.533	0.775	1	3
Years_caleu	184	34.516	22.592	0.5	84
Increincome	135	0.452	0.4995	0	1

For the second group of regressions, a series of models were considered were the frequency of use of ecosystem services were modeled by the same independent variables that were used with the use of ecosystem services models. Tables 4.5 and 4.6 summarize and describe these variables.

Table 4.6. Explain the variables used in the models.

Variable	Description
Sum_use	Summation of all the uses of ecosystem services from a household in a period of a year, in average, for all householders surveyed in Caleu
Sum_freq	Summation of all the frequencies of uses of ecosystem services from a household in a period of a year, in average, for all householders surveyed in Caleu
Age	Age of householder in years
Education	How many levels of education (years) the household finished
Policy	0 before the sanctuary was establish and 1 after the conservation policy was in place
Gender	Gender of the household,1: female, 0: male
Total_income	Total income of the householder in a month
Village	1: La Capilla (closest), 2: Lo Marin, 3: Espinalillo (more distant)
Years_caleu	How many years the household lived in Caleu
Increincome	0: the use of ecosystem services did not increase the income of the household, 1: some products of the ecosystem services were sold and incremented the monthly total income of the house

In Table 4.7, it is presented the models for the sum of use of ecosystem services. Table 4.7 shows that in model 1 for the sum of the uses of ecosystem services the independent variables: age, years of education, and policy, are statistically significant ($p > 0.05$). When the age of the household increases by 1, the use of ecosystem services falls by 0.031, this is for every 10 years of age increase, the household uses 1/3 less of ecosystem services.

For households having more years of education, the use of ecosystem services decreases by 0.15. Also when there is a policy for non-use of ecosystem services then the use will decrease by almost 1, this means that people do not use ecosystem services.

The use of ecosystem services seems to be correlated only with the level of education and the age of the household head. There was no statistical relation with how far they live from the hill as both villages farther away from the hill show no significant differences with the village closer to the hill.

Table 4.7. Showing the first 6 models for the sum of the uses of ecosystem services.

	(1)	(2)	(3)	(4)	(5)	(6)
	Sum_use	Sum_use	Sum_use	Sum_use	Sum_use	Sum_use
Age	-0.0317***	-0.0327***	-0.0357***	-0.0303***	-0.0261*	-0.0107
	(0.00898)	(0.00916)	(0.0105)	(0.00880)	(0.0100)	(0.0104)
Education	-0.147***	-0.154***	-0.166**	-0.158***	-0.177***	-0.102*
	(0.0402)	(0.0408)	(0.0570)	(0.0403)	(0.0468)	(0.0490)
Policy	-0.945**	-0.945**	-0.908*	-0.945**	-0.945**	-0.451
	(0.338)	(0.338)	(0.352)	(0.336)	(0.337)	(0.363)
Gender		-0.275				
		(0.345)				
Total_income			0.000000377			
			(0.000000468)			
Village				-0.374+		
				(0.215)		
Years_caleu					-0.0146	
					(0.0103)	
Increincome						1.292**
						(0.404)
_cons	5.737***	5.994***	5.995***	6.330***	6.214***	4.229***
	(0.764)	(0.831)	(0.897)	(0.820)	(0.843)	(0.937)
N	182	182	174	182	182	133
r2	0.114	0.118	0.114	0.128	0.127	0.172
r2_a	0.0995	0.0976	0.0932	0.109	0.107	0.146
Rmse	2.281	2.283	2.319	2.269	2.271	2.100
F	8.585	6.622	6.341	7.380	7.011	6.349

Standard errors in parentheses

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

If the age of a household is 50 years old and her education is 2 levels, then she will use 3.9 uses in average before the sanctuary was establish compared with 2.95 in the same scenario but when the conservation policy is in place.

Therefore, if there is an increment of the age of the household by 10 years, *ceteris paribus*; then, there will be a reduction of 0.3 in the use of ecosystem services.

On the other hand, if the age is maintain in 50 years old, but education of the household increase by 10 years (to 12 levels); then, it will be a reduction by 1.5 in the use of ecosystem services by that average household.

The frequency of use of ecosystem services is related to education and policy; the only stable variables having an effect, because age, total income and most of the other independent variables seems to be statistically non-significant. However, it is remarkable that, even if no other variable is statistically significant, “increment in income” (“increincome” in tables 4.7 and 4.8) could produce a highly relevant and highly significant regression model.

The results shown in Table 4.8 are nine models of the sum of frequency of use versus 10 different combinations of independent variables.

Models 4, 6 and 7 are the ones which explain better the dependent variable statistically. These models suggest there is a negative effect with age, that is when the age increases by 3, the frequency of use of the services decreases by 1. These models also suggest that there is a negative effect with education, that is with 17 or more years of education, the frequency of use of the services also decreases by 1. These models also suggest that there is a negative effect with change in policy, the frequency of use of the services when its use is forbidden decreases by 208 approx.

Table 4.8. Showing the first 9 models for the sum of the frequencies of use of ecosystem services.

	(1) Sum_freq	(2) Sum_freq	(3) Sum_freq	(4) Sum_freq	(5) Sum_freq	(6) Sum_freq	(7) Sum_freq	(8) Sum_freq	(9) Sum_freq
Age	-2.338	-2.308	-1.282	-4.049*	-3.585*	-3.585*	-3.094*	-3.223*	-0.622
	(1.460)	(1.570)	(1.808)	(1.773)	(1.458)	(1.464)	(1.477)	(1.546)	(1.872)
Gender	106.0								
	(65.94)								
Total_income	-0.000109*	-0.000140*	-0.000179**	0.00000804					
	(0.0000522)	(0.0000562)	(0.0000682)	(0.0000855)					
Village		-0.775							
		(41.89)							
Years_caleu			-1.721						
			(1.691)						
Education				-17.74	-19.35**	-19.35**	-17.69*	-19.78**	-6.536
				(10.73)	(7.010)	(6.737)	(6.968)	(6.860)	(9.266)
Policy						-208.9***	-208.9***	-208.9***	-85.88
						(61.36)	(60.85)	(61.44)	(67.40)
Ownership							-57.45+		
							(33.15)		
Paidjob								46.19	
								(68.08)	
Increincome									422.8***
									(78.79)
_cons	351.7***	415.6***	431.4***	613.6***	610.3***	714.7***	870.6***	677.3***	288.6
	(88.41)	(97.15)	(95.95)	(158.1)	(127.4)	(138.4)	(167.7)	(138.5)	(176.0)
N	174	174	174	174	182	182	182	182	133
R2	0.0347	0.0203	0.0258	0.0350	0.0370	0.0959	0.116	0.0985	0.255
r2_a	0.0177	0.00300	0.00865	0.0180	0.0263	0.0807	0.0959	0.0781	0.232
rmse	429.6	432.8	431.5	429.5	425.9	413.9	410.4	414.4	413.6
F	4.288	3.903	3.795	4.755	5.157	6.282	5.327	4.986	9.645

Standard errors in parentheses

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The model 6 –the most statistically significant in terms of independent variables and F– of Table 4.7. In that model we can observe that the age of a household is 50 years old and education is 2 years; then, he will use 496.75 times in average at year the ecosystem services of El Roble hill before there was a policy, and 287.85 times after it was a sanctuary.

Therefore, if there is an increment of the age of the household by 10 years; then, there will be a reduction to 460.9 times, before the policy was in place, and a reduction to 252 times, after the policy was in place.

On the other side, if there is an increment of education level from 2 to 12 years (*ceteris paribus*); then, there will be a reduction from 496.75 times to 303.25 times before policy, and a reduction from 287.85 times to 94.35 times in average in a year.

4.10. Discussion

Of the 20 ecosystem services found, 19 fall in the first category of ecosystem services of the Millennium Ecosystem Assessment, provisioning services. Only one, recreation, is a cultural service. Neither regulating services nor supporting services were identified to be in use directly by the community of Caleu.

The 19 provisional services, following the Millennium Ecosystem Assessment (2005) framework, are related to provisioning of basic needs, mainly health and basic materials for a good life. The cultural service of recreation is related to a very secondary type of service in comparison to provisional services.

The paired t-test results for the use of ecosystem services shows that the difference between before and after is equal to zero with p=0.0003. Therefore, there is a difference in the use of ecosystem services due to its establishment as a Nature Sanctuary.

In terms of the Millennium Ecosystem Assessment, the difference in use of direct ecosystem services constitute a sociopolitical change (see chapter 3). The change in conservation policy an Indirect Driver of change) is transformed into a Direct Driver of change, the change in behavior of people stopped using

the ecosystem services of the El Roble hill.

In the case of Caleu, this means that the social elite changed a policy (the status of the hill to Nature Sanctuary) and that policy actually changed the direct drivers of change (use and frequency of use of the ecosystem services).

From the Table 4.6 we can see how fit the models with the data, the best fit seems to be (1) showing that in the case of Caleu, the factors age and education level together with policy condition of the hill (as the hill=0 or the Nature Sanctuary =1) are the main indirect drivers of change in the use of ecosystem services from a person.

The Adjusted R^2 is highest in model 4, comparing models 1, 2, 4 and 5 (because models 3 and 6 have a different N). However, the F statistics tell us that model 1 is preferred; also because the independent variables are all highly statistically significant and the constant (data not explained) is smaller.

All the signs of age, education and policy are negative in the regressions of table 4.6. This means that the relationships among use of ecosystem services are negative as people in Caleu get older and more educated; and when a conservation policy is put in place.

For the case of frequency of use of ecosystem services in Table 4.8, from the first four models (N=174), the model 4 seems to be the fittest. The Adjusted R^2 and F are highest. However, models 5 to 8 (N=182) the best models seem to be model 6 when looking at F and model 7 when looking at adjusted R^2. Model 6 has a smaller constant, therefore it can be the best model for the frequency of use of ecosystem services.

Finally, the Nature Sanctuary also can produce spiritual ecosystem services, making people better and happier (data not showed). Therefore, more research should be conducted in this issue, using the broad data results of the surveys developed.

4.11. Conclusions

The conclusions of this chapter are based on discoveries of the ecosystem services; comparison of their use before and after the change in conservation policy of the hill; and the same applied to frequency of use of ecosystem services. In addition, it includes statistical analysis to identify the most important Indirect Drivers of change.

(1) There were identified 20 ecosystem services providing direct use of the community of Caleu.
(2) The majority, 95% of the ecosystem services identified, were provisioning services.
(3) Most of ecosystem services are related to a subsistence economy.
(4) The change in policy conservation for the status of the hill, makes people change the behavior of use and frequency of use of ecosystem services.
(5) Changes in use, before and after the Nature Sanctuary was created, are statistically significant at $p<0.05$.
(6) For the robust OLS regression analysis of use of ecosystem services as a dependent variable the fittest model is 1 in table 4.6.
(7) For the robust OLS regression analysis of frequency of use of ecosystem services as a dependent variable the best explanatory models are model 4 for N=174 and model 6 for N=182 in table 4.6. Model 9 N=133 can not be compared.

4.12. References

Bolund P, Hunhammar S. 1999. Ecosystem services in urban areas. Ecological Economics 29: 293-301.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt Marjan. 1997. The value of the world's ecosystem services and natural capital. Nature, Vol. 387: 253-260.

Daly HE, Farley J. 2004. Ecological Economics: Principles and Applications. Island Press, Washington, D.C.

Daily GC, editor. 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington D.C.

De Groot RS, Wilson MA, Boumans RMJ. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393-408.

INE, 2010. Instituto Nacional de Estadísticas, Chile. Required data online system. [Accessed on August, 2010 http://encina.ine.cl/suru].

IUCN, 2008. International Union for Conservation of Nature and Natural Resources. Guidelines for Applying Protected Area Management Categories. Dudley N, editor. IUCN, Gland, Switzerland.

MA, (Millennium Ecosystem Assessment). 2005. Ecosystems and Human Well-being: Current Sate and trends, Millennium Ecosystem Assessment. Volume 1. Island Press. Washington D.C.

Noss, RF. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology Volume 4. Issue 4 (December): 355–364,. DOI: 10.1111/j.1523-1739.1990.tb00309.x

PASOLAC, (Programa para la Agricultura Sostenible en Laderas de América Central). 2000. Pago por Servicios Ambientales: conceptos y principios. Pérez AC, Barzev R, Herlant P, editores. Costa Rica.

Tansley AG. 1935. The use and abuse of vegetational concepts and terms. Ecology, Vol. 16, No. 3 (July): 284-307.

TEEB, (The Economics of Ecosystems and Biodiversity). 2008. An Interim Report. European Communities. Pavan Sukhdev, Study Leader. Welzel+Hardt, Wesseling, Germany.

5. LANDSCAPE CHANGE AND THE STATE OF HILL EL ROBLE

5.1. Introduction

This chapter lays the foundation for the sustainable management strategies for the Cerro El Roble Nature Sanctuary that are presented in chapters above. The past, present, and future state of the El Roble ecosystem is analyzed using a 38 year series of Landsat satellite images that span 1975 to 2012. The hypothesis that the Nothofagus forest at El Roble is being affected by climate change, like many other forests in Mediterranean and other biomes around the world, is also explored using long-term climate data from the nearby San Felipe weather station, several recent studies of climate change in Central Chile, and projections of future climate based on both global and regional climate models. Several other sources of information are also utilized to assess the state of the El Roble hill ecosystem and inform future conservation strategies. These include the analysis of ecosystem services used from the El Roble hill discussed in previous chapters, as well as onsite observations and related studies by several researchers.

5.2. Degradation of the Earth's Ecosystems and the Loss of Biodiversity

Anthropogenic factors have been affecting the Biosphere for at least several millennia. Over the past 10,000 years, humans have destroyed over 60% of the world's forests and are now using 80% of the planet's surface area for agriculture, habitation, and other human-related activities (Gibson et al., 2011). The current global rate of deforestation is 1.4% per year, with 100-120 million hectares of the Earth's tropical rainforests lost over the past decade, an area

almost twice the size of Chile[41] (Fig. 5.1). The driving forces behind these trends have been: (1) the relentless increase in the human population, which reached 7 billion in 2012 and is projected to grow to 10 billion by 2080 and (2) the market system that has consistently exploited the natural world for economic gain while ignoring the costs of environmental destruction and ecosystem degradation.

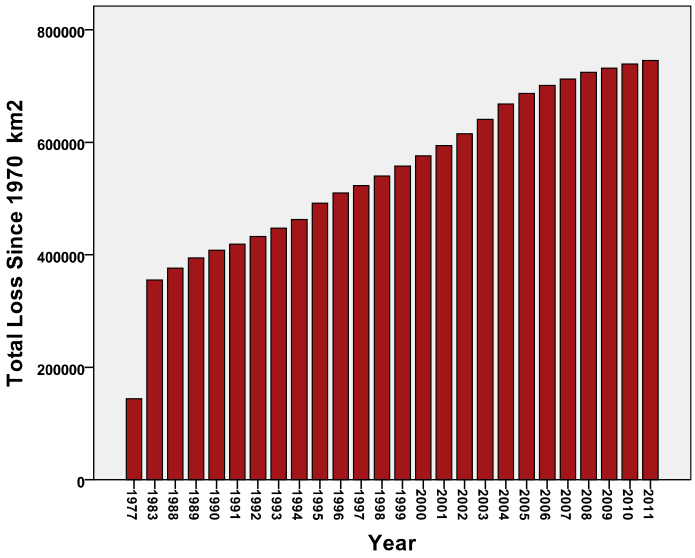


Figure 5.1. Global total land lost 1977 to 2001. (Data from IUCN, 2012).

Human-induced habitat destruction is the major cause behind the accelerating increase in species extinctions and the ongoing loss of the world's biodiversity (Barnosky et al, 2012). Other factors linked to rising extinction rates include over-exploitation, pollution, and invading species. In addition, anthropogenic activity has increased the availability of the two main nutrients for plants. Over the past 100 years, CO_2 has increased in concentration by 40%, while the amount of accessible nitrogen has more than doubled during the past 60 years, leading to the disruption of plant communities and the loss of many resident species (Collins, 2009). The impact of these forces on all taxa continues to grow.

[41] The area of Chile is 750,000 km^2.

As Figure 5.2 illustrates, the total number of threatened species on the IUCN Red List has increased steadily since 1997. The 2012 Red List (IUCN, 2012) estimates that 30% of all amphibians, 23% of reptiles, 21% of mammals, and 13% of extant bird species are critically endangered, endangered, or vulnerable to extinction. Climate change will only exacerbate these trends, causing an additional 15-37% increase in extinctions by 2050 (Thomas et al, 2004). Recent analyses indicate that if currently threatened species go extinct over the next 100 years, and extinction rates remain unchanged, approximately 75% of the Earth's species will go extinct within 250 to 500 years. This would be equivalent to the five largest mass extinctions that have occurred over past 4 billion years (Barnosky et al, 2011).

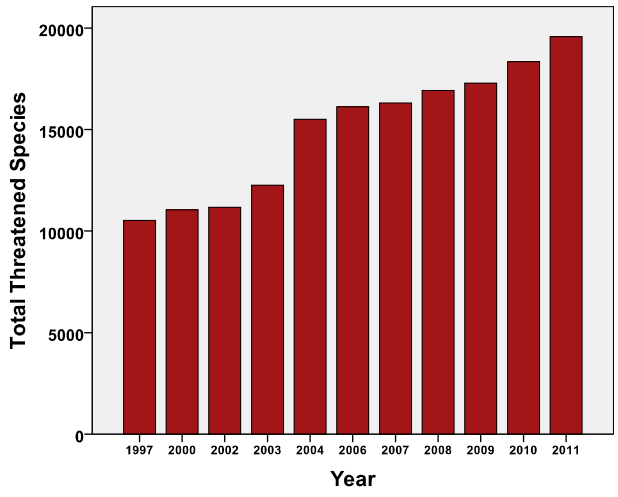


Figure 5.2. The increase in the number of threatened species on the IUCN red list. (Data from IUCN, 2012).

Because of cumulative negative feedbacks, complementary interactions, and non-linear effects, even the loss of a few species from mature, diverse ecosystems can lead to decreases in biomass production, ecosystem stability, and the resilience of ecosystems to further perturbations (Willig, 2011; Reich et al. 2012). Numerous models and studies of disturbed ecosystems indicate that many ecological systems have already reached tipping points with the increased probability of subsequent catastrophic collapse into alternative stable states

(Barnosky et al., 2012). In the coming decades, there will be an increasing influence of drivers such as climate change, associated disturbances like flooding, drought, wildfire, and ocean acidification, as well as land-use change, pollution, and overexploitation of resources (Fischlin, at al. 2007).

During the 21st century, most ecosystems will not only continue to experience large losses of biodiversity at all scales from local to global, the number of exotic species will also continue to increase because of cross-continental introductions, changes in land use, and shifts in geographic range due to Global Warming. The simultaneous establishment and disappearance of species will cause changes in the distribution and abundance of the world's biota and radically alter the functioning of ecosystems (Wardle, 2011). The interactions between social and natural systems that are the underlying cause of these alterations are not well understood, despite a rapidly increasing body of research. Only when we have unraveled the mechanisms linking ecosystem functioning with human-induced change will it be possible to develop predictive models of the ecological consequences of extinction (Cardinale, 2012). In general, however, we can predict that Global Change will drastically alter ecosystem services that are vital for human society and well-being (Schroter et al. 2005).

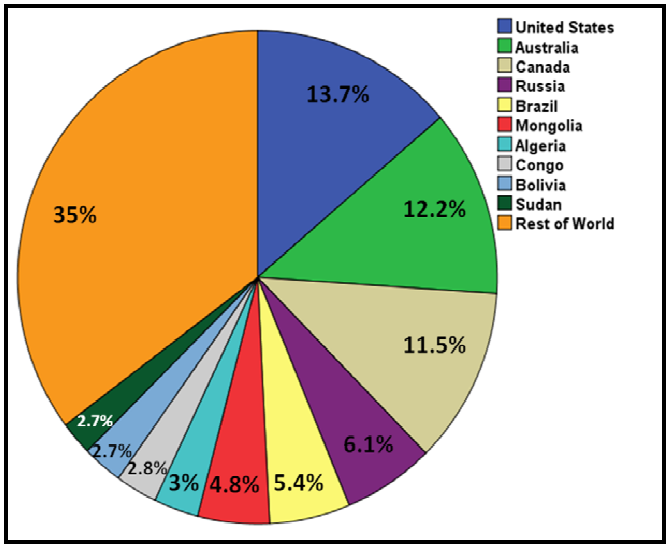


Figure 5.3. Percent of the total area of the world's ecological reserves by country. (Data from IUCN, 2012).

The establishment of protected areas for the conservation of biodiversity is the best strategy for the preservation of species, ecosystems, and the services they provide (Perrings et al, 2010). While genetic inventories, botanical parks, and zoos are important in the struggle to sustain the genetic inheritance of the Earth, protected areas sustain complete ecosystems and communities rather than a limited number of species or samples of genes. Currently, there are approximately 147,000 definable protected areas world-wide that collectively encompass 19.3 million square kilometers, or about 13% of the total terrestrial area of the Earth excluding Antarctica (Borgerhoff and Coppolillo, 2005; see Fig. 5.3).

5.3. Protected Areas in Chile and the Cerro El Roble Nature Sanctuary

In 1907, the Chilean government established the Malleco Forest Reserve, the second such protected area in South America following Argentina's Parque del Sur created in 1903. By 2005, there were 103 protected areas totaling 145,000 square kilometers in land. Chile also contains 8 internationally protected areas encompassing 74,000 square kilometers, and, as part of the International Ramsar Convention, 9 sites covering 1600 square kilometers of wetlands (Chapin et al, 2008).

In the beginning of the 1990s, Chile initiated a movement to create a series of private protected areas beginning with Oncol Park (1989), the Cañi Nature Sanctuary (1990), and Pumalín Park (1991), (Sepúlveda et al. 1997b). Over the next two decades, the number of private protected areas in Chile has continued to grow, even without external incentives or the resources to maintain them, and by 2003 there were 500 private protected areas in the country with a total area of over 500,000 hectares (Sepúlveda 2002; Sepúlveda et al 2003b; Fundacion TERRAM, 2005).

Historically, then, the protected areas in Chile have bifurcated into two major categories: public and private. At present, the central public agency concerned with terrestrial and marine environments managed by the

government is SNASPE (National System of Wildlife Areas Protected by the State). SNASPE was created in 1984 and is supervised by the Ministry of Agriculture's Agency, CONAF. Under SNASPE's purview are 14.3 million hectares of 32 National Parks, 48 Natural Reserves, and 15 Natural Monuments, which correspond to 19% of Chile's total area (FSC-Chile, 2009; FIC-Chile, 2001). However, a number of evaluations and reports have deemed SNAPSE's environmental protection to be grossly inadequate. In 8 of the 13 administrative regions under SNASPE's jurisdiction, only 3% or less of the area is protected, and of the 85 distinct vegetational communities in Chile, 13 lack any form of protection.

Figure 5.4. SPOT Satellite image of Cerro El Roble. The visible green vegetation is primarily composed of white oak (*Nothofagus macrocarpa*) forest. The town of Caleu is at the lower right.

In order to assure the protection of a 5% of the surface area of each of Chile's 85 vegetational formations, SNASPE has repeatedly requested an annual budget of US $100 million, which would be a fourfold increase in SNAPSE funding. In 2003 CONAMA, Chile's National Commission for the Environment, proposed a similar initiative to extend protection to 19% of the area of the most important and threatened ecosystems in Chile. Unfortunately, these requests

have been ignored by the government and they are realistically impossible given past and present budgets (Sepúlveda, 1997).

Chief among the Chile's privately protected areas are Private Parks, Managed Resources Areas, and Natural Sanctuaries. As discussed in chapter 3, the Chilean government established El Roble hill as a Nature Sanctuary in 2000, with protected status granted by the Decreto Exento[42] (DE) 229 of the Ministry of Education. The El Roble Sanctuary is shown in Fig. 5.4. It is located at 33° 07' latitude S 71° 00' longitude with an area of 998.1 hectares and an elevation ranging from 1450 m to 2222 m.

Table 5.1. The total area in hectares (ha) of the major vegetation types within the El Roble Nature Sanctuary. The % of Total Area is based on a total area of ~1000 ha (Data from Donoso, 2007).

Community	***Approx Area (ha)***	***% of Total Area***
Deciduous Oak Forest	520	52%
Spiny Matorral	280	28%
Quillay-Litre Sclerophyllous Forest	100	10%
Romerillo Sclerophyllous Forest	50	5%
Canelo-Chequen Laurophyllous Forest	30	3%
Sclerophyllous Matorral	15	1.50%
High Matorral	3	0.30%

The ecological importance of the El Roble ecosystem is directly related to the diversity and endemism of its flora and fauna. Its flora is rich and biodiverse, and many of the plants are endemic to Chile. This makes El Roble hill a unique place in the Metropolitan Region because it is the only area containing the natural deciduous forest vegetation of central Chile. Hill El Roble is also important because it contains relictual remnants of the Santiago white oak and sclerophyllous forest that dominated the central and northern regions of the country during the Pleistocene glaciations, in particular the northernmost populations of the Santiago white oak, *Nothofagus macrocarpa*.

[42] Decreto Exento is a Supreme Decree, a type of administrative action that usually comes from the executive. A Presidential or Supreme Decree has a statutory regulatory content, making it less than a law hierarchically. Also, it is not under the control of General Finance Office of the Republic (Contraloría General de la República).

The current vegetation of El Roble hill is composed of laurifolious forest (canelo, *Drimys winteri* – chequen, *Luma chequen*), sclerophyllous forest (quillay, *Quillaja saponaria* – litre, *Lithraea caustica*, spiny mattoral shrubland (chagualillo, *Eryngium paniculatum* with Chilean Palm (*Jubaea chilensis*), high matorral, and deciduous white oak forest (*Nothofagus macrocarpa*) (see Table 5.1). Overall, The flora consists of 73 species, 10 of which are classified as vulnerable, one as rare, and one as endemic. Important plants that are threatened or in danger of extinction include *Prosopis chilensis* (the Algarrobo), *Porlieria chilensis* (or Guayacán) and *Adesmia resinosa* (the Paramela of Til-til) (CONAMA, 2005).

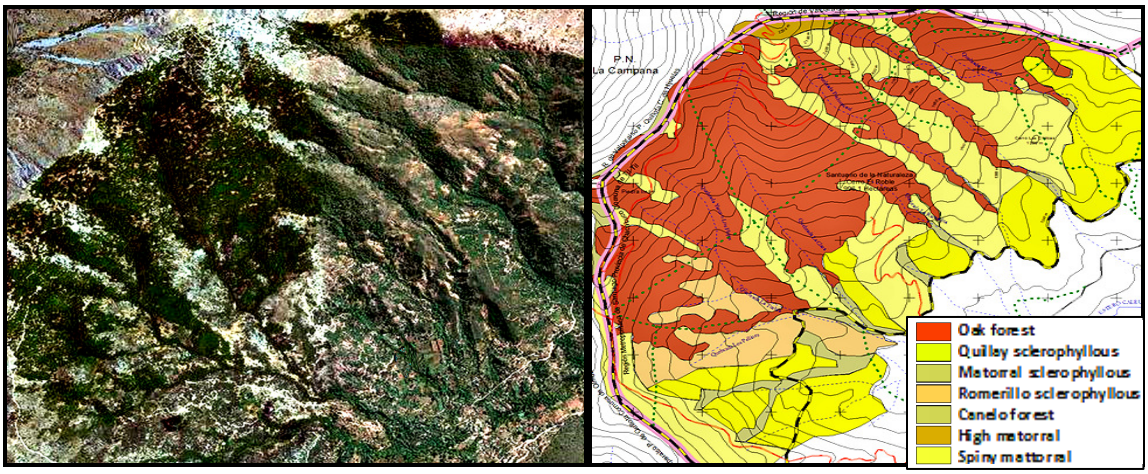


Figure 5.5. Left –Spot Satellite image of the Cerro El Roble Nature Sanctuary. Right – map of major vegetational communities within the Sanctuary. (Map after Proyecto Otas, 2005).

The El Roble fauna includes 75 species of birds, 22 species of mammals, 12 species of reptiles, and 6 species of amphibians (Donoso, 2007). Of these, threatened or endangered species include *Puma concolor* (Puma), *Oncifelis guigna* (the guiña, the smallest cat in the Americas found primarily in central and southern Chile), *Lynchailurus colocolo* (a small, 3 kg cat that ranges from southern Colombia to Patagonia), *Columba araucana* (the Torcaza or Chilean pigeon), *Alsodes nodosus* (the Sapo Arriero, an endemic species of frog), and *Caudiverbera caudiverbera* (the Chilean toad, an endemic species occupying central Chile) (AvesChile, 2006).

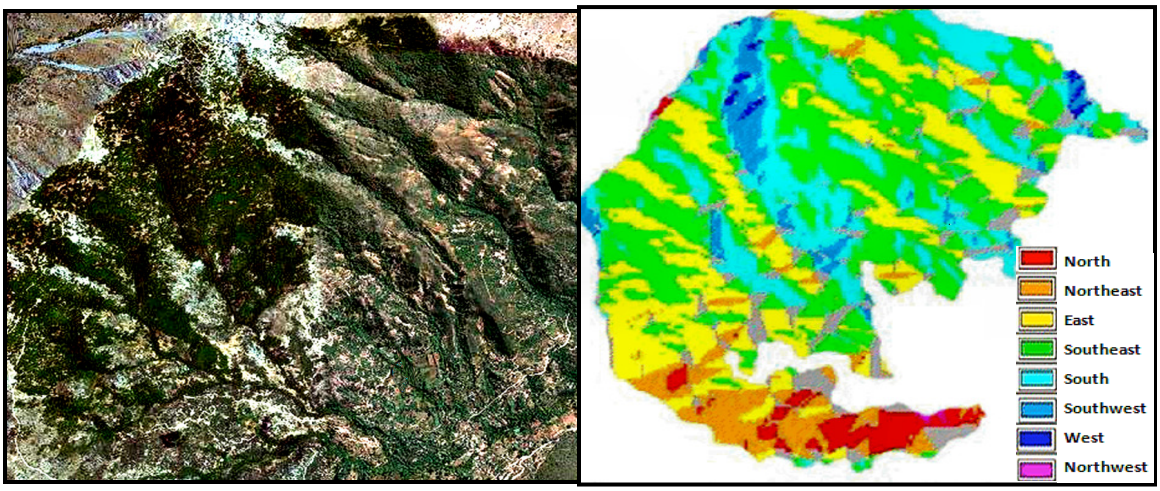


Figure 5.6. Orientation of the hill El Roble slopes. Note that the most dense core areas of the oak forest occur on South and Southwest facing slopes. (After Ibarra, 2008).

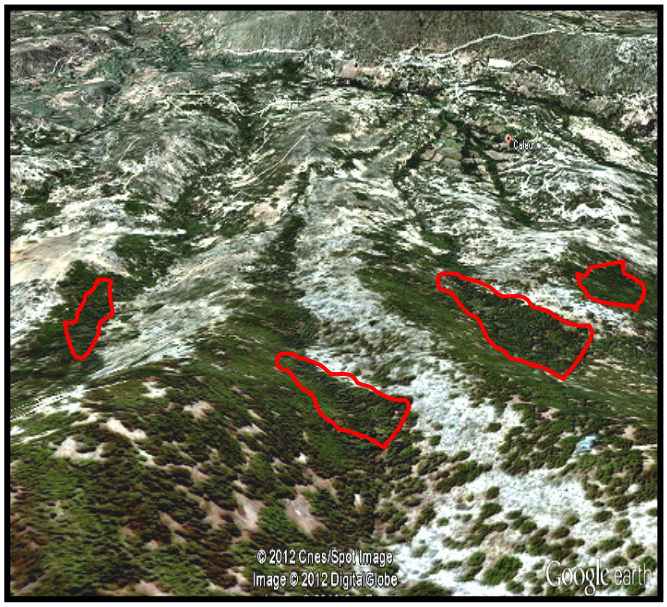


Figure 5.7. Spot Satellite view from the top of El Roble hill looking down towards Caleu. As can be seen, the greener, less fragmented, and more closed canopy areas of the Nothofagus macrocarpa forest occur on the flatter parts of south and southwest facing slopes along arroyos (small stream beds). The soil in these areas is organic humus, much richer and more moist than the soil on steeper slopes.

The deciduous Santiago white oak forest dominates the vegetation of El Roble hill. The forest is found between 1200 and 2200 meters and has a total area of 520 hectares, or over half the total area of the sanctuary (Ibarra, 2008). For comparative purposes, a SPOT satellite image is shown next to a map of the

oak forest and the 6 other major vegetational communities comprising the Cerro El Roble Nature Sanctuary. Table 5.1 gives the areas of the seven main communities delimited in the map in Fig. 5.5.

As Fig. 5.6 illustrates, the dense, closed-canopy oak forest occurs almost exclusively on south and southwest facing slopes, while northwest slopes contain low-lying herbaceous and sclerophyllous vegetation, rock outcroppings, and bare soil. Ibarra (2008) mapped the incident solar radiation at El Roble hill and concluded that the reduced irradiance throughout the year on south and southwest facing slopes led to more favorable moisture conditions which facilitated the growth and regeneration of *N. macrocarpa*.

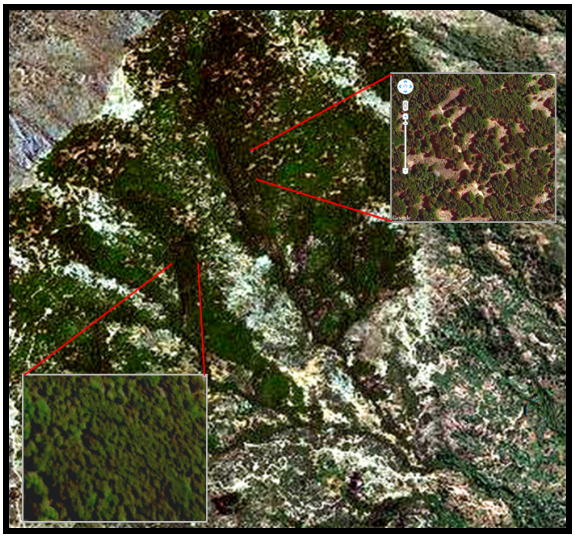


Figure 5.8. The closed canopy, dense oak forest compared to the fragmented an more open canopy of the oak forest on steeper, drier slopes with greater isolation and less soil.

As can be seen in Fig. 5.5, several parts of the Santiago white oak forest at El Roble hill appear darker green than surrounding areas. As Fig 5.7 shows, the darker green patches of the forest occur in flatter areas alongside arroyos or temporary streams that form in the wet season. Erosion is considerably reduced in these areas, the layer of organic soil is thicker, and soil moisture levels are generally higher. The canopy cover is significantly more closed in these areas as well, most often in the range of 90-100% (Donoso, 2007). Figure 5.8 shows the contrast between the thick canopy of the darker green oak forest that occupies

more favorable microhabitats, and the more open canopy of the oaks occupying areas with steeper slopes, greater erosion, less organic soil, and greater exposure to direct sunlight.

5.4. Remote Sensing Analysis of the Hill El Roble Oak Forest

Remote sensing is the detection and capture of electromagnetic energy reflected from the Earth's surface by sensors aboard aircraft and satellites. Since the first LANDSAT satellites were launched in the 1970s, remote sensing data has revolutionized long-term ecological analyses of large spatial areas (Cohen and Goward, 2004). Currently, NASA operates 23 Earth observation satellites that send terabytes of information every day to ground stations all over the planet. These space craft monitor habitat loss due to deforestation, whole Earth trends in productivity, changes in the abundance of tree species, the number and area of terrestrial fires, and the impact of global warming and anthropogenic disturbance on ecosystem functioning (Kerr and Ostrovsky, 2003; Turner et al, 2003).

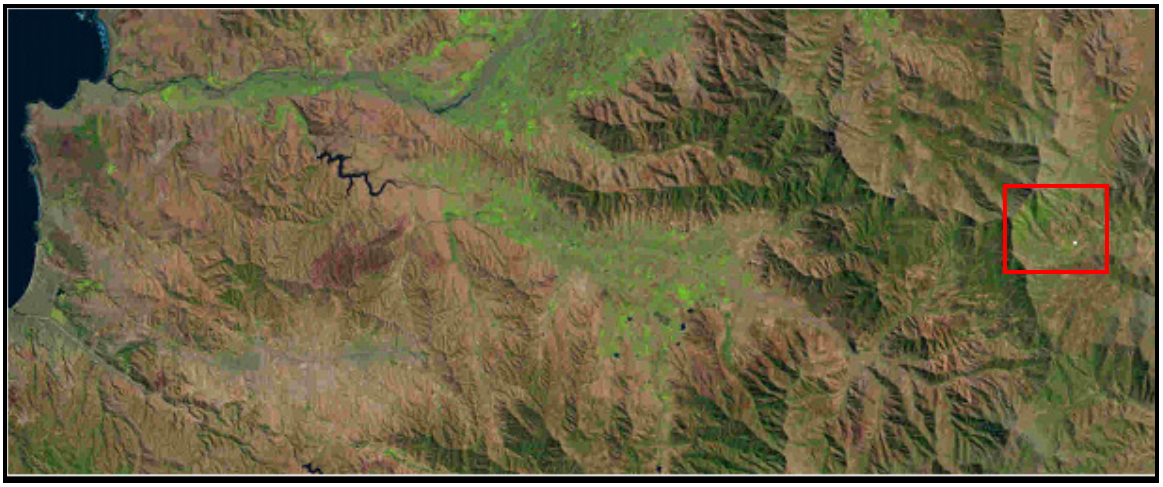


Figure 5.9. One of the Landsat 7 image utilized in the remote sensing analysis. The red square encompasses the Cerro El Roble Nature Sanctuary and the white dot at the lower right is the town of Caleu.

In order to detect long-term changes in the oak forest of the Cerro El Roble Nature Sanctuary, a series of Landsat satellite images of central Chile, dating from 1975 to 2012, were analyzed. The red and infrared bands of the

images were combined to create a Normalized Difference Vegetation Index or NDVI, the most widely used indicator of the amount of photosynthetic vegetation growing within a given area at a given time. Based on the spectral composition of the images, seven distinct plant communities were identified in the images of El Roble hill, including the *Nothofagus macrocarpa* forest. Changes in the aerial extent and the degree of fragmentation of the Oak forest over the past 38 years were calculated with the aim of better understanding the historical and current health of El Roble hill's forest ecosystem. The results were used to inform the management plan presented in chapter 6 for the sustainable use of the Cerro El Roble Nature Sanctuary.

5.5. Methods

The satellite images used for the El Roble hill landscape change analyses were obtained from the USGS Earth Resources Observation and Science (EROS) Center (http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/GLS). A total of 15 LANDSAT images from 1975 to 2012 were downloaded. Only images from February and March were analyzed to minimize the pronounced seasonal changes in the vegetation. These are also the summer months in Chile when the deciduous trees and shrubs are fully leafed out. Three software packages were utilized to process the images and conduct the change analyses: IDRISI from Clark Labs (www.claklabs.org), Pancroma (www.pancroma.com), and Fragstats (http://www.umass.edu/landeco). Pancroma was employed to rectify two major issues with the USGS images: striping and registration.

LANDSAT 7 ETM+ images taken after May 30, 2003, have an evenly spaced series of diagonal black stripes (gaps) due to the failure of the scan line corrector (SLC). Pancroma can automatically fill these gaps using reference LANDSAT 7 ETM+ images taken before the breakdown of the SLC. Several studies have shown that gap filing has no significant impact on the spectral analysis of vegetation and associate conclusions about temporal changes in

ecosystems (Vicente-Serrano et al., 2008). To compare two or more images taken at separate times and/or by different satellites, each pixel in the images needs to be precisely aligned. The Pancroma software can automate this process of registration as well, which saves many hours of time.

IDRISI is one of the major packages used by the remote sensing community to monitor and model the biosphere. IDRISI's Land Change module facilitated the calculation of the Normalized Difference Vegetational Index. The Land Change module was also employed to classify the different vegetational communities in the El Roble hill and to quantify changes in the spatial extent of the Santiago white oak forest from 1975 to 2012.

The Fragstats program (McGarigal et al, 2002) is a widely used software package designed to compute a variety of landscape metrics from categorical maps, aerial photographs, and satellite images. The analysis of fragmentation in the Santiago white oak forest community at El Roble hill, in particular the calculation of indices of aggregation and disassociation, was performed with the Fragstats software.

5.6. Results

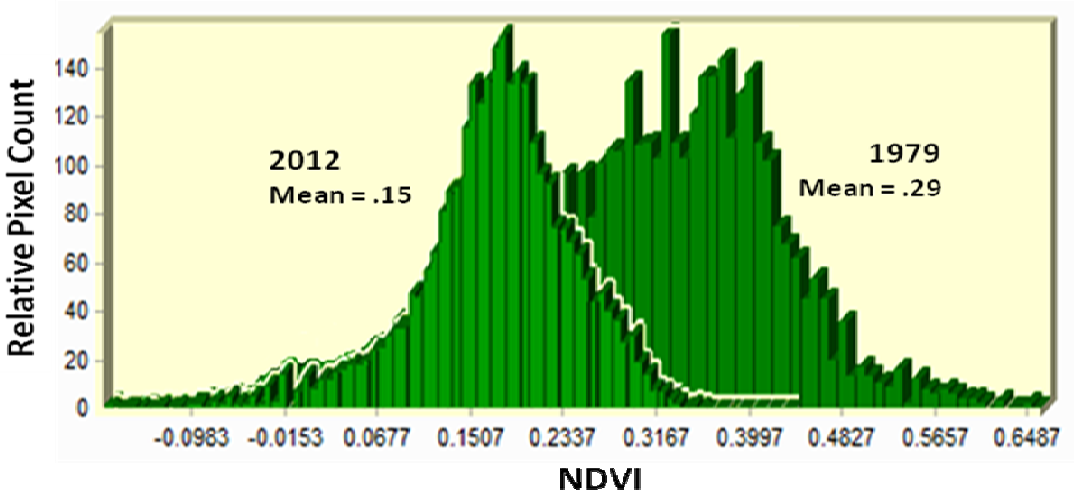


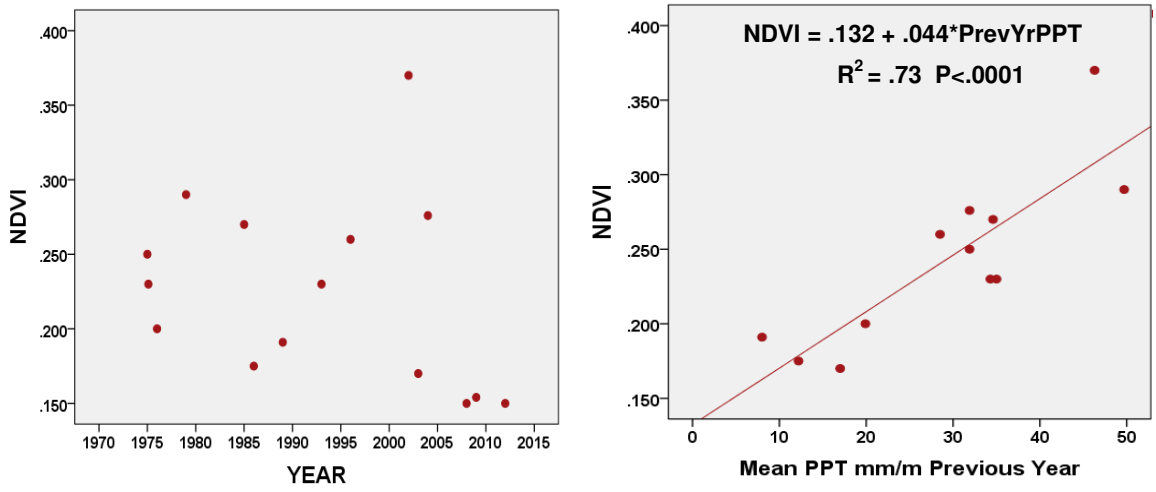
Figure 5.10. Distribution of NDVI values for pixels in Landsat images from March, 1979 and March 2012.

All of the satellites in the Landsat series were equipped with red and infrared detectors. In general, green plants absorb strongly in the red region of the solar spectrum (0.63-0.69 micrometers), while reflecting strongly in the infrared (0.75-1.75 micrometers).

The red and infrared wavelengths captured by any Landsat image can be combined into a general index, the Normalized Difference Vegetation Index, or NDVI, that is highly correlated with the amount of photosynthetic plant tissue in a given habitat. The index is calculated as:

$$NDVI = (NIR — RED)/(NIR + RED)$$

where NIR and Red represent for the spectral reflectance measurements acquired by the satellite sensors in the visible red and infrared regions. The NDVI can range from -1 to 1.



Figures 5.11a (left) and 5-11b (right). The NDVI index for each winter dry season image analyzed, graphed against year and the mean monthly precipitation during the previous rainy season.

From 1975 to 2012, the average NDVI during the summer dry season (February and March) at El Roble hill ranged from 0.15 to 0.37 (Fig. 5.10). There was no significant trend towards decreasing or increasing values over time (Fig. 5.11a). However, the regression of the NDVI on the average monthly precipitation during the previous wet season was highly significant (Fig. 5.11b), and explains 72% of the variation in the NDVI levels over time.

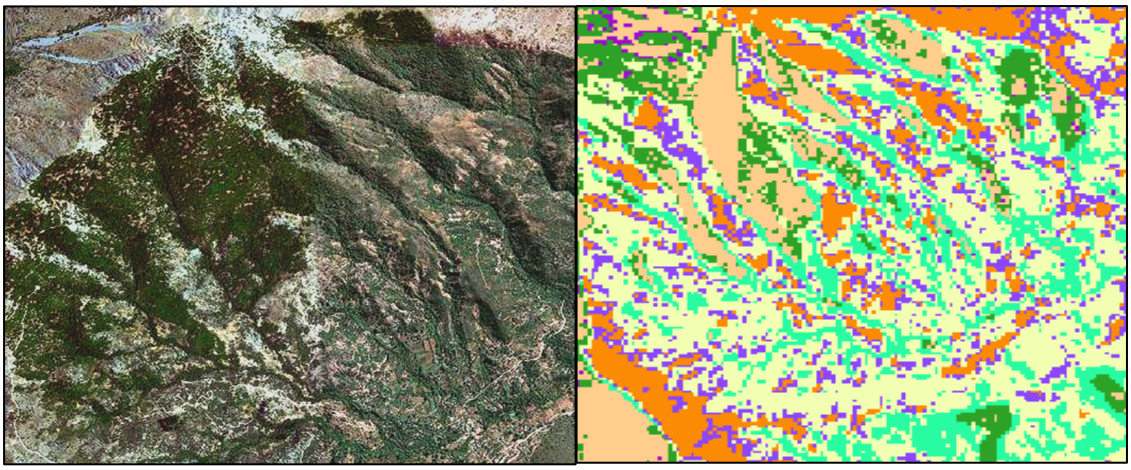


Figure 5.12. The distinct vegetational units (right) within the El Roble hill as classified by the IDRISI Cluster routine using 7 spectral bands from a LANDSAT 5 image taken March 30, 1985.

The dark green, 100% canopy cover oak habitat discussed previously, was one of the 7 distinct El Roble hill habitats detected by the IDRISI cluster analysis routine. The cluster classification map for March 22, 2002 is shown in Fig. 5.12 alongside the SPOT image of the El Roble hill. The light brown areas represents the dense Santiago white oak habitat. By measuring the total area of this habitat for each image, the change in the spatial extent of the dense, core Santiago white oak forest can be tracked over time.

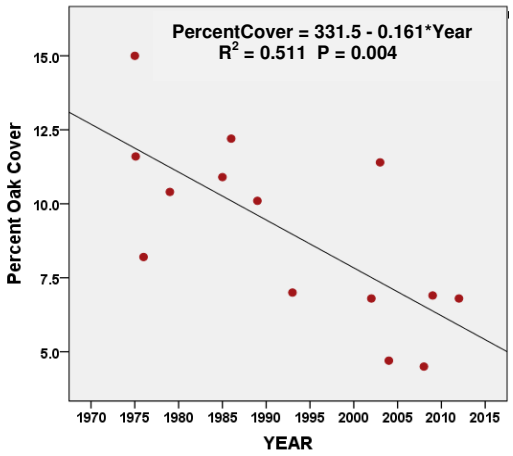


Figure 5.13. Ordinary Least Squares linear regression line and equation for percent core oak forest cover versus year. The regression is significant with P = 0.004 and R^2 = 0.511.

The 2-3 fold decrease in the area of the core oak habitat between 1975 and 2012 is shown in Fig. 5.13. The regression of area on year is significant (P=0.004) and explains 51% of the variation in the spatial extent of the core Santiago white oak habitat over time.

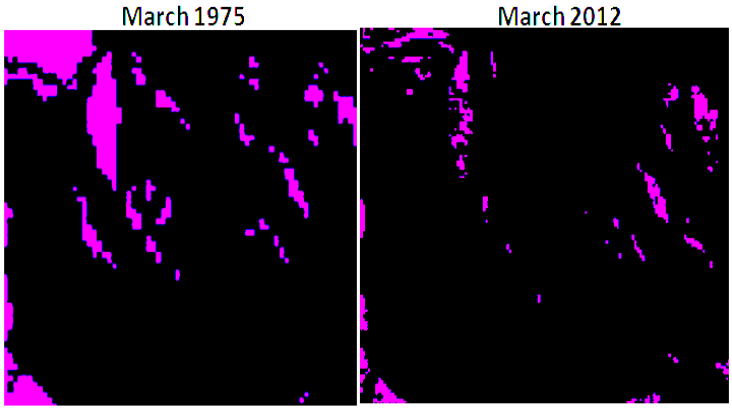


Figure 5.14. Maps of the distribution and structure of the core oak habitat at Cerro El Roble in March 1975 and March 2012. The maps were created from the output of the IDRISI Cluster routine. The reduction in habitat area and the increase in the fragmentation of the habitat through time is evident.

Fig. 5.14 compares maps of the spatial distribution of the same habitat at El Roble hill between February 1975 and February 2012. The evident fragmentation of the Santiago white oak forest over time was analyzed using Fragstats. Fig. 5.15 shows that the number of patches of this habitat roughly doubled over 38 years. The bar chart in Fig. 5.16 illustrates the increase in the Fragstat's fragmentation index between the 1970s and the 2000s.

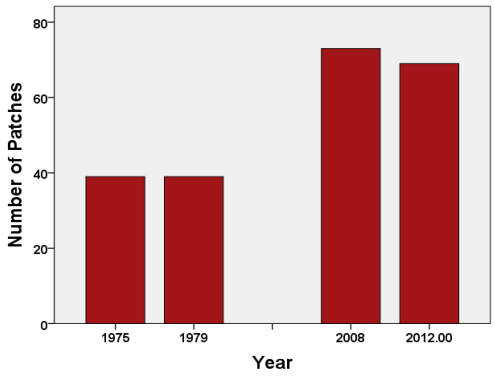


Figure 5.15. The number of patches of core, dense Oak forest identified by Fragstats for 1975 and 1979 and 2008 and 2012.

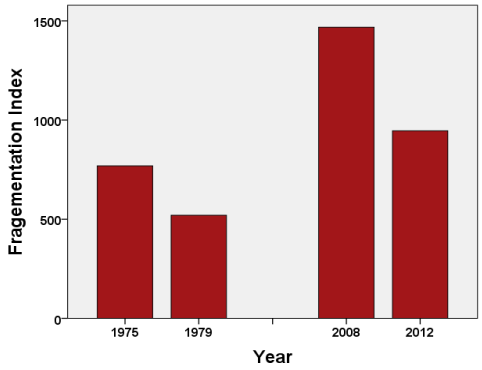


Figure 5.16. Fragmentation indices calculated by Fragstats for 1975, 1979, 2008, and 2012.

5.7. Discussion of Results and the Status of the El Roble Ecosystem

The El Niño Southern Oscillation (ENSO) is a coupled ocean-atmospheric phenomenon that has profound effects on the weather of South America and many other parts of the world (Garreaud, 2009). El Niño refers to the warming of surface waters in the eastern Pacific that are accompanied by high pressure systems in the western Pacific. La Niña weather is associated with low pressure systems in the western Pacific and cooler water temperature in the eastern Pacific.

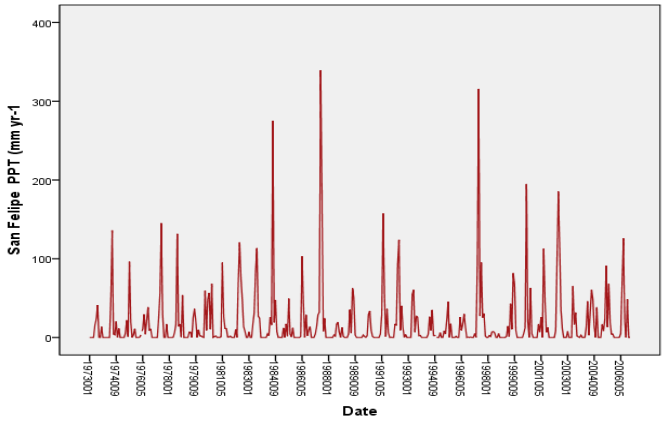


Figure 5.17. Monthly precipitation in mm at San Felipe, Chile, from 1973 to 2006 (Data from INE, 2010).

The two weather systems occur on a quasi-periodic basis with an average of 5 years between systems and a range of 2-7 years. The cycling of El Niño and

La Niña years is responsible for most of the inter-annual variation in rainfall and temperature in central Chile and Caleu (De La Maza et al., 2009).

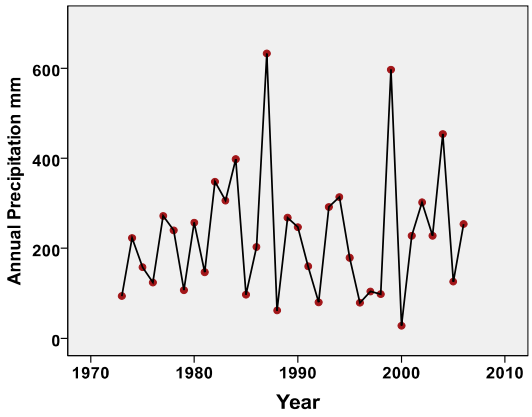


Figure 5.18. Annual precipitation in mm at San Felipe, Chile, from 1973 to 2006 (Data from INE, 2010).

Figure 5.17 shows the monthly precipitation in mm at the San Felipe, Chile, weather station, and Fig. 5.18 shows the total annual precipitation from 1973 to 2006. The station is located 34 km northeast of Caleu at a somewhat lower altitude (600 meters versus 1000 meters). As it is typical of central and northern Chile, there is high seasonal and inter-annual variation in precipitation, with the great majority of rain or snow occurring in the austral winter (JJA), with little or no precipitation during the summer (DJF). The mean annual precipitation over the 34 years of data from San Felipe was 226.7 mm with a range of 28 to 633 mm. Figure 5.19 graphs the serial autocorrelation of annual rainfall at San Felipe for time lags of one to seven years. The results indicate a strong periodicity of five years for El Niño events, with a minor period of three years.

The variation in rainfall driven by ENSO in turn drives the dynamics of vegetational communities in central Chile and throughout South America (Garreaud et al, 2009). In general, El Niño events are correlated with increased precipitation in central Chile and southeast South America, but decreased precipitation in tropical South America. Overall, the El Niño Index explains a remarkable 80% of the inter-annual variation in precipitation across the South

American continent, although the Antarctic Oscillation and the Pacific Decadal Oscillation can exert marked effects as well.

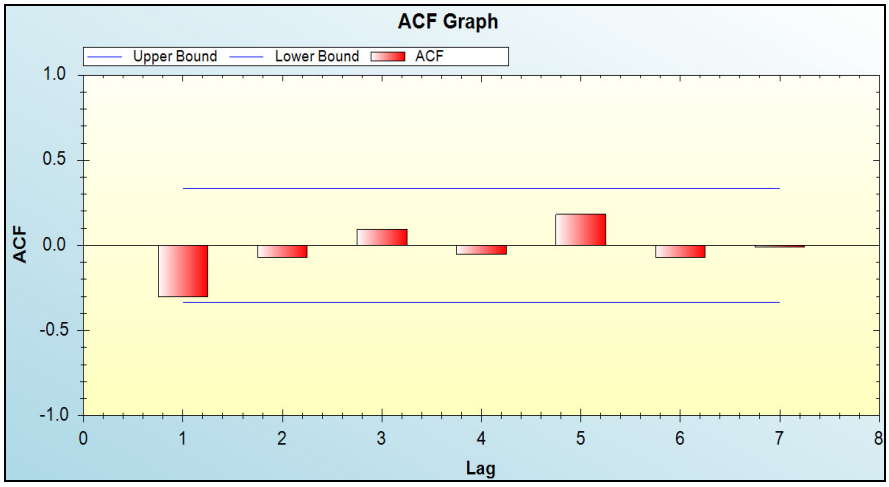


Figure 5.19. Levels of serial autocorrelation (ACF) for lags of 1 to 7 years for the San Felipe rainfall data. A major period of 5 years, typical ENSO effects, and a minor periodicity of 3 years can be seen.

Recently, De La Maza et al (2009) calculated NDVI indices for two areas north of El Roble hill, the Las Chinchillas National Reserve (31°30'S,71°06'W), and the Fray Jorge National Park (30°38'S,71°40'W). These semi-arid areas have annual rainfalls of 175 and 141 mm respectively. Like El Roble hill, high levels of El Niño-related rainfall occur on average every five years. In keeping with the results presented here, the maximum NDVI at both sites was positively correlated with annual precipitation, and an index of annual plant productivity (the INDVI) also had a significant, positive and nonlinear association with annual rainfall. The lack of any significant association between NDVI and time at El Roble hill is not surprising given that rainfall did not change significantly between 1973 to 2006 at San Felipe, and, by inference, at El Roble hill between 1975 and 2012 (see trend analysis in Figure 5.20). The time series trend analysis for temperature, however, indicates that there has been an approximately one degree centigrade increase over 34 years at San Felipe (Fig. 5.21).

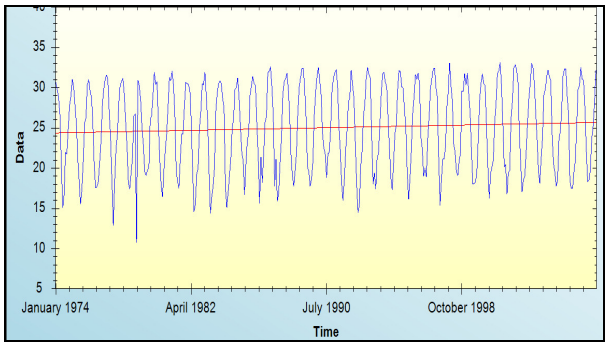


Figure 5.20. Total monthly precipitation in mm at San Felipe, Chile, from 1973 to 2006.

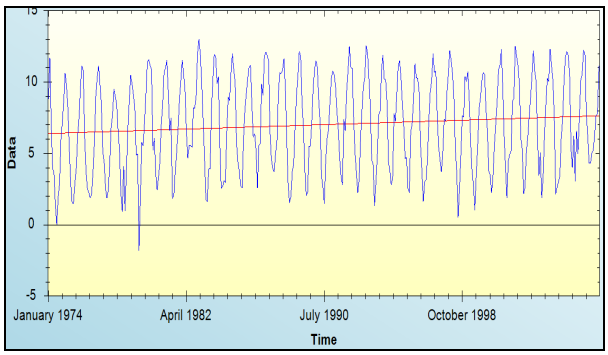


Figure 5.21. Mean monthly temperature at San Felipe, Chile, from 1973 to 2006 (Data from INE, 2010).

Both of these findings are in agreement with larger studies of long-term climate change in central and northern Chile that utilized a greater number of data sets for precipitation and temperature. Over a 28 year time period (1979-2006), the coast of central and northern Chile has experienced a cooling of surface temperatures at a rate of 0.25^{o} C per decade. This is in contrast to the general warming trend that has occurred with increasing distance from the coast that is primarily a function of altitude (Falvey and Garreaud, 2009). At an elevation of 500-1000 m in central Chile, the rate of warming has proceeded at 0.4 - 0.5^{o} C per decade, which is consistent with the 1.2^{o} C increase in temperature found at San Felipe over 34 years. With respect to rainfall, several analyses have found no significant change in average rainfall in central and northern Chile during the past 20-40 years.

However, an increase of 1.2^{o} C is a potential driver of observed changes in the oak forest. The average change in temperature over the past 30 years has

been 0.61° C at global level; therefore, in El Roble hill area, the increase has been 100% higher in comparison with the world global warming.

Therefore, in addition to the anthropogenic direct drivers of change over the population of N. macrocarpa, the biological communities, and the ecosystems in El Roble hill; it could be also by driven by a vast indirect driver of change: the increasing of the temperature. Which derivates in higher rates of tree mortality, due to physiological stress and interaction with other climate-mediated processes (e.g. insects outbreaks, wildfires, biogeochemistry cycles change) can alter the composition, structure and biogeography of this type of forest (Allen et al, 2010).

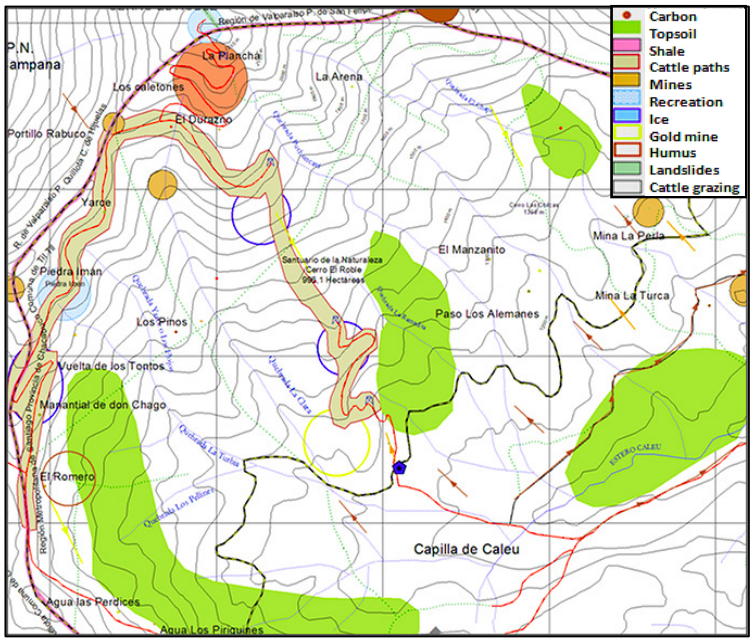


Figure 5.22. Map of the current and historical human uses of the Cerro El Roble ecosystem (Map after Proyecto Otas, 2005).

The climate data analyzed here, as well as the results from a number of related studies, indicate that global Climate Change and high local global warming may have effects on central Chile and the El Roble hill. Given these results, the observed degradation of the *Nothofagus macrocarpa* forest is most likely the result of a mix of anthropogenic disturbance and global warming. As a consequence of the historical extraction of ecosystem services detailed in

chapter 4, the El Roble hill vegetational community has undergone longstanding perturbation. Until the 1970s, mining for gold, silver and shale was extensive. Other destructive practices include the cutting of trees for firewood and charcoal production, and the extraction of soil for sale. Logging, especially of large Santiago white oak trees, appears to have been extensive at El Roble hill up until 30-40 years ago. The lingering effects are a reduction in forest regeneration, the conversion of tall forest into low shrubland, and the widespread occurrence of small saplings proliferating from the stumps of cut trees (Armesto, 1995; see Fig. 5.24).

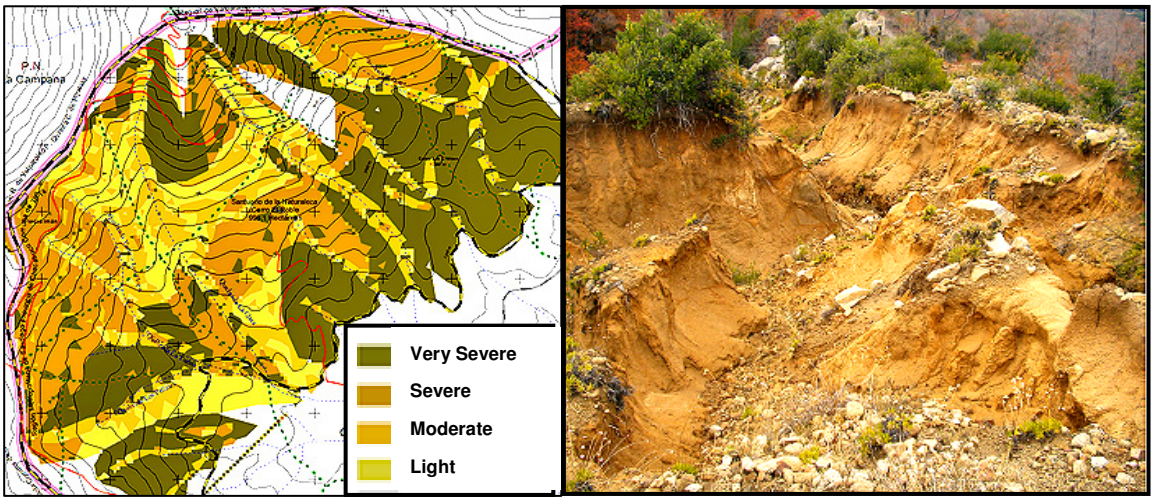


Figure 5.23a (left) and Figure 5-23b (right). Map of erosion severity within the Cerro El Roble Nature Sanctuary (Map after Proyecto Otas, 2005). Example of severe erosion at El Roble (After Donoso, 2007).

Like many other areas in the Mediterranean biome of central Chile, the El Roble ecosystem has also been impacted by the introduction of exotic plants and animals (Sala et al. 2000). In particular, European rabbits have seriously limited the regeneration of *Nothofagus macrocarpa* and other plant species through predation on seeds and seedlings (Fuentes, 1983). The ongoing reduction in the abundance of native predators has also exacerbated the impact of the rabbit population (Jaksic 1997). Besides introduced rabbits and hares, vegetation in the foothills and mountains of the coastal range has also been affected by intense

grazing pressure from cattle and goats. As a consequence many species of exotic annuals have proliferate throughout the area. Among the most common introduced annuals are *Erodium spp*., *Bromus spp*., and *Avena spp*. (Mattei 1995). Adding to this problem are many species of alien weeds that have also spread through central Chile. In total, Chile's Mediterranean biome has more than 400 exotic species of plants (Arroyo & Cavieres, 1997). One of the many negative impacts of this proliferation of introduced flora is the intense competition with the endemic flora for limited water and nutrients and the reduction of native species diversity. At El Roble hill, the historical use of the ecosystem for cattle grazing continues and, by most accounts, still impacts the entire area of the Cerro El Roble Nature Sanctuary (Fig. 5.22).

One of the major consequences of these anthropogenic disturbances has been an increase in runoff which has resulted in greater erosion and consequent loss of topsoil and nutrients (Figs. 5.23a and 5.23b). As runoff increases, the restoration of soil moisture and aquifers, vital for the regeneration of the ecosystem during the dry season, and especially during extended droughts, is significantly reduced. As the map in Figure 5.23b illustrates, severe to very severe erosion now afflicts 15-20% of the area of the Cerro El Roble Nature Sanctuary.

Figure 5.24. Example of shoots growing out of the stump of a large oak tree in the El Roble sanctuary (After Donoso, 2007).

Thirty years ago, Golowash (Golowash et al, 1982) noted the alarming lack of regeneration of the Santiago white oak forest at El Roble hill. The net impact of the factors discussed above have continued to cause further deterioration of the ecosystem over the ensuing three decades. If the shrinkage of the core Santiago white oak habitat continues at historic rates, dense oak stands will cover only 1.5% of the area of El Roble hill by 2050 compared to 12% or more in 1975.

Given the long-term trend towards greater fragmentation identified here, the remaining Santiago white oak forest will also consist of increasingly small and isolated patches of trees. Projecting from established species-area considerations, the reduction in the extent of the Santiago white oak forest alone has undoubtedly caused extinctions within the resident flora and fauna, and will continue to have a negative impact on biodiversity if current conditions continue into the foreseeable future. The deleterious effects of fragmentation on forest ecology have also been thoroughly documented (Bierregaard et al, 2001).

In general, greater separation of habitat fragments reduces pollination, seed dispersal, productivity, and resident population abundances. Greater edge to core habitat ratios also increase rates of predation and parasitism, and change the physical conditions of the remaining forest (Tewksbury et al, 2002).

While the establishment of the Cerro El Roble Nature Sanctuary appears to have alleviated some of the anthropogenic impact on El Roble hill, the prognosis for the future health of the ecosystem and the services that it provides is discouraging. Central to the recovery and future sustainability of the Cerro El Roble Nature Sanctuary is a viable management plan that is based on a foundation of sound ecological science and best practices in conservation. The next chapter addresses this complex issue in light of the conclusions reached in this and previous chapters.

5.8. Conclusions

The specific conclusions emerging from this chapter are:

(1) Hill El Roble is important for its high endemism, richness, biodiversity and uniqueness of its flora and fauna.

(2) Hill El Roble contains a relict remnant of Santiago's white oak (*Nothofagus macrocarpa*).

(3) The deciduous Santiago's white oak forest dominates the vegetation of the El Roble hill and it is the northern area in Chile.

(4) The dense-closed canopy of *Nothofagus macrocarpa* is present only on south and southwest facing slopes, which have more favorable moisture conditions.

(5) There is a highly significant regression between NDVI (equivalent to photosynthetic tissue) and the average monthly precipitations during austral winter.

(6) There is a statistically significant increase in fragmentation from 1975 to 2012. However, there is a small reduction since 2008 to 2012, which could indicate a possible protected status effect.

(7) Local temperature increase (1.2 ℃) and Climate Change seems do have a relationship with the losses of forest, but it is not possible to identified the effect of them from the losses are due to anthropogenic disturbances.

(8) The introduction of rabbits, cattle and goats had a great impact in the hill, including increased erosion.

5.9. References

Armesto JJ, Arroyo MTK, Hinojosa LF. 2007. The Mediterranean Environment In The Physical Geography Of South America. Veblen, Young, Orme, editors. Oxford University Press. UK.

Arroyo MTK, Cavierres L, Marticorena C, Muñoz-Schick. 1995. Convergence in the Mediterranean floras in central Chile and California: insights from comparative biogeography. Arroyo MTK, Zedler PH, Fox MD, editors. Ecology and Biogeography of Mediterranean Ecosystems in Chile, California and Australia. Springer-Verlag, New York. Pages:43-88

Aveschile, 2006. Sitio Prioritario El Roble, Comuna de Lampa. Guia Educativa Para La Conservación De La Biodiversidad. Santiago, Chile.

Barnosky AD, Hadly EA, Bascompte J, Berlow EL, Brown JH, Fortelious M, Gerz WM, Harte J, Hastings A, Marquet PA, Martinez ND, Mooers A, Roopnarine P, Vermeij G, Williams JW, Gillespie R, Kitzes J, Marchall C, Matzke N, Midell DP, Revilla E, Smith AB. 2012. Approaching a state shift in earth's biosphere. Nature 486: 52–58.

Barnosky AD, Matzke N, Tomiya S, Wogan GOU, Swartz B, Quental TB, Marshall C, Mcguire JL, Lindsey EL, Maguire KC, Mersey B, Ferrer EA. 2012. Has the earth's sixth mass extinction already arrived? Nature 471: 51–57.

Bierregaard R, Gascon C,. Lovejoy TE, Mesquita R, editors. 2001. Lessons From Amazonia: The Ecology And Conservation Of A Fragmented Forest. Yale University Press. USA.

Borgerhoff Mulder M, Coppolillo P. 2005. Conservation: Linking Ecology, Economics, And Culture. Princeton University Press. Princeton, NJ. USA.

Cardinale, B. 2012. Impacts of biodiversity loss. Science Vol. 336: 552-553.

Collins, SL. 2009. Biodiversity under global change. Science Vol. 336: 1353-1354.

Chambers JQ, Asner GP, Morton DC, Anderson LO, Saatchi SS, Espırito-Santo FDB, Palace M, Souza Jr. C. 2007. Regional ecosystem structure and function: ecological insights from remote sensing of Tropical forests. TRENDS In Ecology And Evolution 22: 414-423.

Christensen NL, Bartuska AM, Brown JH, Carpenter S, Cohen C, Warren B, Goward SN. 2004. Landsat's role in ecological applications of remote sensing. Bioscience 54:535-545.

Collins SL. 2009. Biodiversity under global change. Science Vol. 336: 1353-1354.

CONAMA. 2004. Plan De Acción El Roble. Gobierno de Chile. Santiago, Chile.

De La Maza M, Lima M, Meserve PL, Gutierrez JR, Jaksic FM. 2009. Primary production dynamics and climate variability: ecological consequences in semiarid Chile. Global Change Biology 15: 1116–1126.

Donoso L. 2007. Propuesta De Intervención Silvícola Con Fines De Conservación Para La Formación Boscosa De Nothofagus Macrocarpa. Tesis. Departamento De Silvicultura. Escuela De Ciencias Forestales Facultad de Ciencias Forestales. Universidad de Chile. Santiago, Chile.

Falvey M, Garreaud RD. 2009. Regional cooling in a warming world: recent temperature trends in the southeast Pacific and along the west coast cf Subtropical south America (1979–2006). Journal Of Geophysical Research 114: 1-16.

Fischlin A, Midgley GF, Price J, Leemans R, Gopal B, Turley C, Rounsevell M, Dube P, Tarazona J, Velichko A. 2007. Ecosystems, Their Properties, Goods, And Services. In Parry ML, Canziani OF, Palutikof JP, Van Der Linden PJ, Hanson CE, editors. Climate Change 2007: Impacts, Adaptation And Vulnerability. Contribution Of Working Group II To The Fourth Assessment Report Of The Intergovernmental Panel On Climate Change. Cambridge University Press. Cambridge, UK. Pages: 211-272.

Foreign Investment Committee (FIC). 2001. Chile's Environmental Management Framework. Riquelme M, editor. Gobierno de Chile. Santiago, Chile.

FSC-Chile. 2009. Controlled Wood Risk Assessment: Plantations In Chile. Forest Stewardship Council. Santiago, Chile.

Fuentes ER, Jaksić FM, Simonetti JA. 1983. European rabbits versus native rodents in central Chile: effects on shrub seedlings. Oecologia 58: 411-414.

Fuentes ER, Avilcs R, Segura A. 1989. Landscape change under indirect effects of human use: the Savanna of central Chile. Landscape Ecology 2: 73-80.

Fundacion TERRAM. 2005. Áreas Protegidas Privadas En Chile. Documento de Trabajo. Santiago, Chile.

Gajardo R. 1994. Clasificación De La Vegetación Natural De Chile. Editorial Universitaria. Santiago de Chile.

Garreaud RD, Vuille M, Compagnucci R, Marengo J. 2009. Present-day south American climate. Palaeogeography, Palaeoclimatology, Palaeoecology 28: 180–195.

Golowash J, Arroyo MK, Villagran C, Armesto JJ. 1982. Características demográficas de una población de *Nothofagus oblique* (Mirb.) Blume Var. Macrocarpa DC. en el cerro El Roble (33° Lat. S) en Chile. Bol. Mus. Nac. Hist. Nat. Chile, 39: 37-44.

Holmgren M, Lopez BC, Gutierrez JR, Squeo FA. 2006. Herbivory and plant growth rate determine the success of El Niño southern oscillation-driven tree establishment in Semiarid south America. Global Change Biology 12: 2263–2271.

Ibarra Basoalto MF. 2008. Determinación De La Incidencia De La Radiación Como Factor Físico Y Facilitador Ecológico En El Santuario “Cerro El Roble”. Tesis. Universidad de Chile, Santiago, Chile.

IUCN (International Union for Conservation of Nature). 2012. International Union for Conservation of Nature Red List. [Accessed on 5/13/2012 http://www.Iucn.org/About/Work/Programmes/Species/Red_List/]

Jaksic FM. 1997. Ecología de Vertebrados de Chile. Ediciones Universidad Católica de Chile. Santiago. Chile.

Kerr J, Ostrovsky M. 2003. From space to species: ecological applications for remote sensing. TRENDS In Ecology And Evolution 18: 306-314.

Klausmeyer KR, Shaw MR. 2009. Climate change, habitat loss, protected areas and the climate adaptation potential of species in Mediterranean ecosystems worldwide. PLoS ONE 4(7): e6392. doi:10.1371/journal.pone.0006392

Liu J, Dietz T, Carpenter SR, Alberti M, Folke C, Moran E, Pell AN, Deadman P, Kratz T, Lubchenco J, Ostrom E, Ouyang Z, Provencher W, Redman CL, Schneider SH, Taylor WW. 2007. Complexity of coupled human and natural systems. Science Vol. 317: 1513-1516.

Mcgarigal K, Cushman SA, Neel MC, Ene E. 2002. FRAGSTATS: Spatial Pattern Analysis Program For Categorical Maps. Computer Software Program. University Of Massachusetts, Amherst. [Accessed on 5/13/2012: http://Www.Umass.Edu/Landeco/Research/Fragstats/Fragstats.Html]

Maestre FT, Quero JL, Gotelli NJ, Escudero A, Ochoa V, Delgado-Baquerizo M, García-Gómez M, Bowker MA, Soliveres S, Escolar C, García-Palacios P, Berdugo M, Valencia E, Gozalo B, Gallardo A, Aguilera L, Arredondo T, Blones J, Boeken B, Bran D, Conceição AA, Cabrera O, Chaieb M, Derak M, Eldridge DJ, Espinosa CI, Florentino A, Gaitán J, Gatica MG, Ghiloufi W, Gómez-González S, Gutiérrez JR, Hernández RM, Huang X, Huber-Sannwald E, Jankju M, Miriti M, Monerris J, Mau RL, Morici E, Naseri K, Ospina A, Polo V, Prina A, Pucheta E, Ramírez-Collantes DA, Romão R, Tighe M, Torres-Díaz C, Val J, Veiga JP, Wang D, Zaady E. 2012. Plant species richness and ecosystem multifunctionality in global drylands. Science, Vol. 335: 214-218.

Murcia C, Kattan G. 2009. Application of science to protected areas management: overcoming the barriers. Annals Of The Missouri Botanical Garden. Volumen 96, Number 3:508-520.

Noss, RF. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology Volume 4, Issue 4, (December). Pages 355–364.

Perrings C, Duraiappah A, Larigauderie A, Mooney H. 2011. The biodiversity and ecosystem services science-policy interface. Science Vol. 331: 1139-1140.

Perrings CS, Naeem FA, Bunker DE, Burkill P, Canziani G, Elmqvist T, Ferrati R, Fuhrman J, Jaksic F, Kawabata Z, Kinzig A, Mace GM, Milano F, Mooney H, Prieur-Richard AH, Tschirhart J, Weisser W. 2010. Ecosystem services for 2020. Science 330: 323-324.

Reich P, Tilman D, Forest I, Mueller K, Hobbie SE, Flynn, Eisenhauer DFB, Nico E. 2012. Impacts Of Biodiversity Loss Escalate Though Time As Redundancy Fades. Science Vol. 336: 589-592.

Sala OE, Chapin FS, Armesto JJ, Barlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke L, Jackson RB, Kinzing A, Leemans R, Lodge DM, Moonet HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Hall DW. 2000. Global biodiversity scenarios for the year 2100. Science 287: 1770-1774.

Schröter D, Cramer W, Leemans R, Prentice IC, Araújo MB, Arnell NW, Bondeau A, Bugmann H, Carter TR, Gracia CA, De La Vega-Leinert AC, Erhard M, Ewert F, Glendining M, House JI, Kankaanpää S, Klein RJT, Lavorel S, Lindner M, Metzger MJ, Meyer J, Mitchell TD, Reginster I, Rounsevell M, Sabaté S, Sitch S, Smith B, Smith J, Smith P, Sykes MT, Thonicke K, Thuiller W, Tuck G, Zaehle S, Zierl B. 2005. Ecosystem service supply and vulnerability to global change in Europe. Science Vol 310: 1333-1337. DOI:10.1126/Science.1115233.

Sepúlveda C. 1997. Incentivos para la creación y manejo de áreas silvestres protegidas privadas en Chile. Ambiente y Desarrollo. CIPMA. Chile. Vol XIII Nº 3. Pages: 38-46.

Sepúlveda C, García D. 1997b. Cooperación público-privada como estrategia para la conservación de la biodiversidad en Chile. Ambiente y Desarrollo. CIPMA. Chile. Vol XIII - Nº2. pp. 59 – 68.

Sepúlveda C. 2002. Áreas privadas protegidas y territorio: la conectividad que falta. Ambiente y Desarrollo. CIPMA. Chile. Vol XVIII Nº 2-3-4:119-124.

Sepúlveda C, Tacón A, Letelier E, Seeberg C. 2003. Las áreas silvestres protegidas de propiedad privada en la Ley de Bases Generales del Medio Ambiente. Ambiente y Desarrollo. CIPMA. Chile. VOL. XIX Nº 1:32-63.

Tewksbury J, Levey DJ, Haddad NM, Sargent S, Orrock JL, Weldon A, Danielson BJ, Brinkerhoff J, Damschen E, Townsend P. 2002. Corridors affect plants, animals, and their interactions in fragmented landscapes. Proc. Natl. Acad. Sci. 99: 12923–12926.

Thomas C, Cameron A, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, Erasmus BFN, Ferreira De Siqueira M, Grainger A, Hannah L, Hughes L, Huntley B, Van Jaarsveld AS, Midgley GF, Miles L, Ortega-Huerta MA, Peterson AT, Phillips OL, Williams SE. 2004. Extinction Risk From Climate Change. NATURE 427: 145-148.

Turner W, Spector S, Gardiner N, Fladeland M, Sterling E, Steininger M. 2003. Remote sensing for biodiversity science and conservation. TRENDS In Ecology And Evolution 18: 299-305.

Ustin SL, Roberts DA, Gamon JA, Asner GP, Green RO. 2004. using imaging spectroscopy to study ecosystem processes and properties. Bioscience 54:523-534

Wardle DA, Bardgett Richard D, Callaway Ragan M, Van Der Putten, Wim H. 2011. Terrestrial ecosystem responses to species gain and losses. Science Vol 332: 1273-1277.

Willig, M. 2011. Biodiversity and productivity**.** Science 333: 1709-1710.

6. STRATEGIES FOR MANAGEMENT AND RECOMMENDATIONS FOR CERRO EL ROBLE NATURE SANCTUARY

6.1. Introduction

The Cerro El Roble Nature Sanctuary has a Participatory management plan that closely follows that of La Campana National Park —a coastal climate park belonging to Chile's V Region and administered by the central government— making it inadequate for El Roble hill; because they are conformed by different ecosystems. Therefore, there is an impending need for developing a sound management plan for Cerro El Roble Nature Sanctuary.

This section addresses the necessity for a sound management approach to nature in a context of rapid and frequent changes (Turner III, 2008). Management approaches have evolved from simple exploitation to ecosystem management with a broad gamut of other intermediate approaches (Chopin III et al. 2009).

Ecosystem management looks to maintain ecosystem services (Christensen et al. 1996). However, this approach also has the setback that often uses historic reference conditions and factors, many of those not attainable in a rapid-changing world (Chopin III et al. 2009). The definition of Ecosystem Management, by Christensen et al. (1996), expresses that it is management-driven (by goals), executed (by policies, protocols and practices), and made-adaptable (by monitoring and research based on the understanding of the ecosystems at hand) by studying the ecological interactions and processes necessary to sustain ecosystem composition, structure and function, (Noss, 1993).

Ecosystem management does not focus on ecosystem services providers, or ecosystem services units; but rather on the sustainability of the ecosystem structure and processes necessary to maintain recurrent deliveries from those providers (Christensen et al, 1996).

Community-based Resource Management is a management system that involves community members and local institutions, and produce a reconciliation between socio-economic goals with conservation goals. However, there is a collection of inadequate results for those goals, as show in Table 6.5.

Ecosystem stewardship is an evolving ecosystem management strategy that aims to better equip society to manage challenges by identifying pragmatic strategies that increase the likelihood of socially beneficial outcomes while reducing the possibility of adverse outcomes. The central goal of ecosystem stewardship is integrating three basic approaches to sustainability, mainly: (1) anticipate changes and stresses in order to assess and reduce vulnerability, (2) confront perturbations and uncertainty; it in order to foster proactive strategies for resilience to sustain desirable conditions; and (3) when specific opportunities become available; it acts upon the ecosystems to transform undesirable trajectories (Chopin III et al. 2009).

The recommendations given below are based on a management effectiveness evaluation and on critiques of the Participatory management plan of Cerro El Roble Nature Sanctuary. Based on those results and with the knowledge obtained in the studies presented in other chapters, I offer a set of recommendations for the future management of the hill.

Next, I review the concepts supporting four main strategies for managing protected areas, mainly: science-based, community-based, landscape, and ecosystem stewardship. These approaches will be used to examine the Management Plan of Cerro El Roble Nature Sanctuary.

6.2. Science-based Management for Protected Areas

6.2.1. Definition of Ecosystem Management

As stated in chapter 4, Ecosystem can be defined as the joint product of biotic and abiotic elements and the complex interactions among them. On the other side, Management can be described as a way of administering to achieve “sustained superior performance”. As stated above by Christensen et al. (1996), the ecosystem management is “driven by goals; executed by policies, protocols and practices; and made-adaptable by monitoring and research based on the understanding of the ecosystems at hand, this being possible by studying the ecological interactions and processes necessary to sustain ecosystems and landscapes”.

6.2.2. Elements of Ecosystem Management

Ecosystem management is composed of 8 elements proposed by Christensen et al. (1996) in the Report of the Ecological Society of America (Committee for Ecosystem Management). The first element draws attention to sustainability. Ecosystem management takes among its working criteria intergenerational sustainability. Because of this, the manager needs to assume responsibility to deliver opportunities and resources at several generations.

The important second element is the goals. Establishing goals should be directed towards attaining “desired future trajectories” or “desired future behavior” of processes necessary for sustainability more than directed towards maintaining ecosystem goods and services. It is important that the goals be written in such a way that they can be measured and monitored, providing a mean to assess progress.

Ecological Models are the third element to consider since ecosystem management depends on conducting research in all ecological hierarchy levels

of organization. The fourth component of ecosystem management is complexity. Biodiversity and structural complexity together with connectedness are critical to ecosystem's functions for resistance and resilience to perturbations. Ecosystem management acknowledges that events and perturbations happen given sufficient time and space.

Conservation and preservation do not mean keeping the status quo; on the contrary, the fifth element is the dynamic of ecosystems. Ecosystem management recognizes change and evolution over space and time as inherent to all ecosystems.

The sixth component of the ecosystem management is space and time scales, because ecosystems behave over a wide range of scales, their behavior is also affected by external factors. Determining the ecosystem's behavior at a particular location in those scales is of basic importance for ecosystem management.

Social systems are integral components of ecosystems in the ecosystem management approach, and must be engaged to achieve sustainability. It is necessary, as a society, to address issues such as population growth, poverty or human perception with regard to the use of ecosystem services and energy; this is why Christensen et al. (1996) listed social systems as the seventh component of ecosystem management.

Finally, the eighth element is adaptability and accountability. Ecosystem management needs to acknowledge the fact that it is just one paradigm and is subject to change, for that reason; adaptation to new knowledge and paradigms is a must in ecosystem management.

6.2.3. Ecology-based Ecosystem Management

Hierarchical scales of organization in ecology are individual, population, community, ecosystem, landscape, biome, biosphere and ecosphere. The special characteristic of the ecosystem level is that, it is the first level in the

ecological hierarchy that not only includes the biotic part (animals and plants), but also the abiotic part (rocks, air, sediments, water, glaciers, among others). Therefore, ecosystem management not only is interested in stewardship the biodiversity, but also the abiotic components, which are not included as "environment" of the living organisms, but as part of the system.

Christensen et al. (1996) state that different challenges, such as management of wildlife or development of a plan for ecological restoration, may need to work mainly with one scale of organization, but for a complete understanding or resolution of ecosystem management issues, the integration of different scales and levels of organization need to happen.

The only reason why we keep defining boundaries of management jurisdictions with no reference to ecological process is our ignorance of the importance of these processes operating under wide ranges of temporal and spatial scales (Christensen et al. 1996).

Ecosystem functions are usually related to ecosystem processes, especially those referring to biogeochemical cycles. One process, or a set of processes, could lead to the development of one ecosystem service or a multitude of them. There is not a linear relationship between one function and one service; instead, the relationship is dynamic and complex. Examples of ecosystem functions and their related –but not unique- ecosystem services are presented in Table 6.1.

Table 6.1. Shows some examples of Ecosystem Functions and an Ecosystem Service related to it.

Ecosystem Function	Ecosystem Service closely related
Microclimatic regulation	Regulation of extreme temperatures
Nitrogen cycle	Availability of nitrogen in chemically-usable forms
Water cycle	Fresh water availability
Polinization	Available pollinated fruits
Ecosystem operations	Scenic view and aesthetics

Ecosystems have two types of boundaries: spatial and temporal. An ecosystem has a defined extension and shape, while also having a defined

temporal scale, which is characterized by the timing of processes and flow interactions among components.

Biological diversity inside ecosystems provides for stability or resistance, and for recovery after a perturbation (resilience) or “disturbances that disrupt” ecosystem processes (Christensen et al. 1996). Ecosystem management is a hard task because managers usually try to work with areas that change. For example, ecosystem dynamics may happen in a “continuous long-term change” (Christensen et al. 1996).

At this point in sciences, ecosystem ecology is still a field under-developed with an important amount of knowledge yet to learn, specially about the ecosystem’s behavior. “Unpredictable processes and phenomena that produce unknowable responses” are the main cause for uncertainty (Christensen et al. 1996), together with limitations in our understanding and measurement errors. Ecosystem management does not stop uncertainties from happening; it is instead an adaptative process that mixes science, education, and institutional learning with democratic values.

Historically, ecology has studied the relation of distribution and abundance of the populations and the material, energy or information fluxes in ecological systems, without the intervention or interaction with humans. Humans have not been part of the components in the ecosystem models.

6.2.4. Scientific Models for Ecosystem Management

Christensen et al. (1996) highlight that knowledge and ways of understanding ecosystem function, services, and best management practices are subject to change, with new information and changes in paradigms in science.

The ultimate goal in management is maintaining the provision of many goods and services in a sustainable fashion for future generations. This broadly stated conservation goal should be translated into specific operational objectives

and expectations (Christensen et al, 1996); generally stated, “desired future behavior” is the notion that captures these objectives better.

In order to more accurately determine if specific management activities are leading towards attaining the desired objectives, it is necessary that the expectations be stated in such a way that relate to specific measurements that can be incorporated into monitoring programs (Christensen et al, 1996).

The implementation of –for example– a prescribed fire program should lead to specific expectations with respect to key ecosystem properties and processes to be protected (Christensen et al, 1996).

In order to understand the evolution of complex systems, models are essential tools. Based on the fact that it is impossible to design monitoring programs to measure the dynamics of every biodiversity feature, models are needed to identify specific components or to better calibrate the expectations for the behavior of particular ecosystem processes. Models can also be very useful for defining or identifying specific indices and indicators that provide appropriate measurements of the behavior of the ecosystem properties (Christensen et al, 1996).

The current challenges with data processing for ecosystem management are that: (1) despite the fact that much data is being gathered, most of it is not easily accessible or has serious problems of data incompatibility; (2) some areas –like hydrology– have well-developed standards for gathering of data while others –like biodiversity– have none; and (3) because of institutional structures and organizational management bureaucracies, there is valuable information that is largely inaccessible. In addition, there is the need for guaranteeing that accurate information is made available in a timely fashion to managers in ways that can directly impact decision making (Christensen et al, 1996). Monitoring, defined as “the gathering and analysis of data”, is mainly (1) focused on management expectations, and (2) designed to test the proficiency and efficacy of the specific decisions and actions. Monitoring needs to be better designed to

determine whether or not decisions and actions are producing the expected results (moving the ecosystem towards the goals and objectives). Monitoring programs need to be based on accepted rigorous statistical sampling design methodologies that assure precision and avoid biases in data gathering.

Limitations of the monitoring processes are not an excuse not to establish monitoring programs. However, those limitations should never be reflected in any conclusion about management actions. Even more, the design, development and maintenance of monitoring programs requires long-term vision. A decision to continue, modify or abandon a given management strategy is often directly related to actions that present the greatest risk to long-term sustainability.

There is much need for further research in the area of ecosystem management, not only in ecosystem management as an applied discipline, but also ecosystem ecology as a basic science in order to have a better understanding of how ecosystems work and of how ecosystem functions are related and interconnected to each other, and therefore to have a better understanding of how ecosystem services are ultimately produced.

6.2.5. Implementing Ecosystem Management

Ecosystem management should be seen as a collection of protocols and actions that allow the ecosystem to deliver its ecosystem services in the very long-term (Christensen, 1996). Ecosystem management should be focused on ecosystems and their value determined beyond typical market prices including indirect value or even intrinsic value. There is a necessity for sustainable goals and objectives in the implementation of ecosystem management strategies.

For most governmental agencies, sustainability is a legally mandated requirement for the stewardship of natural resources. This concept is understood as an acknowledgement of the importance of diversity and complexity, and its influence of and impact on proximity areas under management (Christensen, 1996).

The strategies followed by the ecosystem management should have sustainability as the primary objective for the ecosystem and its ecosystem services, and levels of commodities and amenities provisioning should be adjusted to meet that goal (Christensen, 1996).

Reconciling spatial and temporal scales is another important defiance in the implementation of ecosystem management. Spatial scales and borders of management jurisdictions, most of the time, are not congruent with the behavior of processes central to sustaining ecosystem functions. Therefore, reconciliation of management objectives and actions of the various stakeholders within the domain of an ecosystem must be a central element in the implementation of sustainable management strategies (Christensen, 1996).

One of the most important challenges for implementing ecosystem management, and because of it, for accomplishing any ecosystem management plan, will depend on the identification and involvement, from the beginning, of stakeholders into the planning process (Christensen, 1996). On the other side, ecosystem management needs to deal with time scales that usually transcend the human span, and almost always exceed the timeline for the political, social and economics agendas (Christensen, 1996).

In order to implement ecosystem management with success, we must develop strategies that not only incorporate long-term planning, but also recognize the necessity to make short-term decisions (Christensen, 1996).

Adaptive management should be a fundamental component of the implementation of ecosystem management. Ecosystem management must acknowledge uncertainty and lack of knowledge, and adaptable and accountable systems are needed. Ecosystem management depends on institutions that are adaptable to variations and changes in ecosystem features, as same as changes in our basic knowledge of ecosystems (Christensen, 1996).

In order to be aware of the consequences that conventional management procedures have on complex and dynamic ecosystem components and

processes, needed to keep ecosystem functions and services maintained over time, it is necessary that decision makers be driven towards improving outcomes over biological and ecosystem timescales, while also being aware that ecosystem management is still of experimental nature; and be willing to accept risk of failure (Christensen, 1996).

The IPCC was in charge of organizing the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) to identify causes and consequences of human-driven change in ecosystems. The conclusions were that there is a growing consensus: “solution to the problems created by environmental global change requires a coordinated international research guidance, better resources than before, and taking into account social sciences as much as natural sciences.” (Perrings et al., 2011).

6.3. Community-based Resource Management for Protected Areas

6.3.1. Who is the Community?

Stakeholders, locals, and “community” are not undifferentiated groups, but a collection of people belonging to different ethnic groups, gender, clans, economic classes, social classes, etc. Every community is unique in its compositions of groups of interest; they could be directly or indirectly involved with the ecosystem services, or in our case, with the whole El Roble hill. Any attempt to involve the community in a participatory approach should recognize and respect the differences and diversity among groups.

It is possible to recognize that there are two types of community. The geographical community is formed by people who live inside a specific geographical area. The functional community, on the other side, is a group of individuals or families who might be living in different geographical areas, but who share really important characteristics of life (habits, customs, manners, languages, traditions, among others).

All the people who live in a delimited area and depend on the ecosystem services, including representatives of government and NGOs, are all sometimes part of the community, and could play key roles in planning and implementing a management plan for a protected area.

6.3.2. Working with the Community

There are at least three management approaches for looking inside of a community:

(1) *Integrated management* is usually top-down using a central-plan designed and implemented by authorities that are different of the resources' users. In this approach, decisions are consistent with the national legal and jurisdictional framework for management. Also, this approach involves the implementation and enforcement of public policies. (National Marine Sanctuaries, no date available)

(2) *Community-based management* involves local management and local responsibility; it is a bottom-up approach that involves local users of the resources and active members of the community. (National Marine Sanctuaries, no date available)

(3) *Collaborative management* (horizontal), it involves dynamic partnerships; it's more complex to reach and incorporate both a top-down and bottom-up approaches. It is used usually when (local) governments share responsibility and work together in dynamic partnerships. (National Marine Sanctuaries, no date available).

6.3.3. Community-based Resource Management

Community-based Resource Management (C-bRM) is a management system that includes community forestry, community wild life management, and buffer zone management, among others. The general characteristics of C-bRM are: (1)

involves community members and local institutions in the management and conservation of natural resources (ecosystem services in our case); (2) reconciles the goals of socio-economic development and conservation, and protection of nature; (3) has a tendency to legitimize the locals and their rights; and (4) tries to include traditional values and ecological knowledge in the management (Kellert et al, 2000).

C-bRM is used as a way to improve socioeconomic level of life of local and rural people, with emphasis on power structure, participation and property rights of the indigenous, locals and other marginalized people.

Identifying stakeholders is the first step; however, we need to ensure that they will be involved in the planning process. Usually the local community has some form of elected or designated authorities who want to be incorporated in the management plan and in its debate. Active participation leads to empowerment through learning of resource management matters, and as a result, the community becomes involved in finding and implementing solutions.

It is important to realize that community participation is a learned skill and depends on their level of confidence to articulate their concerns and visions and take an active role. The community organizer works with local community members to improve their participatory skills.

A study of the individuals, groups, and institutions that could have some control or influence over the plan's success should be developed to identify the best approach to involve these individuals in the management plan.

This evaluation should include at least: (1) assessing characteristics of the group; (2) determining the general stance of the group; (3) identifying the current situation of the group and problems they face; (4) recognizing strengths and weaknesses of the group; (5) identifying interests, needs and goals of the group; (6) capturing expectations and fears of the group; (7) assessing capabilities and skills of the group; (8) estimating availability of resources of the group; and (9)

specifying goals and mandates of the institution or organizations in relation to the protected area and resources (National Marine Sanctuaries, no date available).

The levels of Community Involvement of the stakeholders can be classified into seven categories, as illustrated in Table 6.2.

Table 6.2. Shows the type of participation identified and its description. (Source: National Marine Sanctuaries, ND).

Typology	Description
Passive participation	In this type of participation people are being told what is going to happen or has happened. The administration or project manager is in power and they receive unilateral announcements without involving the feedback of the people.
Participation by giving information	This type of participation involves answering questions made from researchers. In this case, again people are powerless.
Participation by consultation	In this case, people are "consulted by some external agents" who listen to their views. Once again, the people are powerless.
Participation for material incentives	Participation is given by the people providing the resources (labor, information), in return for any material incentives.
Functional participation	People form groups to meet determinate goals or objectives about the project. Usually those groups are dependent on external initiators and facilitators.
Interactive participation	In this type of participation there is a joint analysis. These analyses produce results that will influence actions and plan formations of new local institutions. Also, this interactive participation produces groups that take control over local decisions, and because of that, the community has a stake in maintaining structures and practices.
Self-motivation	Some people participate by taking their own initiative independent of external institutions for pressure, recourses or technical advice. However, they usually keep control over how resources are used.

It is possible the identification of four main types of actions in interaction with the locals, this is illustrated in Table 6.3.

Table 6.3. Identification and activities with Community. (Source: National Marine Sanctuaries, ND).

Community	Description
Identifying stakeholders and forming partnerships	The first step in a community-based approach is the identification of the most important (key) stakeholders, the community and other participants.
Community organization and mobilization	The NGO or local government can assist the community in finding a good community organizer. The community organizer helps local communities participate more. Organized stakeholders are more accessible and involved.
Community participation in the planning process	With a good community organizer, it is easier for the community to participate in the planning process and the implementation process. Participation is important in this step. Also, the Plan should apply best management practices in the implementation of the plan and in the ongoing monitoring and evaluation, ensuring that the plan keeps meeting the community defined goals.
Information, education and communication	In order to release public awareness and for promoting the strategies and goals of the management plan, it is fundamental to have information, education and communication initiatives through the management plan planning and implementation steps.

6.3.4. Rhetoric and Reality in Community-based Resource Management

C-bRM, developed throughout the world for managing national parks and protected areas, led the idea among many experts that the combined effects of ecological insulation and permanent conflict with local people jeopardize the long-run sustainability of protected areas (Kellert et al., 2000).

Table 6.4. Show the results of an evaluation by Kellert et al (2000), about the accomplishment of goals in C-bRM.

Goal	Definition	Results
Equity	The distribution and allocation of socioeconomic benefits	A highly uneven distribution of benefits, some individuals and communities benefit differentially ones over others
Empowerment	Distribution of power and status, among local people, including authorities of government, plus participation in decision making, sharing of information and control and democratization	The extent and effectiveness of the devolution of power ended up being uneven and often questionably effective. Frequently, local communities were marginally more empowered that before C-bRM
Conflict Resolution	Resolution of conflicts and disputes over ecosystem services or environmental goods, among local and national institutions and interest	C-bRM didn't reduce the extent or frequency of resources disputes. Even more, sometimes it originates some conflict by expanding individual and group expectations, producing frustration associated with unrealistic assumptions.
Knowledge and Awareness	Consideration, incorporation and production of traditional and modern knowledge in management wilderness	Studies about C-bRM show that implementation of its goals was difficult to sustain and elusive to implement. There have been few occasions of systematic attempts of incorporate ecological knowledge from both traditional and scientific approaches.
Biodiversity Protection	Conservation and protection of biodiversity and ecosystem services	Socioeconomic goals of C-bRM usually are given much higher priority than the goals of biodiversity conservation at a point where the last one is subverting to socioeconomics objectives.
Sustainable Utilization	The use (consumptive and non-consumptive) of ecosystem services in such a way that it is assured to maintain long-term availability for present and future generations	In the C-bRM sustainable goals tended to be underemphasized and usually are mismanaged. C-bRM sometimes even increases the pressure to exploit ecosystem services and natural resources generally due to fueling expectations and increasing access. Monitoring of ecosystem to determine sustainability over long term was never an important priority.

6.4. Ecological Management of Landscape for Protected Areas

There are six broad issues in ecological management of landscape that are important to pay attention in order to carry on a relatively complete ecosystem management plan, as explain Lindermayer et al. (2008).

The first issue is Landscape Classification using a conceptual model to characterize a landscape grouping landscape elements into categories. These are very different from vegetation models and gradient-based models. Even given this diversity of tools, researchers usually continue using the patch-corridor matrix model; however, those models are too simplified dividing the landscape into habitat / no-habitat, thus losing many intermediate aspects of the landscape.

Habitat amount, including amount of cover land, patch sizes and mosaics is the second issue of interest. As it was stated before, habitat loss is one of the most important drivers of species loss around the world; therefore, it is fundamental to obtain data on how much habitat is needed to meet specific conservation goals. Habitat can be defined as: (1) a species-specific entity and (2) a particular land cover type. The area of a given land cover type usually doesn't demonstrate the actual amount of suitable habitat for the species of interest. The notion of "habitat" together with how landscapes are classified and mapped will determine what finally ends up being a "patch". This is relevant because there is a relationship between patch size and (1) size and extinction proneness of populations of species; (2) richness, and (3) many other factors (like immigration rates, disturbances, etc.).

A third issue is structure and condition of individual species, it could be somehow easy assessing the structure and condition of them, however, "assessing vegetation structure and condition is more complex for multiple species particularly because nearly all change in vegetation condition benefits some species but not other" (Lindermayer et at. 2008).

Connectivity is the fourth issue to keep in mind for the ecosystem management approach. Connectivity is a complex notion. Therefore, it is important to make a distinction between (1) habitat connectivity, which is the connectedness of the habitat patches for a specific reason, (2) landscape connectivity, which is the physical connectedness of patches of a singular land

cover type, and (3) ecological connectivity, which is the connectedness of ecological processes at multiple spatial scales (Lindermayer et at. 2008).

Edge effect refers to change in biological and physical condition that occurs at patch boundaries and within adjacent patches. To different edges effects may differ independently of the magnitude of the response (Lindermayer et at. 2008). This is why the significance of edges is the fifth issue to take into account.

The sixth issue to pay attention –and final one– is "disturbance, resilience and recovery". Because perturbations change and shape patches, ecosystems and landscapes; they influence biota and highlight the depth complexity and dynamics of ecosystem and landscapes. Improved biodiversity conservation might be better achieved by using natural disturbances to guide anthropogenic perturbation regimes.

Lidenmayer at al. (2008) identified four main themes that need to be considered for conservation decisions. These themes, partially modified by the author, gather 13 different factors as it is showed in Table 6.5.

Table 6.5. Themes and factors that should be considered for biodiversity conservation decisions. Modified from Lidenmayer at al. (2008).

Themes	Factors
Goals	Long-term visions and objectives
Spatial issues	Manage the mosaic Habitat (amount and configuration) and land cover types Endemic and endangered species and ecosystems Integration of aquatic and terrestrial ecosystems Landscape classification and models appropriate to objectives
Temporal issues	Resilience Management for change and adaptation Awareness for time lags
Management approaches	Experimental framework Complex biodiversity (genes, species and ecosystems) Management of multiple scales Contingencies

Among the conservation goals, it is possible to identifying three conservation objectives following Soule and Simberloff (1986) and other authors: (1) large ecosystems including their ecosystem services; (2) hotspots and natural communities; and (3) species of high or special interest.

(1) *Ecosystem and Ecosystem Services*: in order to comprehensively protect a functioning ecological system, it is necessary that the protected area be very large, not only to hold all the ecosystem processes, functions and services in the area, but also this type of conservation goal provides the only hope for also saving large-bodied mammals, like the *Puma concolor* (mountain lion), *Pudu puda* (small Chilean deer), and *Pseudalopex griseus* (grey fox), found in the areas of central-southern Chile.

(2) *Hotspots*: this concept was created with the finality of concentrating efforts in a few high priority areas where, using long-term management strategies, it is possible to protect at some basic level, most of the world's biodiversity. It is accurate to say that hotspot areas, covering only 1.4% of the land surface of earth, contain approximately 44% of all vascular plant species and 35% of all species in four vertebrate groups.

(3) *Species*: This is the most used approach to conservation because of the so-called "Umbrella Species" that most of the time are conspicuous cases of the most endemic and endangered species. In central Chile, the white oak is of special importance; it has a very limited range of distribution and is being heavily impacted by anthropogenic sources. In particular, *N. macrocarpa*, also known as Santiago's white oak has the category of been the northernmost white oak of the country. Some scientists consider it a living fossil.

6.5. Ecosystem Stewardship for Protected Areas

The first step to ecosystem stewardship calls for reducing the exposure to well recognized stresses both local and global in impact. Local stresses are well known to local managers, who also know what impact mitigation approaches have worked best in the past (Chopin III et al. 2009). Global-scale stresses require global policy changes; local efforts can only mitigate the effects while not reducing the magnitude of the stresses. Moreover, by monitoring trends over time for specific stressors, it is possible to reduce stresses or the exposure to them while also mitigating the social impact onto some of the most vulnerable people. For stresses that persist in spite of active management efforts, trajectories of expected change are more appropriate management goals than historical objectives or preset ranges of variability (Chopin III et al. 2009).

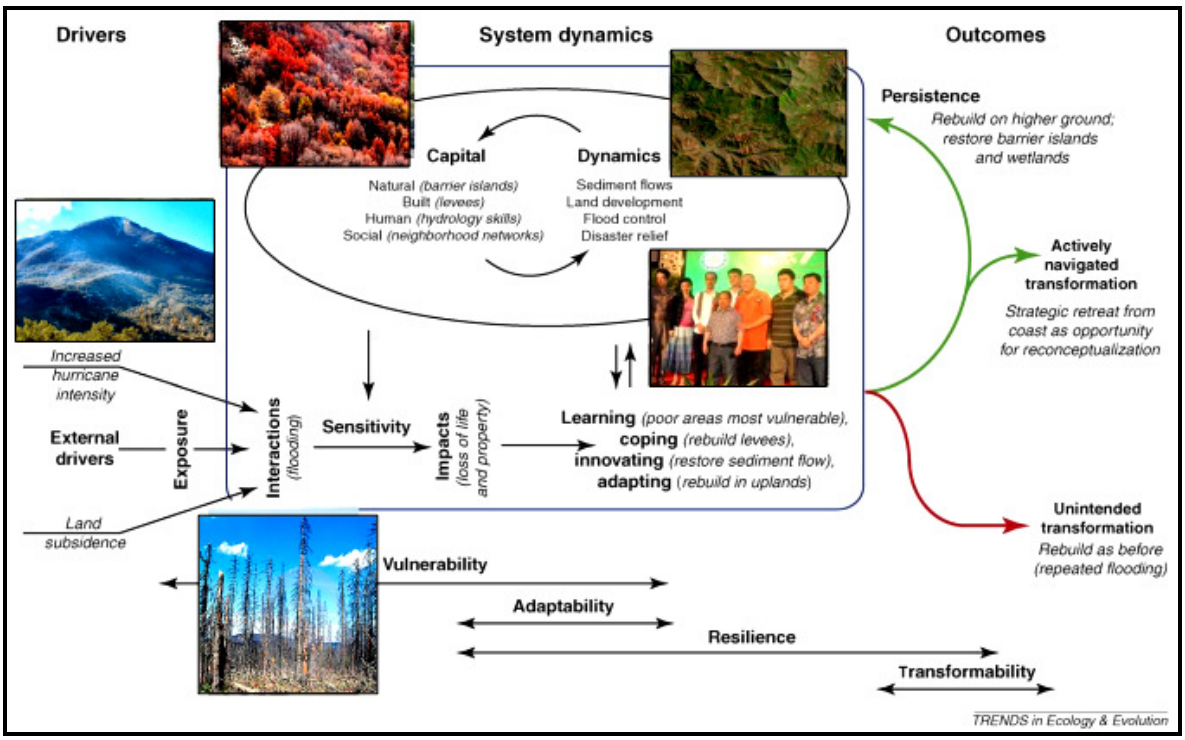


Figure 6.1. Ecosystem stewardship model. (Source: Chopin III et al. 2009).

The second step to ecosystem stewardship calls for relying on proactive strategies to address the challenges arising from uncertain changes that are often further exacerbated by indecision and paralysis resulting from over-analysis. Ecosystem stewardship pursues upfront intervention through resource management that seeks to actively induce change for sustainability while also preparing for unexpected challenges.

The third step to ecosystem stewardship calls for pursuing anticipatory decisions designed to convert systems trapped in an undesirable state into a more benign system characterized by different social-ecological controls.

Overall, ecosystem stewardship allows for actions that fully acknowledge social-ecological interdependencies between human activities and ecosystem services. It also allows for promoting innovation and negotiating tradeoffs as environmental and social challenges push any given system beyond its limits of adaptability. Furthermore, it allows for better utilization of available sources of socio-economic, biological and institutional diversity that along with social learning, managed experimentation and flexible governance facilitate system adaptation. Lastly, it allows for promoting alternative and more desirable trajectories of social-ecological change.

Ecosystem stewardship offers a pragmatic approach to adaptability that applies to all social ecological systems since no system is so resilient as to ignore the potential for threshold changes or so optimal as to ignore the potential for improvements of well-being, adaptive capacity and resiliency. Active ecosystem stewardship recognizes the need for dynamically optimizing people's perceptions, cultural values and governing systems to the dynamics of the biosphere.

6.6. Results of Strategies of Management

The management of the hill currently is carried on by the Comuneros Association of Caleu, without governmental supervision or help (see chapter 3). It produces

unsustainable management in terms of the environment and nature of the forest, plus, it is economically untenable because the Comuneros Association of Caleu spends money needed to improve the operating circumstances of the sanctuary and the conditions for tourism.

I conducted a review of the pros and cons of the (1) ecosystem management (2) community-based management, (3) landscape management, and (4) ecosystem stewardship. These are my results:

The Ecosystem management is too much complex to be developed in Caleu, and it needs an important budget and adequate institutions to make it work. Given the case of Caleu, where the owners are in charge of the management of the Cerro El Roble Nature Sanctuary, they also are poor and do not have the knowledge or skills to do it themselves. Chapter 5 shows how under their administration the Santiago white oak forest is disappearing through the decades.

The Community-based Resource Management is the best approach to work closely with the community; because this methodology: assess the groups; identify their situation; recognize their strengths and weaknesses, and their needs, expectations, capabilities; and it estimate resources available and goals.

Participation, on the participatory management plan of Cerro El Roble Nature Sanctuary, was passive, informative and by consultation (see Table 6.2), in opposition to active engaged participation. Moreover, results from a series of studies show that the Community-based Resource Management approach has a strong tendency to good intentions and failed results (see Table 6.4).

The Ecological Management of Landscape takes care in depth six issues to carry out a plan: landscape classification, habitat availability, condition or state of species, ecological connectivity, edge effect and perturbations. Lindermeyer et al. (2008) grouped and classified those issues as illustrated in Table 6.5. Regardless of the excellent approach to the ecology of the protected area, this

type of management does not pay attention to the community or social subsystem, therefore, is not a good fit for management of El Roble hill.

Ecosystem stewardship focuses on stresses, up-front intervention, anticipatory decisions and asks for actions that acknowledge the socio-ecological interactions.

Ecosystem stewardship is the necessary approach for the management of the Cerro El Roble Nature Sanctuary due to the necessity of including the community's opinions and needs (including those of the Comuneros and those of the no-Comuneros), political context (social elite and Calegüanos), economic situation, and the ecological state of the El Roble hill and the Santiago white oak forest (distribution and abundance).

6.7. Assessment of Management Effectiveness

The assessment of management effectiveness (IUCN Report) is defined as "how well protected areas are being managed" and most important "which is the extent of the management in achieving values, goals and objectives". The notion of *management effectiveness* involves evaluating three aspects of protected areas management: (1) "design" related to either individual sites or systems; (2) competence and suitability of management processes; and (3) reaching protected area objectives including conservation of values (Hockings et al. 2006).

Evaluation of management effectiveness is a responsive, pro-active and essential tool at local, regional, national, and increasingly, at international level. Nations are agreeing to report on progress in conservation to their peers through institutions such as the WHC[43] and the Convention on Biological Diversity. Different demands for information on status and trends and the needs for more data to meet the practical challenges of managing protected areas has produced

[43] World Heritage Convention.

exponential increases in monitoring and evaluation of management effectiveness (Hockings et al. 2006).

The four main evaluation criteria of management effectiveness are: (1) producing improved management under changing conditions; (2) helping tool for better allocation of resources; (3) involving the community; and (4) promoting conservation values.

The unfeasible task of developing one unique tool for assessment is a consequence of the wide range of management effectiveness evaluation principles together with the biological, cultural and social diversity of protected areas. To solve this challenge, a common framework was developed to serve as the basis for designing assessment systems.

In this way, different systems based on using a gradient of assessment tools can be used to carry out evaluations with different criteria and different scales and depths (Hockings et al. 2006).

The management of a protected area can usually follow a path with six elements as explains Hockings et al. (2006): (1) recalling the context of the area; (2) establishing a 'vision' for area management[44]; (3) planning and allocation of resources; (4) producing a result of management actions; (5) producing goods and services; and (6) having impacts or outcomes. These six stages are classical for a participatory management plan.

These indicators for the assessment of management effectiveness will be used in the results section to evaluate the management plan of the Cerro El Roble Nature Sanctuary.

6.7.1. Designing and Conducting an Assessment

For the purpose of designing and conducting an assessment Hockings et al. (2006) express that it is necessary go through the five phases: (1) defining

[44] Within the context of existing status and pressure.

assessment objectives (the scope of the assessment and resourcing); (2) choosing and developing a methodology (this includes establishing an assessment team and defining indicators); (3) Implementing the assessment; (4) interpreting and communicating to the community and stakeholders; and (5) use results to improve management.

I will develop an assessment based on the indicators captured in previous chapters, comparing the four criteria with the six paths that should be followed.

6.7.2. Management Effectiveness Evaluation

Management effectiveness evaluation has as its most important goal that of obtaining results[45] in support of better managed protected areas; these goals require identifying practical knowledge and taking action based on that knowledge. Another significant area is communication with community and stakeholders, with special emphasis on broadly disseminated public reports, along with good on-time feedback to the helpers of the assessment process.

In order to reach a successful management effectiveness evaluation, there are six aspects that need to be considered as identified by Hockings et al. (2006): first, move from trial and intermittent evaluations to regular exercises integrated assessments into the management and planning cycles of protected area institutions. Second, develop cooperative work (improves data coordination) to allow global compilation of essential reporting information. Third, "further develop cost-effective, meaningful monitoring systems and indicators, with emphasis on ecological integrity assessment and indicators for social, cultural and economic factors" (Hockings et al., 2006). Fourth, identify and practice new and better ways to interact with managers and communities. Fifth, draw data to find trends, themes and lessons across regions. Finally, results should be interpreted, communicated and used.

[45] Results can be used to adapt plans and practices, adjust resource allocation, revise policies and affirm good work being undertaken, at local, regional and global levels.

The six aspects for a successful ‘management effectiveness evaluation’ that Hockings et al (2006) explains should be regarded as being a third major step in the process of developing: (1) a new management plan, (2) a new assessment and (3) a management effectiveness evaluation plan per the six steps and directions of Hockings et al. (2006).

These six aspects are needed to conduct future research, to correctly implement in timely fashion, and relying on experts and monetary resources, a proper assessment plan for the sanctuary.

6.7.3. Results of the Management Effectiveness Assessment

Table 6.6. Illustrates how the six necessary steps should follow the path of the Participatory management plan of Cerro El Roble Nature Sanctuary and it is assessed by the four criteria of Hocking et al. (2006).

	Criteria			
Steps of the Path	*Producing improved management under changing conditions*	*Helping tool for better allocation of resources*	*Involving the community*	*Promoting conservation values*
Recalling the context of the area	Did not take into account the context of Caleu	They did not issue allocation of resources	They involve passively the community who was never empowered	There were no studies on the cultural richness of the area or community
Establishing a 'vision' for area management	There was no 'vision'	They copy the plan from La Campana and applied to El Roble hill	They didn't asked the community what they wanted	There was nor 'vision' for conservation, neither goal, just "protect"
Planning and allocation of resources	No planning for resources was made	There was no planning for resources	The community was not involve in allocation of resources	Due to the lack of resources there are no promotion of conservation
Producing a result of management actions	Nothing of the number of activities has been put in place	Caleu is poor and there was no training in how to ask for support	The community has no results to show of their management actions	There are no results of promoting conservation
Producing goods and services	The only service is the tourism, but is minimum and it is a bad service	Because there is no money the only services is aesthetics	The only service is again the hill itself, but community don't do much	The only service in this area is tourism but with no promotion of conservation
Having impacts or outcomes	No detectable positive impact has been shown in Caleu	No impact nor social neither environmental	The community until now has only negative impacts with the sanctuary	Because the lack of promotion of conservation has been only negative impacts

The Results of the Management Effectiveness Assessment are shown in Table 6.6, which illustrates how the six necessary steps should follow the path of the Participatory management plan of Cerro El Roble Nature Sanctuary and it is assessed by the four criteria of Hocking et al. (2006).

6.8. Critiques of the Participatory Management Plan

My critiques are based on closely reviewing the Participatory management plan of Cerro El Roble Nature Sanctuary and incorporating the knowledge gained in the previous chapters and sections. Given the critiques identified, following them, I present recommendations, marked as (R) for each one of those critiques. My main critiques are:

(1) The El Roble hill currently has more than one classification or category in the international and Chilean law. This produces consequences such as contradictory goals and objectives from each legal document, which interfere with the normal good functioning and management of the protected area. One way to solve this situation is to choose a criterion that produces the most benefits for each part. The criterion could say: “the higher law document is the valid one, and invalidate all others as references for the management plan”. A different criterion could be “the law that declared Nature Sanctuary El Roble hill”, or could be “the law that offers the highest protection to the Nature Sanctuary”, among other criteria. This decision should be taken by the community under the consultancy of experts in the issue.

(R) The problem of having more than one category in the actual legislation is difficult to solve. However, if the new management plan incorporates the different concepts of different laws, it is possible to make a zone classification that agrees with the international and domestic laws of Chile and that also makes sense ecologically.

(2) The participatory management plan (2005) has an important number of errors in its information content. Among them, it says that roads arriving to the Nature Sanctuary are double-sided, which is inaccurate, because it is one side used in both directions. The plan also says that the “other” trails in the El Roble hill –with exception of the legal and main ones– are “historical” and not

in use currently; this again is inaccurate because people use them currently to extract ecosystem services, as I showed in chapter 4. This fact should be corrected.

(R) The mistakes and errors previously described in the Critiques section can be corrected with a more accurate description of the place in the new management plan.

(3) The authorities steering the development of the participatory management plan worked with the community using workshops with pre-planned agendas and forced methodologies. This is one of the least recommended methods for interaction with a community (see Table 6.3. for more detail) since the organizers left the community very little room to express their worries and opinions in the document.

(R) The solution to this problem is to carry out and develop new participatory activities involving the community with better approaches to people.

(4) The biggest problem of the participatory management plan is the lack of implementation of all the proposed “Programs” for conservation, protection, research, use and management of natural resources. The participatory management plan in this sense is almost a complete collection of bibliographic materials of “recipes of what to do”, but lacking of specificity for the El Roble hill in particular, and also, lacking of measures of implementation, for example specific know-how. It resulted in a nice description of things that “needed to be done”, without a real reference to the problem or guidance for its implementation.

(R) A possible way to solve this problem is developing specific know-how guidance for the implementation of each program. Also, it is necessary to follow those recommendations to develop those programs. In addition, it will be good that the Calegüanos have some assessors and external experts.

(5) Another problem present in the participatory management plan is the lack of particularity to the community of Caleu and El Roble hill. In other words, there was no evaluation of which approach to a management plan of a protected area should be the best for this particular case, characterized by existence of common land, a hill with endangered forest, and a community that seeks satisfying some basic needs for survival. The solution to this problem will be a reassessment of which one of the three options, scientific-based, community-based or ecosystem stewardship, is the best choice for the particular case of Caleu and El Roble hill.

(R) When the new management plan is finally developed, it is necessary to produce information about the El Roble hill and the particular needs of the population. This information should be incorporated in the management plan in a feedback improvement, in such a way that all proposed measurement be in agreement with the reality of the hill and the community.

(6) Another important problem is the lack of watershed management plan in a context of overuse of bad-use of water.

(R) A workshop is needed to address the water issue, to teach to the population how to manage the water, and how the system works, and to keep in mind a sustainable use of water, including an efficient irrigation methods for the particular case of Caleu.

(7) Another important aspect left unaddressed in the participatory management plan is the lack of a recuperation plan and program for the areas used and damaged in past mining activities.

(R) In the long-run, projects need to be developed for the recuperation and restoration of all the lands and areas where mines destroyed vegetation and soil. Design the reforestation plan using Santiago's white oak.

(8) Finally, the Participatory management plan also lacks plans and programs for controlling and restoring areas affected by erosion.

(R) Developing, with the help of external experts, a restoration plan for all the areas with erosion (including financial and technical issues) is needed.

6.9. General Recommendations

My recommendations are based on closely reviewing the Participatory Management plan of Cerro El Roble Nature Sanctuary and incorporating the knowledge gained in the previous chapters and sections. My main recommendations are:

(1) General Recommendations

1. Reorganize the long-time residents and Calegüanos for an "open discussion" to fix the values, goals and objectives of Cerro El Roble Nature Sanctuary
2. Include experts as needed to help understand Calegüanos that assessors should be acceptable to them.

There have been 52 problems identified by the community of Caleu, grouped in eight non-mutually exclusive topics; I present a recommendation for a possible solution to each of the problems.

(2) Detriment of Ecosystem Services

1. *Erosion and soil loss.* There should be no allowances for cattle, goats, and farm animals inside the Nature Sanctuary. Also, there should be a restoration of the ecosystem project submitted

to FPA [46] that should include funding for services by external experts.

2. *Fires (on common land).* Develop a project for submission to FDA for an irrigation system for Caleu optimized for preventive action against fires in the Nature Sanctuary.
3. *Unmanaged Fires (there are no sanctions).* There is a need for environmental education, first, of the community of Caleu, and second, of the tourists that visit the Nature Sanctuary. It is necessary to implement a system such that rangers periodically visit pre-identified areas at high risk of fire. Finally, it is important to decide whether to implement or not a camping area supervised by park rangers. This action should be an internal decision of the community of Caleu.
4. *Mining Exploitation.* It is already controlled.
5. *Jobs losses mitigation.* There is a need for mitigating jobs lost in Caleu due prohibition of firewood and humus extraction. Affected people should be identified and integrated into Nature Sanctuary related job creation programs.
6. *Controlling illegal hunting.* Notify using posters, signs and active park rangers enforcement actions, existent prohibition for endemic animals hunting.

(3) <u>Sanctuary Protection</u>

7. Set vigilance posts along the trails and main paths. Close secondary trails to the public.
8. Establish a permanent budget for vigilance and control using park rangers.

[46] FPA: Fondo de Proteccion Ambiental (Chile). Environmental Protection Fund.

9. Close secondary trails to public with signs and shrubs specially planted to prevent people from crossing. Secondary trials should only be accessible to rangers and Comuneros.
10. Habilitation of the road and secondary trails to facilitate actions against fire, including emergency huts that store shovels and fire extinguishing equipment.
11. Bring experts to produce specific data needed from the Nature Sanctuary, and a facilitator to help social organization of the community.
12. Address the lack of knowledge of what is and what implies a Nature Sanctuary. Plan workshops to teach about "how to teach others about the Nature Sanctuary" and train local guides for the tourism.

(4) Water Uses

13. Teach the community of Caleu how to implement a project for the canalization of irrigation of lands.
14. Develop a project to raise funds to pay for a hydrological study about the best place to set up small irrigation water dams.
15. Establish a "Complaints System" with the police for when a Comunero states that her/his Water Rights have been used by other parties. Develop a process for prosecution and establish fines enforced by the police.
16. Petition to the MOP[47] and the Til-Til Municipality to build a sewage network and build a sewage water treatment plant.

(5) Solid Waste

17. Change the garbage recollection system. Teach to Calegüanos the concept of Reduce / Reuse / Recycle. Emphasize organic

[47] MOP: Ministerio de Obras Publicas. Public Constructions Ministery.

garbage composting. Establish a recycling system for paper, cans and glass.

18. Create a garbage recollection system for El Roble hill managed and operated by Comuneros against a small payment.
19. Organize a Workshop for teaching good practices for garbage management.

(6) Transportation and communication

20. Propose MOP certain tourists access improvements such as road improvements and sign installation.
21. Purchase a small number of low cost transportation vans to interconnect the community of Caleu with surrounding communities. The Association of Comuneros La Capilla de Caleu should manage the service, including finding funding and managing ticket sales.
22. Propose SERNATUR[48] and Ministry of Transportation the implementation of signs and complementary tourism resources in selected areas.
23. Enforce law for maximum speed limits.
24. Establish a system of fines, with police assistance, for the owners of animals found in the public road. Punish non-payment by seizing the animal.
25. Establish regulations to keep farm and domestic animals under care handlers in open areas; or when unattended, in enclosed fields or barns.

(7) Ownership of the Land

26. Engage volunteer lawyers (i.e. practicing students of the locals Universities) to regularize titles of ownership for the community.

[48] SENATUR: Servicio Nacional de Turismo. National Tourism Office.

(8) Local Development

27. Prioritize the creation of jobs and finish implementation of the management plan of the Nature Sanctuary. Develop marketing and publicity campaigns through SERNATUR for attracting tourists seeking a folklore experience and local food.
28. Begin a strategy for Social Development. Propose a project for funding by the Ministry of Planning and Social Development.
29. Implement scholarships for excellent students in elementary and middle (basic) school.
30. Develop a joint project with the Municipality to improve the basic (elementary) school of Caleu.
31. Develop and implement a plan to have a night school for the literacy of adults. The Municipality of Til-til should add another teacher. Open the night school to other nearby communities.

(9) Community Participation

32. Implement a series of workshops to teach techniques for "solutions and management of conflicts".
33. Develop a new registration right that involves an agreement in a document signed by each one.

Given the Ecosystem Services identified, as follows, I will give recommendations for the management of most of them.

(10) Ecosystem Services:

1. Stockbreeding: Cattle should not enter the Nature Sanctuary. Fences should be built and periodically maintained.
2. Goatbreeding: Goats should not enter the Nature Sanctuary anymore. Fences should be built and periodically maintained.

3. Sandrock: Extraction of small quantities should be allowed. (a study is required for determining how much is left and what rate of extraction is sustainable).
4. Timber: All collection should be forbidden and the restriction actively enforced.
5. Firewood: Only a quota should be allowed to Calegüanos in justifiable need and only from dead trees and fallen branches.
6. Seeds: Collection of seeds should be allowed with 50% of the collections going to supply the greenhouse of Caleu and the remaining 50% sold.
7. Mushrooms: An evaluation is needed to estimate how much is produced in a season and a quota collection established in favor of those previously indentified as users of Digüeñes for income replacement.
8. Medicinal Plants: Sustainable extractions should be allowed for personal consumption, and of small amount for sale to tourists.
9. Humus: Extraction of humus should be completely forbidden and replaced as an economic activity by the production and sale of Compost.
10. Bees: Production should be maintained and a project started to incorporate more Calegüanos into this economic activity.
11. Rabbits: People should organize themselves and hunt rabbits for sale in Caleu as an economic mitigation measure.
12. Chicken: These birds do not produce soil damage; therefore, it is acceptable to fully allow them in the foothills. However, it should be the owner's sole responsibility if a fox or other animal kills them.
13. Eggs of wild birds: Collection of eggs of wild birds should be completely forbidden since we do not know yet if their respective populations are vulnerable, endangered or other stage. Teach

Calegüanos the consequences of damaging them during the workshops.

14. Crystal Rock (quartz): Extraction of this mineral is acceptable in small quantities, as long as, it is done without causing impact to the environment.
15. Grass Extraction: Should be completely forbidden as an activity inside the Nature Sanctuary.
16. Fresh Water Supply: Organize a workshop to train Calegüanos to use fresh water in a sustainable way.

6.10. Discussion

This chapter introduced four different types of protected area management. The Ecosystem Management seems to be the best option, but it needs resources and a team of experts, which Caleu and its local population do not have.

The Community-based Resources Management is great in taking into account not only passively but actively engaged with the community. However, it is very difficult to put into practice successfully, a challenge that the community of Caleu will not be able to take.

The Ecological Management of Landscape is very connected with the preservation of nature, but somehow disconnected from the social subsystem and community.

Nonetheless, Ecosystem Stewardship is a strategy for protected areas that have the exact need for the community of Caleu: (1) reduction of the stress on the El Roble hill; (2) proactive strategies for unexpected challenges; and (3) look for anticipatory decisions designed to balance socio-ecological controls. This is a programmatic, adaptable and flexible approach and it looks for a balance between people's perceptions, cultural values, governing systems and the dynamic of the biosphere.

In results for strategies of management, I compare each type of management applied to the case of the Cerro El Roble Nature Sanctuary in Caleu, and again Ecosystem Stewardship is the best to go for changing the management of the hill in the future.

From results of the Management Effectiveness Assessment in the Table 6.6, and the comprehension of the previous chapters, it is possible to compare the goals of Cerro El Roble Nature Sanctuary Plan, with the notion of "management effectiveness".

The first point "design" was poorly performed due to the Nature Sanctuary was designed only following the remnant of Santiago White oak forest and the boundaries of habitation houses, but not paying attention to the close area of the La Campana National Park. In the future, it should be easier to implement a biological corridor between both protected areas.

The second point, "competence and suitability of management process", is complex to develop because the regulations and laws that currently exist given the administration and management to the Comuneros, and they are not the best fitted to the task, but it is how the law is designed.

The third and final issue in the management effectiveness is "reaching protected area objectives". This last point, even though the people changed their behavior, is still there and are big threats to the forest and no one is taking care of it.

The path of six elements (Hockings et al, 2006) of which we can evaluate the management of a protected area discussed in the introduction of this chapter, applied to the six elements: (1), (2) and (3) were not even developed in this management and of course there were no results of management actions. The ecosystem services are still operating in the hill, but there is no information until when. And finally, there were no impacts or outcomes; this is a very bad sign in the case of management of protected areas.

6.11. Conclusions

The conclusions of this chapter of strategies of management for protected areas and in particular the Cerro El Roble Nature Sanctuary are:

(1) Different types of protected areas have specific contexts and needs, therefore it is necessary study the area and its local community before taking any step into the management of the protected area.
(2) The Cerro El Roble Nature Sanctuary has its special Mediterranean conditions; the characteristic of being a sanctuary in a private common land; the hill was overused for ecosystem services in the past; and the forest of Santiago white oak, unique to this place, is fragmenting and dying. Therefore, this context makes it difficult to chose a sound management strategy for the sanctuary.
(3) The strategy of the Ecosystem Management is excellent but highly costly, and the poor community of Caleu does not have access to that.
(4) The Community-based Resource Management strategy is good for local and difficult to implement, because it has weaknesses that may make the strategy fail easily.
(5) The Ecological Management of Landscape has as a target the patches and the landscape based on Biogeography of Islands Theory, which does not apply to the case of Caleu at all.
(6) Ecosystem Stewardship seems to be simple enough, and at the same time flexible and adaptative. Specially what the Cerro El Roble Nature Sanctuary needs, because it is a private and common land managed by the locals (see chapter 3).
(7) An important number of changes need to be done in order to improve the whole management system of the Cerro El Roble Nature Sanctuary.
(8) A new management plan should be developed.

(9) It is necessary to work closely with the Comuneros (especially in engaging activities), so they can improve their knowledge and skills to manage adequately the Nature Sanctuary.

6.12. References

Barnosky AD, Hadly EA, Bascompte J, Berlow EL, Brown JH, Fortelious M, Gerz WM, Harte J, Hastings A, Marquet PA, Martinez ND, Mooers A, Roopnarine P, Vermeij G, Williams JW, Gillespie R, Kitzes J, Marchall C, Matzke N, Midell DP, Revilla E, Smith AB. 2012. Approaching a state shift in Earth's biosphere. Nature 486: 52–58.

Barnosky AD, Matzke N, Tomiya S, Wogan GOU, Swartz B, Quental TB, Marshall C, McGuire JL, Lindsey EL, Maguire KC, Mersey B, Ferrer EA. 2012. Has the earth's sixth mass extinction already arrived?. Nature 471, 51–57.

Borgerhoff Mulder M, Coppolillo P. 2005. Conservation: linking ecology, economics, and culture. Princeton University Press. Princeton, NJ.

Cardinale B. 2012. Impacts of biodiversity loss. Science Vol. 336: 552-553.

Collins SL. 2009. Biodiversity Under Global Change. Science. Vol. 336: 1353-1354.

Chapin III FS, Carpenter SR, Kofinas GP, Folke C, Abel N, Clark WC, Olsson P, Smith DMS, Walker B, Young OR, Berkes F, Biggs R, Grove JM, Naylor RL, Pinkerton E, Steffen W, Swanson FJ. 2010. Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends in Ecology and Evolution. Volume 25, Issue 4 (April). Pages 241–249.

Christensen NL, Bartuska AM, Brown JH, Carpenter S, D'Antonio C, Francis R, Franklin JF, MacMahon JA, Noss RF, Parsons DJ, Peterson CH, Turner MG, Woodmansee RG. 1996. The report of the ecological society of america committee on the scientific basis for ecosystem management. Ecological Applications 6:665–691.

Fischlin A, Midgley GF, Price J, Leemans R, Gopal B, Turley C, Rounsevell M, Dube P, Tarazona J, Velichko A. 2007. Ecosystems, their properties, goods, and services. In Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Climate Change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press. Pages: 211-272.

Francis J, Johnstone R, van't Hof T, wan Zwol C, Sadacharan D, editors. ND. Training for the Sustainable Management of Marine Protected Areas: A Training Manual for MPA Managers. CZMC/WIOMSA.

Gajardo C. 1994. Clasificación de la Vegetación Natural de Chile. Editorial Universitaria. Santiago, Chile.

Hockings M, Stolton S, Leverington F, Dudley N, Courrau J. 2006. Evaluating Effectiveness: A framework for assessing management effectiveness of protected areas. Second edition. IUCN, Gland, Switzerland.

IUCN (International Union for Conservation of Nature). 2012. International Union for Conservation of Nature Red List. [Accessed on 5/13/2012 http://www.Iucn.org/About/Work/Programmes/Species/Red_List/]

Kellert SR, Mehta JN, Ebbin SA, Lichtenfeld LL. 2000. Community natural resource management: promise, rhetoric, and reality. Society and Natural Resources, 13: 705-715.

Lindenmayer D, Hobbs RJ, Montague-Drake R, Alexandra J, Bennett A, Burgman M, Cale P, Calhoun A, Cramer V, Cullen P, Driscoll D, Fahrig L, Fischer J, Franklin J, Haila Y, Hunter M, Gibbons P, Lake S, Luck G, MacGregor C, McIntyre S, Mac Nally R, Manning A, Miller J, Mooney H, Noss R, Possingham H, Saunders D, Schmiegelow F, Scott M, Simberloff D, Sisk T, Tabor G, Walker B, Wiens J, Woinarski J, Zavaleta E. 2008. A checklist for ecological management of landscapes for conservation. Ecology Letters. Volume 11, Issue 1 (January). Pages: 78–91. DOI: 10.1111/j.1461-0248.2007.01114.x

Liu J, Dietz T, Carpenter SR, Alberti M, Folke C, Moran E, Pell AN, Deadman P, Kratz T, Lubchenco J, Ostrom E, Ouyang Z, Provencher W, Redman CL, Schneider SH, Taylor WW. 2007. Complexity of coupled human and natural systems. Science Vol. 317: 1513-1516.

Maestre FT, Quero JL, Gotelli NJ, Escudero A, Ochoa V, Delgado-Baquerizo M, García-Gómez M, Bowker MA, Soliveres S, Escolar C, García-Palacios P, Berdugo M, Valencia E, Gozalo B, Gallardo A, Aguilera L, Arredondo T, Blones J, Boeken B, Bran D, Conceição AA, Cabrera O, Chaieb M, Derak M, Eldridge DJ, Espinosa CI, Florentino A, Gaitán J, Gatica MG, Ghiloufi W, Gómez-González S, Gutiérrez JR, Hernández RM, Huang X, Huber-Sannwald E, Jankju M, Miriti M, Monerris J, Mau RL, Morici E, Naseri K, Ospina A, Polo V, Prina A, Pucheta E, Ramírez-Collantes DA, Romão R, Tighe M, Torres-Díaz C, Val J, Veiga JP, Wang D, Zaad E. 2012. Plant species richness and ecosystem multifunctionality in global drylands. Science, Vol. 335: 214-218.

Mannigel E. 2008. Integrating parks and people: how does participation work in protected area management?. Society and Natural Resources, 21: 498-511.

MA, (Millennium Ecosystem Assessment). 2005. Ecosystems and Human Well-being: Current Sate and trends. Volume 1. Island Press. Washington, D.C.

Murcia C, Kattan G. 2009. Application of science to protected areas management: overcoming the barriers. Annals of the Missouri Botanical Garden. Vol. 96, Number 3:508-520.

National Marine Sanctuaries. Community-based Management. ND. [Accessed on 9/09/2012 http://sanctuaries.noaa.gov/management/pdfs/comm_based_mod3_curr.pdf].

Noss RF. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology Volume 4, Issue 4 (December). Pages 355–364. DOI: 10.1111/j.1523-1739.1990.tb00309.x

Perrings C, Duraiappah A, Larigauderie A, Mooney H, 2011. The Biodiversity and Ecosystem Services Science-Policy Interface. Science Vol. 331: 1139-1140.

Reich PB, Tilman D, Forest I, Mueller K, Hobbie SE, Flynn DFB, Eisenhauer N. 2012. Impacts of biodiversity loss escalate though time as redundancy fades. Science Vol. 336: 589-592.

Schröter D, Cramer W, Leemans R, Prentice IC, Araújo MB, Arnell NW, Bondeau A, Bugmann H, Carter TR, Gracia CA, de la Vega-Leinert AC, Erhard M, Ewert F, Glendining M, House JI, Kankaanpää S, Klein RJT, Lavorel S, Lindner M, Metzger MJ, Meyer J, Mitchell TD, Reginster I, Rounsevell M, Sabaté S, Sitch S, Smith B, Smith J, Smith P, Sykes MT, Thonicke K, Thuiller W, Tuck G, Zaehle S, and Zierl B. 2005. Ecosystem service supply and vulnerability to global change in Europe. Science Vol 310: 1333-1337. DOI:10.1126/science.1115233

Sepúlveda C. 1997. Incentivos para la creación y manejo de Áreas Silvestres Protegidas Privadas en Chile. Ambiente y Desarrollo. CIPMA. Chile. Vol XIII Nº 3, Pages: 38-46.

Sepúlveda C, García D. 1997. Cooperación público-privada como estrategia para la conservación de la biodiversidad en Chile. Ambiente y Desarrollo. CIPMA. Chile Vol XIII - Nº 2. Pages. 59 – 68.

Sepúlveda C. 2002. Áreas privadas protegidas y territorio: la conectividad que falta. Revista Ambiente y Desarrollo. CIPMA. Chile. Vol XVIII Nº 2-3-4: 119-124.

Sepúlveda C, Tacón A, Letelier E, Seeberg C. 2003. Las áreas silvestres protegidas de propiedad privada en la Ley de Bases Generales del Medio Ambiente. Ambiente y Desarrollo. CIPMA. Chile. Vol. XIX Nº 1: 32-63.

Vicente-Serrano SM, Pérez-Cabello F, Lasanta T. 2008. Assessment of radiometric correction techniques in analyzing vegetation variability and change using time series of Landsat images. Remote Sensing of the Environment 112. Pages: 3916-3934.

Wardle, DA, Bardgett RD, Callaway RM, Van der Putten, Wim H. 2011. Terrestrial ecosystem responses to species gain and losses. Science Vol 332: 1273-1277.

Willig M. 2011. Biodiversity and productivity. Science 333: 1709-1710.

7. MULTIDISCIPLINARY CONCLUSIONS

7.1. Introduction

In this chapter, I present a compilation of conclusions of each of the studies that I carried out, supplemented by further interpretation, interpolation, and extrapolation. A second group of conclusions will also be presented concerning the basics for understanding the complex environmental system developed in this section, via a system-based, multidisciplinary conceptual model. This environmental system includes the social subsystem, the economic subsystem and the natural subsystem.

In the following sections, I summarize the conclusions of the political ecology research I conducted within the community of Caleu, my research on the ecological economics use of ecosystem services from El Roble hill, a long term analysis of landscape change and the status of the El Roble hill, and my recommendations for its sustainable management.

After that, I develop conceptual environmental models for the two situation under study: one for the period previous to the change in status of the hill, and the second for the time period following the change in status. Then, I explore the implications of the environmental model and summarize the systemic and holistic conclusions that emerge.

Finally, I discuss future research designed to produce dynamic models that would lead to a better understanding of the complexity of environmental systems, improved forecasts of future behavior, and result in mode informed policy and decision making concerning the management and conservation of the ecosystems and their services.

7.2. Summary of Disciplinary Conclusions

A compilation of the conclusions of the studies in different chapters is presented here.

The conclusions developed from chapter 3 are:

(1) Closed and isolated communities usually confront conflicts when they open politically and economically to the rest of the society.

(2) The study case of Caleu shows how political and economic allocation of resources can result in an imbalance in the small communities, when they were isolated at length and social elites incorporate into them, and these small communities are externally driven by social elites, who are better educated, wealthier, and mode politically powerful.

(3) These influential outsiders exerted political and economic power at the nation-state level, and enacted policy that was against the preferences of long-time residents, who used the hill as a source of ecosystem services and natural resources.

(4) A profound implication and important conclusion, in terms of the social dynamic of the community, is the fact that even though the long-time resident Comuneros have ownership of the common land, including the almost 1,000 hectares of the Nature Sanctuary, they currently depend for their livelihood on salaries for working in the houses of the newcomers.

The conclusions of chapter 4 are based on discoveries about the detailed use of ecosystem services, especially their use before and after the change in conservation status of the hill. The major conclusions also pertain to statistical

analysis aimed at identifying the most important Indirect Drivers of change in those ecosystems.

(1) There were identified 20 ecosystem services providing direct use of the community of Caleu.

(2) The majority, 95%, of the ecosystem services identified, were provisioning services, related to a subsistence economy.

(3) The change in conservation status of the hill, together with associated changes in the policies and rules for the use of the El Roble hill, resulted in a change in the community's relationship with the hill, and a statistical significant change in behavior in terms of the use and frequency of use the hill's ecosystem services.

(4) The change in policy conservation for the status of the hill makes people change the behavior of use and frequency of use of ecosystem services. These changes in use, before and after the Nature Sanctuary was created, are statistically significant at $p<0.05$.

(5) Robust OLS regression analysis of use of ecosystem services as a dependent variable, the fittest model is 1 in table 4.6.

(6) Robust OLS regression analysis of frequency of use of ecosystem services as a dependent variable, the best explanatory models are model 4 for N=174 and model 6 for N=182 in table 4.6. Model 9 N=133 cannot be compared.

The specific conclusions emerging from chapter 5 are:

(1) Hill El Roble is an important protected area in Chile's Mediterranean biome because of its high endemism, richness, biodiversity and uniqueness of its flora and fauna.

(2) Hill El Roble contains a relict remnants of Santiago's white oak (*Nothofagus macrocarpa*). It also contains the northernmost relict remnants of deciduous Santiago's white oak forest (*Nothofagus macrocarpa*), which dominates the vegetation of the El Roble hill.

(3) The dense closed canopy of *Nothofagus macrocarpa* is presented only on south and southwest facing slopes, on flatter areas near ravines. This areas have richer organic soil and more favorable moisture conditions.

(4) There is a highly significant regression between NDVI (equivalent to overall mass of photosynthetic tissue in a given area) and the average monthly precipitations during austral winter.

(5) There is a statistically significant increase in fragmentation from 1975 to 2012. However, there is a small reduction since 2008 to 2012, which could be result of the hill protected status over the past 12 years.

(6) Analysis of long climate data from a nearby station in San Felipe over the past 38 years indicated that local temperature increase (1.2 ℃) and Climate Change seems do have a relationship with the losses of forest and they are indirect drivers in the deterioration of the Santiago white oak forest, but it is not possible to differentiate the effect of them from the losses are due to anthropogenic disturbances.

(7) All available evidence points to the fact that the documented changes in the El Roble hill forest are directly due to anthropogenic disturbances, including the introduction of rabbits, cattle and goats, the cutting of the oak trees, extraction of soil and stone, mining and the consequent increased in erosion.

The conclusions of chapter 6 are related to my design for improved strategies for the sustainable, science-based management for protected areas, and in particular the Cerro El Roble Nature Sanctuary are:

(1) Different types of protected areas have specific contexts and needs. Therefore, it is necessary to carry out thorough analysis of both the ecology in the area and in the local community, before taking any step towards crafting and implementing a management plan of the protected area.

(2) In this regard, Cerro El Roble Nature Sanctuary is located within a dry and climatically variable Mediterranean conditions, and has suffer from long-term perturbation and decay due to extraction and overexploitation of ecosystem services by the local population who actually own the land and have traditionally enjoyed all rights and privileges to its use. The community is now divided by socio-political conflicts that arose over the establishment of the Nature Sanctuary, primarily by upper class outsiders. Clearly any effective management strategy must take into account these overarching socio-environmental factors that are peculiar to the El Roble hill.

(3) The strategy of the Ecosystem Management is excellent but highly costly, and the poor community of Caleu do not have the resources to realize management plan based on these methods.

(4) Community-based Resource Management is in theory a a sound method promoting participatory stewardship in small communities like Caleu. However, it is very difficult to implement due to several inherent weaknesses and unrealistic, unviable assumption that make the strategy non-robust and prone to failure.

(5) The Ecological Management of Landscape is based on Islands Biogeography Theory and applies to degraded ecosystems that are

patchily distributed across the landscape. In essence, it does not apply to the case of Caleu at all.

(6) Ecosystem Stewardship is a more straightforward and less costly in its application to protected area management than other methods, and at the same time highly flexible and adaptative. It is specially applicable to Cerro El Roble Nature Sanctuary, because of its common land status and the need for participatory management by the local community (see chapter 3).

(7) An number of changes and a new management plan (detailed in chapter 6) are needed to ensure the sustainable management of the Cerro El Roble Nature Sanctuary and prevent further degradation of the ecosystem.

(8) It is necessary to work closely with the Comuneros (especially in engaging activities), so they can improve their knowledge and skills to make informed decisions and effectible manage the Nature Sanctuary.

7.3. Interdisciplinary Conceptual Models for Environmental Systems

Establishing the Cerro El Roble Nature Sanctuary produced a social conflict, economic problems for the community and reveal complex issues surrounding the ecology and management of the sanctuary.

This environmental problem presented by the future fate of the El Roble hill lie at the intersection of three interconnected spheres: political ecology, ecological economics and protected area management.

The only way to understand this complex scenario is to view it as a system, and identifying the components, feedbacks, structure and emergent properties that can form the foundation for a conceptual model of the environmental system. Eventually a quantitative model is needed that would

allow forecast concerning the state of the El Roble hill given various scenarios related to climate change, management strategies and socio-political context. By environmental system, I mean the socio-political subsystem, the natural subsystem and the economic subsystem. These subsystems interact with each other through flows of energy, materials, or information. These flows are intrinsic processes that pertain to the particular environmental system identified. Each subsystem is simultaneously a component element of the system in a higher hierarchical scale, and it is a black-box for the interior processes, flows and elements that they contain in a lower hierarchical level.

The emphasis here is at the level at which the environmental system operates, and changes in its structure and dynamics though time. At this level, the social, natural, and economics subsystems are essentially a black-box. Ultimately, if we want to understand more in depth the dynamical behavior of a given the environmental system, we need to convert the conceptual model into a computer simulation (in a software[49]) that parameterizes the subcomponents and spans appropriate scales of space and time.

The research presented here represent an initial step towards this goal. First I identified the main components of the social subsystem, as specified in chapter 3. These elements provide the basis for describing the most relevant social components of the system: the Calegüanos, the residents, and the Newcomers; an aggregation of people that is ultimately based on the criteria of "level of seniority" respect to the ownership of the land. However, there are also important other criteria, to identify the Association of Comuneros La Capilla of Caleu –ACCC– (political representation of the locals) and the social elite (political and economic power of Newcomers).

[49] For example, STELLA ©.

As a second step, I identified the components of the natural subsystem: the common land and the El Roble hill, the climate, long-term changes in the landscape, and later designated Cerro El Roble Nature Sanctuary.

Third, I identified the part of the economy (economic subsystem) that is relevant to the problem on hand using ecological economics: the ecosystem services produced by the hill and their classification into extractive and non-extractive services, their intersection with the Millennium Ecosystem Assessment, and the restrictions on their use following the creation of the Nature Sanctuary.

Finally, I identified the major interactions amongst these various components of the system in order to structure two conceptual models: (1) the scenario before the Nature Sanctuary was established, and (2) the scenario after it was created by decree of law from the Chilean government.

As follow, I develop and explain a conceptual environmental model for two situations: one, previous to the change in status of the hill, and second, ulterior to the change of status. Additionally, I develop a section of results and conclusions for the conceptual environmental model, summarizing systemic and holistic conclusions obtained from the comparison of both conceptual models.

Figure 7.1 is a conceptual model that represents in a simplified fashion the problem on sight, including its participants and relations. We can visualize in this model that the whole community of Caleu was homogeneous because even if there were differences in social and economic status, those differences did not involve socio-environmental problems of any kind before the creation of the Cerro El Roble Nature Sanctuary. The ACCC is only differentiated because this organization has the political power over the decisions around the common land, as well as El Roble hill. Also, the component of ecosystem services is simplified in the model because the community was using or consuming services regardless of its condition, extractive or non-extractive.

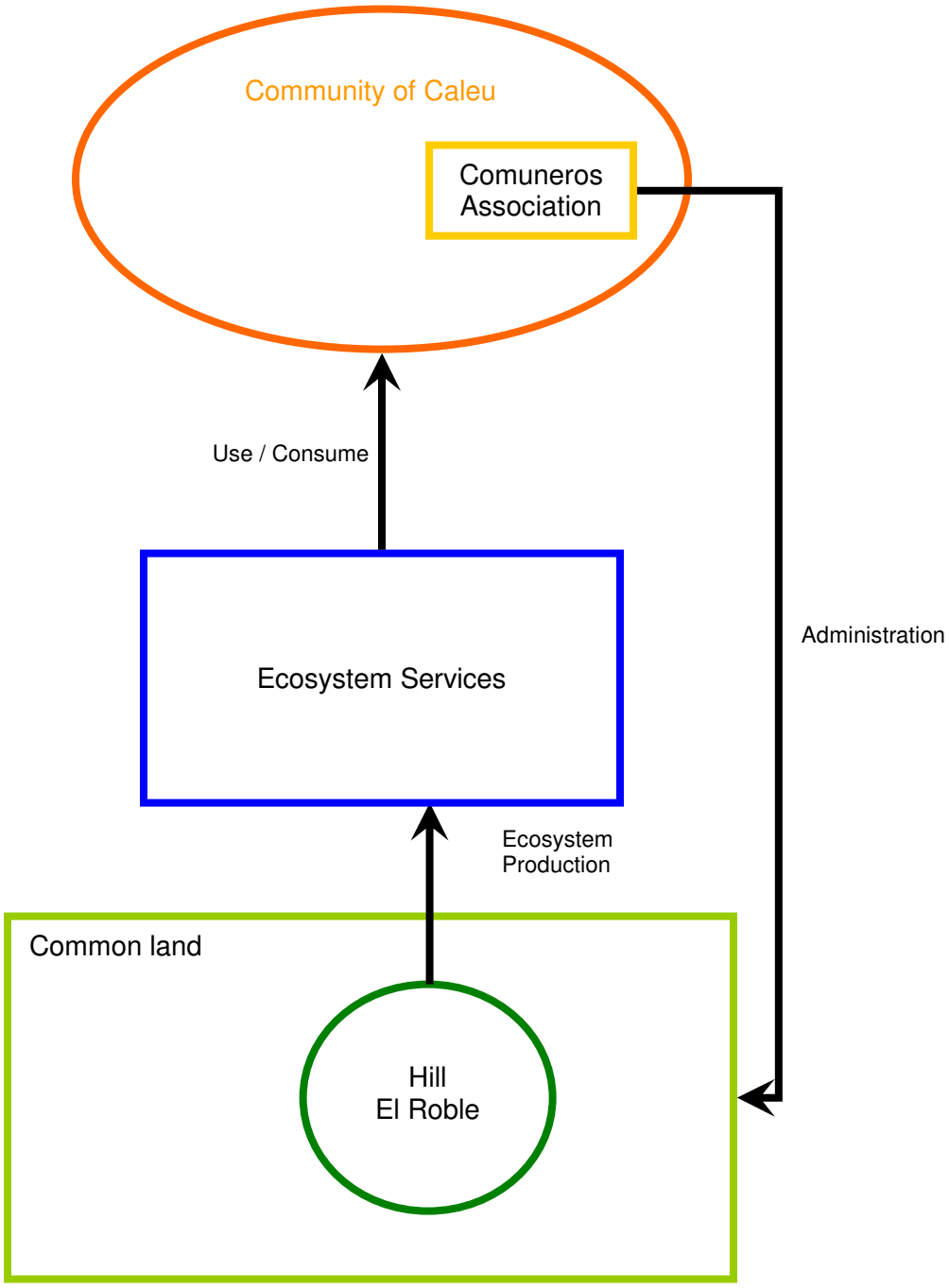


Figure 7.1. Conceptual Model of Environmental System before the El Roble hill was turned into a Nature Sanctuary.

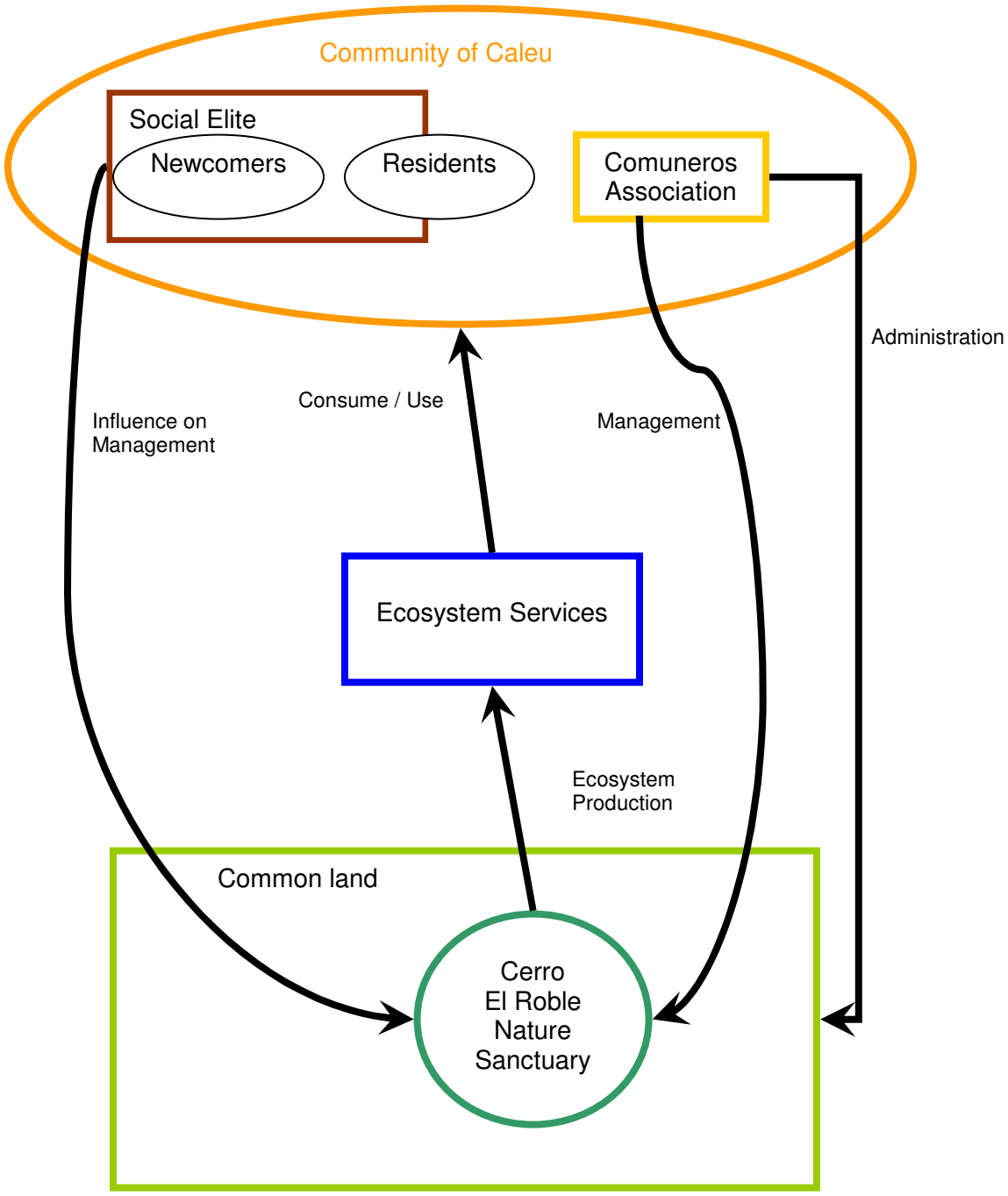


Figure 7.2. Conceptual Model of Environmental System after the creation of the Cerro El Roble Nature Sanctuary.

In the conceptual model 2 (Fig. 7.2), it is depicted how the community of Caleu turned in a more complex element, with at least 3 different important subgroups: Newcomers, and the Social Elite, some residents.

Two new interactions were formed (1) between the Comuneros Association and Cerro El Roble Nature Sanctuary, through management of the sanctuary, and (2) there is influence over the management of the Cerro El Roble Nature Sanctuary from the Social Elite of newcomers.

The most important change in the conceptual model 2 of the environmental system, it is the reduction on the ecosystem services element. Due to change in status of the hill, now the community of Caleu reduced drastically the use of ecosystem services.

The models above show the relationships among the three main components of the environmental system: the social subsystem, the natural subsystem and the economic subsystem. The interaction of between each subsystem represents flows of materials, energy or information.

In the first model, the element “Community of Caleu” represents the social subsystem and it is a black-box for the differences in the groups of the community, only differentiating among the Comuneros Association, a socio-political institution that administrates the common land in Caleu.

The second element “Ecosystem Services” is the part of the economic subsystem in the environmental system. They are consumed or used by the community.

When doing a comparison of the two models, it is possible to observe that from a very simple structure and interactions (Figure 7.1), it was transformed in a complex system in which the social and economic areas together with nature interacted through more processes and produced a more intricate structure (Fig. 7.2).

7.4. Multi & Interdisciplinary Conclusions from Conceptual Models

From the comparison of the conceptual models 1 (Fig. 7.1) and 2 (Fig. 7.2), the following points can be extracted as “changes in the system”:

1. The complexity of structure and dynamic of the social subsystem increased.
2. There are more interactions between the social component and the El Roble hill.
3. There is a formation of a new component in the system, the “economic services”.
4. There was a reduction of ecosystem services used by the community of Caleu; however, there are still flows of materials from the hill to the community.

7.5. Final Discussion

The Cerro El Roble Nature Sanctuary and Caleu and its community have special characteristics that make complex to develop an unified argument. First, the protected area is under a Mediterranean climate, flora, and fauna, with the exception of the relict forest at the high altitude in El Roble hill, where it is still remnants of a deciduous rainy forest that maintain itself by especial microclimatic conditions (see chapter 2).

Second, the land where the Nature Sanctuary was created is private common land belonging to the local Calegüanos that lived forever in Caleu. However, it was the social elite of Newcomers (with vacation homes) that made possible the creation of the sanctuary. This produced conflicts and changed the relationship between both groups, generating tensions in the sessions of the ACCC. For more details on the creation of the sanctuary, see chapter 3.

Third, there has been an extensive use of the 20 ecosystem services identified in chapter 4, which deteriorates the forest and the ecosystem of the hill. Some of those ecosystem services (Table 4.2) are not heavily impacting the forest of Santiago white oak, like hunting rabbits, or some extraction of medicinal plants. However, there is still presence of feces and prints of cattle, horses and goats, which walk freely in the sanctuary. Therefore, even if most of the Calegüanos follow the policy change, still there is a small group not wiling to change.

Fourth, the current status of the forest of *Nothofagus macrocarpa*, has a tendency to fragmentation and reducing dense canopy cover over the last decades. The exact reason is unclear, but the direct drivers of change are likely anthropogenic disturbances and indirect drivers of change are increase in local temperature (local warming) and Climate Change. The trees are cut and present shoots growing from the stump, and there is no presence of renewals of seedling. It is urgent to take actions (it is necessary develop a Restoration Project) to avoid the despairing of this beautiful species endemic to Chile and unique in the central area. All the ecological context of the landscape of the Cerro El Roble Nature Sanctuary can be found in chapter 5.

Five, the current participatory management plan for the sanctuary failed to integrate the community, develop a vision, target goals and produce services taking into account the maintenance of the conservation values (see chapter 6). Therefore, it is necessary to make an intervention and develop a new sound management plan with the community and implemented it.

Now, seeing the environmental system in a broader context, I can say a critical point is the heaviest impact of the ecosystem services damage will be over the poorest people on the planet. The direct dependence on biodiversity and the consequences of its loss –including ecosystem services degradation and disappearance– are not being shared equitably across the world population. In other words, rich people and rich countries are not going to suffer as much as

direct ecosystem dependents such as subsistence farmers, fisherman and rural poor in traditional societies.

The only viable way to maintain some ecosystem services operating is through a large amount the conservation lands and sea, that will allow us to continue receiving those ecosystem services without catastrophic consequences in the long run. These conservation lands are the protected areas so needed for the continuum of the human civilization and some wilderness.

Protected areas are diverse entities as far as categories, and as far as regulatory, political and socioeconomic context. When they are established in land with some degree of ownership, the process of creation generates conflict between groups.

The process of protected areas management can reduce these conflicts if they are adequately done. In the case of Caleu, the management plan was not made taking into consideration the complex socio-political context in which the protected area was created, neither tried to solve the ulterior conflict generated by the Nature Sanctuary itself. Due to –among other causes– lack of implementation, most of the programs of the plan were not developed, and either assessments or any other measurement of effectiveness was made. Luckily, the law of creation of the Nature Sanctuary (change in policy) produced a change in the behavior of the community, who reduced the comparative use of the ecosystem services before and after the change in status.

The Santiago white oak, *Nothofagus macrocarpa*, is a rare and endangered species, a relict forest of the South maintained under unique conditions in the Mediterranean biome. Evidence shows that the forest it is not recovering. In this regard, the creation of the Nature Sanctuary was not a success since it failed to protect it.

The political decision taken for managing the conflict was not the best possible one, and this produced an even bigger conflict that remains unresolved.

Therefore, it is important to study the socio-economic context of a protected area in order to understand the behavior and thinking of the community.

Also, it is important to identify possible causes of conflict in the future and plan, accordingly, methods of conflict resolution. Once the conflict is solved or alleviated somehow it is fundamental to turn all the efforts into producing sufficient information particular to the area and to the community to evaluate, with the community, a management plan in the best possible way. A critical point of this issue is that most of the Comuneros are against receiving help from external experts, which given the complexity of the context, is necessary.

This study is a complex case, where two theories from political ecology (conservation and control thesis and the environmental conflict thesis) explain the consequences of the actions of one part of the community of Caleu, in central Chile, (the social elite of Newcomers and some few Calegüanos) –as I presented in chapter 3– when they changed the status of the El Roble hill into a Nature Sanctuary. This action, diminished significantly the use of Ecosystem Services of the hill, from other part of the community, as I presented in chapter 4, which produced socioeconomic consequences for them. Mostly, to aged Calegüanos, who has rights to the common land (see chapter 3).

Therefore, it is necessary to develop a good new plan of management for the Nature Sanctuary in order to read the goals of conservation and sustainable use of ecosystem services in Cerro El Roble Nature Sanctuary.

7.6. Future Research

The next steps in this study are in three directions:

(1) To work with the community in a new management plan and to implement in the field the best possible strategy to improve the conditions of the hill and the community.

(2) The other evident next step is to develop the environmental conceptual model into a dynamic one, through to a software (like STELLA©). Use the data obtained in surveys and interviews and get some new field ecological data for incorporation per model requirements. Simulate the model to understand the behavior over time of the system and establish possible scenarios for the future of the community of Caleu and El Roble hill.

(3) Also, from the surveys it was collected a important amount of data that it was not possible to process in just this dissertation. Therefore, there are several topics of interest to research, like: the relationship between happiness, high quality of life, high level of life and the existence of the sanctuary; how was affected in monetary terms the community of Caleu who used to lived from the hill, what is the approximate value of the Cerro El Roble Nature Sanctuary in monetary terms, given the market prices, shadow prices and other valuation systems for the ecosystem services used and in use by the Calegüanos.

8. APPENDICES

8.1. Appendix 1: The Main Survey

Locality: □ La Capilla □ Lo Marin □ Espinalillo

Address:_____ Lot number:_____

A) USAGE OF THE HILL THE ROBLE AND THE RELATION WITH THE COMMUNITY

1. You or your family to develop any of the following activities in the Hill El Roble for sale or personal use?

□ Stockbreeding
□ Goat breeding
□ Sandrock extraction
□ Timber extraction
□ Firewood extraction
□ Seeds extraction
□ Digüeñes extraction
□ Medicine plants extraction
□ Snow extraction
□ Humus extraction
□ Bees feeding
□ rabbit hunting
□ Recreation (landscape)
□ Gold or silver mining
□ Coal burning
□ Other_____
□ Other_____
□ Other_____
□ Nothing

2. If you don't develop any, why?

_____
_____

3. How often you develop these activities?

□ Stockbreeding _____ in a day _____in a week _____ in a month ____in a year
□ Goat breeding_____ in a day _____in a week _____ in a month ____in a year
□ Sandrock extraction____ in a day _____in a week _____ in a month ____in a year
□ Timber extraction_____ in a day _____in a week _____ in a month ____in a year
□ Firewood extraction____ in a day _____in a week _____ in a month ____in a year
□ Seeds extraction_____ in a day _____in a week _____ in a month ____in a year
□ Digüeñes extraction____ in a day _____in a week _____ in a month ____in a year
□ Medicine plants ext.____ in a day _____in a week _____ in a month ____in a year
□ Snow extraction_____ in a day _____in a week _____ in a month ____in a year
□ Humus extraction_____ in a day _____in a week _____ in a month ____in a year
□ Bees feeding_____ in a day _____in a week _____ in a month ____in a year
□ Rabbit hunting _____ in a day _____in a week _____ in a month ____in a year
□ Recreation _____ in a day _____in a week _____ in a month ____in a year
□ Gold or silver mining___ in a day _____in a week _____ in a month ____in a year
□ Coal burning_____ in a day _____in a week _____ in a month ____in a year
□ Other___ _____ in a day _____in a week _____ in a month ____in a year
□ Other___ ____ in a day _____in a week _____ in a month ____in a year
□ Other____ _____ in a day _____in a week _____ in a month ____in a year
□ Nothing

4. Due to these activities is there an increase in your income? Yes/ No

If yes:
5. By how much? (approx.) $_____or (%)_____

6. Due these activities is there an improvement in your quality of life? yes / no

7. You or your family developed any of the following activities in the Hill El Roble for sale or personal use before it was declared Nature Sanctuary?

□ Stockbreeding
□ Goat breeding
□ Sandrock extraction
□ Timber extraction
□ Firewood extraction
□ Seeds extraction
□ Digüeñes extraction
□ Medicine plants extraction
□ Snow extraction
□ Humus extraction
□ Bees feeding

□ Rabbit hunting
□ Recreation (landscape)
□ Gold or silver mining
□ Coal burning
□ Other_____
□ Other_____
□ Other_____
□ Nothing

8. If not, why?

_____
_____

9. How often did you develop these activities?

□ Stockbreeding _____ in a day _____in a week _____ in a month ____in a year
□ Goat breeding_____ in a day _____in a week _____ in a month ____in a year
□ Sandrock extraction____ in a day _____in a week _____ in a month ____in a year
□ Timber extraction_____ in a day _____in a week _____ in a month ____in a year
□ Firewood extraction____ in a day _____in a week _____ in a month ____in a year
□ Seeds extraction_____ in a day _____in a week _____ in a month ____in a year
□ Digüeñes extraction____ in a day _____in a week _____ in a month ____in a year
□ Medicine plants ext.____ in a day _____in a week _____ in a month ____in a year
□ Snow extraction_____ in a day _____in a week _____ in a month ____in a year
□ Humus extraction_____ in a day _____in a week _____ in a month ____in a year
□ Bees feeding_____ in a day _____in a week _____ in a month ____in a year
□ Rabbit hunting_____ in a day _____in a week _____ in a month ____in a year
□ Recreation _____ in a day _____in a week _____ in a month ____in a year
□ Gold or silver mining___ in a day _____in a week _____ in a month ____in a year
□ Coal burning_____ in a day _____in a week _____ in a month ____in a year
□ Other___ _____ in a day _____in a week _____ in a month ____in a year
□ Other____ ____ in a day _____in a week _____ in a month ____in a year
□ Other____ _____ in a day _____in a week _____ in a month ____in a year

10. Due to these activities is there an increase in your income? Yes/ No

If yes:
11. By how much? (approx.) $_____or (%)_____

12. Due these activities is there an improvement in your quality of life? yes / no

13. In your opinion the quietness, the silence and the clean air thanks to the existence of the Nature Sanctuary improve your quality of life?

□	□	□	□	□
Nothing	A little	Regular	Enough	A lot

14. In your opinion, which is the relation between the people of Caleu with the Hill El Roble?

□ very bad, because it is not possible to use the Hill El Roble like before
□ bad
□ regular, because it is possible use it only with restrictions
□ good
□ very good, because the Nature Sanctuary improve the quality of life of people of Caleu

15. How important is for you the Hill El Roble?

□	□	□	□	□
very irrelevant	irrelevant	regular	relevant	very relevant

16. Why?

_____
_____

B) VALUATION OF HILL EL ROBLE

17. If you needed you set a value over the benefits that produce Hill El Roble, how much will be this value? (in pesos)

□ Nothing □<100.000 □100.000 □1.000.000 □10.000.000 □>10.000.000

18. In an imaginary situation, if a private want to develop a project in the Hill El Roble, what is your willingness to receive a payment (compensation) in order to lose the Hill el Roble as a Nature Sanctuary? (pesos)

□ Nothing □<100.000 □100.000 □1.000.000 □10.000.000 □>10.000.000

19. In an imaginary situation, if a private want to develop a project in the Hill el Roble, What is your willingness to pay in order to keep the Hill el Roble in its natural state as a Nature Sanctuary? (pesos)

□ Nothing □<100.000 □100.000 □1.000.000 □10.000.000 □>10.000.000

20. If you don't have willing to pay, why?

□ Because you can't afford it
□ Because the Nature Sanctuary should be protected by law and we shouldn't pay to protect them
□ Because the protection of Natural Sanctuaries is not important
□ Because the protection of Natural Sanctuaries is not that important in the case of Hill El Roble
□ Other reason _____

C) LEVEL OF LIFE AND QUALITY OF LIFE

21. Do you rent or you are owner? □ rent □ owner □ other: _____

22. Do you have:

□ refrigerator
□ water-heater for shower
□ car
□ phone
□ washing machine
□ television
□ computer
□ internet

23. Currently do you have a paid job? yes / no

24. Given all this material things, how do you consider your *level of life*?

□	□	□	□	□
very bad	bad	regular	good	very good

25. What health system do you belong:

□ Public System group A
□ Public System group B
□ Public System group C
□ Public System group D
□ Public System don't know group
□ Isapre

□ None (particular)
□ Other _____

26. The resting time you have is:

□ very insufficient	□ insufficient	□ regular	□ sufficient	□ more than sufficient

27. The recreation time that you have is:

□ very bad	□ bad	□ regular	□ good	□ very good

28. Your emotional and spiritual state is:

□ very bad	□ bad	□ regular	□ good	□ very good

29. Given all this previous characteristics, how do you consider your *quality of life*?

□ very bad	□ bad	□ regular	□ good	□ very good

30. How happy you consider yourself in these days?

□ very unhappy	□ unhappy	□ regular	□ happy	□ very happy

31. How you consider you general well-being taking into account all the material things, health and happiness?

□ very bad	□ bad	□ regular	□ good	□ very good

D) IDENTIFICATION OF THE FAMILY

32. How many persons live in your house? _____

33. How long do you have living in Caleu?_____years / months

34. Sex □ Female □ Male

35. How old are you? _____ years

36. What level of education do you have? _____

37. What is the occupation of the head of house?
_____

38. Are there more sources of income? yes / no

39. Which ones? 2nd)_____3rd)_____

40. What is the family monthly income? _____

8.2. Appendix 2: The Complementary Survey

Locality: □ La Capilla □ Lo Marin □ Espinalillo

1. Did you or someone in your family do any of the following activities (past)? With what frequency?

□ Stockbreeding _____ in a day _____in a week _____ in a month ____in a year
□ Goat breeding_____ in a day _____in a week _____ in a month ____in a year
□ Sandrock extraction____ in a day _____in a week _____ in a month ____in a year
□ Timber extraction_____ in a day _____in a week _____ in a month ____in a year
□ Firewood extraction____ in a day _____in a week _____ in a month ____in a year
□ Digüeñes extraction____ in a day _____in a week _____ in a month ____in a year
□ Humus extraction_____ in a day _____in a week _____ in a month ____in a year
□ Rabbit hunting _____ in a day _____in a week _____ in a month ____in a year
□ Charcoal burning_____ in a day _____in a week _____ in a month ____in a year

2. Do you or someone in your family do any of the following activities (present)? With what frequency?

□ Stockbreeding _____ in a day _____in a week _____ in a month ____in a year
□ Goat breeding_____ in a day _____in a week _____ in a month ____in a year
□ Sandrock extraction____ in a day _____in a week _____ in a month ____in a year
□ Timber extraction_____ in a day _____in a week _____ in a month ____in a year
□ Firewood extraction____ in a day _____in a week _____ in a month ____in a year
□ Digüeñes extraction____ in a day _____in a week _____ in a month ____in a year
□ Humus extraction_____ in a day _____in a week _____ in a month ____in a year
□ Rabbit hunting _____ in a day _____in a week _____ in a month ____in a year
□ Charcoal burning_____ in a day _____in a week _____ in a month ____in a year

3. Can you make an estimation of the following activities per day of work (past)?

□ Stockbreeding: How many cows did you have?_____
□ Goat breeding: How many goats did you have?_____
□ Sandrock: How many kilograms of rock did you extract?_____
□ Timber: How many kilograms of timber did you extract?_____
□ Firewood: How many kilograms of firewood did you extract?_____
□ Digüeñes: How many kilograms of mushrooms did you extract?_____
□ Humus: How many kilograms of humus did you extract?_____
□ Rabbits: How many rabbits did you hunt?_____
□ Charcoal burning: How many kilograms of charcoal did you produce?_____

4. Can you make an estimation of the following activities per day of work (present)?

□ Stockbreeding: How many cows do you have?_____
□ Goatbreeding: How many goats do you have?_____
□ Sandrock: How many kilograms of rock do you extract?_____
□ Timber: How many kilograms of timber do you extract?_____
□ Firewood: How many kilograms of firewood do you extract?_____
□ Digüeñes: How many kilograms of mushrooms do you extract?_____
□ Humus: How many kilograms of humus do you extract?_____
□ Rabbits: How many rabbits do you hunt?_____
□ Charcoal burning: How many kilograms of charcoal do you produce?_____

5. Why you have goats/cows? (tradition, heritage, neighbors have, it's a good Business)
_____
_____

6. What you do with the goats/cows? (personal consume, sales, etc)
_____
_____

7. If you do any of the following activities you use fallen trees or live trees?

□ Timber: Fallen_____ Alive_____
□ Firewood: Fallen_____ Alive_____
□ Charcoal burning: Fallen_____ Alive_____

8. Why you use timber/firewood/charcoal?
_____
_____

9. How much money do you get for a kilogram/unit of:

□ Stock _____
□ Goat _____
□ Sandrock _____
□ Timber _____
□ Firewood _____
□ Digüeñes _____
□ Humus _____
□ Rabbit _____
□ Charcoal _____

10. Why and how you or your family use the charcoal that you produce?

_____

_____

11. How much Money do you or others get for aprox. A kilogram, bag or unit:

□ Stockbreeding _____
□ Goatbreeding _____
□ Sandrock _____
□ Timber _____
□ Firewood _____
□ Digüeñes _____
□ Humus _____
□ Rabbits _____
□ Charcoal _____

12. Do you participate actively in the Association of Comuneros of Caleu? Yes / No

Why not?_____

13. In what year did you know for first time that El Roble hill is a Nature Sanctuary?

2000 – 2001 – 2002 – 2003 – 2004 – 2005 – 2006 – 2007 – 2008 – 2009 – 2010 – 2011

14. How did you know the existence of the Nature Sanctuary?

a) In the regular meetings of the Association of Comuneros
b) In an extraordinary meeting of the Association of Comuneros
c) In the meetings organized by the FPA project of promotion of the Nature Sanctuary (organized by the Association of Comuneros and Newcomers)
d) In the meetings and Workshops organized by CONAF
e) By street rumors
f) Other_____

15. What is your opinion about the existence in the El Roble hill of a Nature Sanctuary?
Good / Bad Why? _____

_____

_____

16. Do you think that the Nature Sanctuary give some benefits to the community of Caleu? Yes / No

How?_____

17. What should do the Directive of the Association of Comuneros in order to the Nature Sanctuary produce more benefits to the community of Caleu?

_____
_____
_____

18. Do you think that the Directive needs external support (expert professionals) to carry on the actions that will produce more benefits to the community of Caleu? Yes / No
Why? _____

19. Do you think there is mistrust from the Calegüanos to the Newcomers? Yes / No
Why? _____

20. Do you think there is mistrust among the Calegüanos? Yes / No Why? _____

21. How do you think is the management and use of the water in the community of Caleu? Good / Bad
Why? _____
_____

8.3. Appendix 3: Questionnaire for in-depth interviews.

I am going to ask you some questions about Caleu, Cerro el Roble, and the Nature Sanctuary.

1. First, tell me about yourself. Have you always lived in Caleu? Is your family from here?
    a. If no: When did you move here, and why?
    b. If yes, ask the following questions:
        i. Growing up here, how often did you and your family go to Cerro el Roble?
        ii. Was Cerro el Roble important to your family? Why?
        iii. In earlier times, how did your parents and grandparents use the hill?
        iv. In the past, were there always enough resources, like firewood, for everyone in Caleu to use?
        v. Have you seen a change in how people use the hill from the time you were a child? What has changed?

I am trying to understand different ways that people in Caleu use and manage the resources on Cerro el Roble.

2. Could you tell me about the Association de Comuneros de Caleu?
    a. When was the association formed? Why?
    b. Do the *comuneros* have a leader? How is the association organized?
    c. What does the Association of Comuneros of Caleu do? What are the association's responsibilities?
    d. How many people approximately, in current times, are *comuneros*?
    e. Do you think that the *comuneros* do a good job managing and protecting the natural resources on Cerro el Roble?

3. Are there people in Caleu who are not *comuneros*?
    a. Why are some people *comuneros* and others not?
    b. Do the people who are not *comuneros* also use resources on the hill, like take firewood, hunt for animals, gather food, etc?

4. I understand that there are vacation homes here. How do people who come here for vacation use Cerro el Roble? For example, do they hike there, gather firewood, hunt there, or do other activities?

5. I understand that there have been some mining activities on Cerro el Roble. Could you tell me about that?

a. When did mining begin?
b. Were there outside companies involved?
c. Do mining activities continue?
d. What were the impacts of mining activities on Cerro el Roble and this community?

I would like to learn more about this community.

6. What are the major economic activities in Caleu today? How do people here earn a living?

7. In your lifetime, have you seen many changes in the ways that people earn a living here? What are the changes?

8. Do the vacation home owners participate in community activities here? For example, do they participate in any organizations or the local government?

9. Would you say that people in Caleu get along pretty well, or are there conflicts among different groups of people here?

a. If there are conflicts: What kinds of conflicts?

Now I would like to ask about the Nature Sanctuary.

10. Could you tell me how the idea of creating a Nature Sanctuary originated?

b. Who was the first person or group of people to have the idea of making a Nature Sanctuary of the hill?
c. How this idea originate?
d. Why this idea originate?
e. Was there a specific event which starts this idea?
f. How the petition for Nature Sanctuary was organize?
g. Who contact and bring the idea to the CONAMA?

11. When the Nature Sanctuary was proposed, was there disagreement about it?

a. Did the *comuneros* support or reject this idea? Why?
b. Did *comuneros* divide because of this idea? Why?
c. Did other residents divide because of this idea?

d. Did the vacation-house owners support or stand against the idea?

e. What is the proportion of people who stand in favor and against the idea?

f. What did the people do who were against the idea?

12. Was disagreement about the Nature Sanctuary resolved?

a. Was there a public debate about it?

b. Was there a process to discuss the issue?

c. Was a compromise reached?

d. Do people still disagree about the Nature Sanctuary?

e. Did people against the Sanctuary participate in creating the management plan for the protected area?

13. How did the Nature Sanctuary affect the right of the *comuneros* to use the hill as their own land?

a. Is the management plan of the hill open to sustainable use of it? Or is any extraction is completely forbidden?

b. Why was decided in that way?

14. What are the current and future plans for managing the Nature Sanctuary?

a. In your opinion, are these plans viable?

15. Do you think people against the Nature Sanctuary will eventually take actions to recover their land?

Thank you very much for your help. Now, I wish to ask you about some reference you can give me to gather more opinions about these issues. Can you recommend me someone?

8.4. Appendix 4: Table of Interviewees

Table A. List of Interviewees organized in the six types of groups of people interviewed classified by Long-time residents (Calegüanos/as) or Newcomers (without ancestors in Caleu), Comuneros or No-comuneros and the type of residence in Caleu, permanently or vacational homes. There is another category: Local No-Comunero, however, those people are very few (2-3 in total) and also they do not participate actively in the community.

	Long-time residents			Newcomers					
	Comuneros			Comuneros			No-comuneros		
Permanent residency in Caleu	ID	Date Interview	Age	ID	Date Interview	Age	ID	Date Interview	Age
	Ms. A	6/21/2011	+60	Mr. B	6/21/2011	+65	Mr. D	6/22/2011	+50
	Ms. C	6/22/2011	+70	Mr. J	7/04/2011	+60			
	Mr. E	6/27/2011	+60						
	Ms. G	6/28/2011	+60						
	Mr. H	6/28/2011	+65						
	Mr. I	6/30/2011	+70						
	Mr. K	7/04/2011	+65						
	Ms. N	7/21/2011	+55						
	Ms. O	7/21/2011	+55						
	Mr. P	7/22/2011	+50						
	Mr. Q	7/22/2011	+45						
	Mr. V	7/29/2011	+60						
	Mr. X	8/09/2011	+55						
Vacational home in Caleu	Mr. L	7/05/2011	+55	Ms. F	6/28/2011	+35	Mr. M	7/11/2011	+60
				Ms. R	7/25/2011	+60	Mr. S	7/25/2011	+50
				Mr. U	7/28/2011	+70	Mr. T	7/26/2011	+50
							Mr. W	8/02/2011	+70
							Mr. Y	8/09/2011	+50