ECUADOR'S CHOCO ANDEAN CORRIDOR: A LANDSCAPE APPROACH FOR CONSERVATION AND SUSTAINABLE DEVELOPMENT

by

REBECA MARIA JUSTICIA

(Under the Direction of C. Ronald Carroll)

ABSTRACT

This dissertation describes the history of establishment of the Chocó Andean Corridor of Northwest Ecuador, elaborates on a systematic process of prioritization of conservation areas, illustrates how ambitious plans are being implemented on the ground and, along the way, addresses such difficult issues as integrating research, conservation, funding, development and political agendas. The general aim is to advance the understanding of the key elements essential for successful Neotropical forest conservation; the specific goal is to provide baseline studies that can be used to formulate conservation and land-use management policy related to the development of the Chocó Andean corridor. To encompass the geographic magnitude and thematic complexity of my object of study, I use an embedded case study methodology. An ecoregional approach reconciles the protection of biodiversity beyond the boundaries of the established National System of Protected Areas (SNAP) with the human needs of community development and economic alternatives to deforestation and may well present the best future conservation scenario. Protected areas alone do not serve well the two main objectives of biodiversity conservation—representation and permanency. Economic pressure drives deforestation, and viable alternatives to deforestation must be implemented. Reforestation with the native bamboo (*Guadua angustifolia*) and management of wild stands of this bamboo are described as a novel tool to integrate biodiversity conservation, sustainable development and climate change mitigation. Other key findings are that well organized human communities are the best partners for conservation; land tenure security is essential for conservation; conservation projects that also invest in productive infrastructure are the most successful; novel policy tools, such as carbon trading that could provide economic incentives for conservation, should be pursued; economies of scale must be reached to successfully market and commercialize the products and services of conservation; and finally, monitoring of conservation success should be planned from the onset and should be scientifically sound and participatory.

INDEX WORDS: Tropics, Conservation, Corridor, Biodiversity, Eco-regional conservation, Maquipucuna, Chocó Andean Corridor, Climate Change, Clean Development Mechanism, Carbon trading, Deforestation, Prioritization, Land use change, Bamboo, Guadua angustifolia, Ecuador, Ecotourism, Coffee, Cacao, Sustainable development, NGO

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DEDICATION

I dedicate this dissertation the memory of my father, Fernando Justicia, and my children Isabel and David.

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CHAPTER 1

INTRODUCTION

1.1 AIM

This dissertation describes the history of the establishment of the Chocó Andean Region of Northwest Ecuador, elaborates on a process of prioritization of conservation areas, and designs a bamboo-based sustainable system that links capturing carbon and conserving biodiversity. I also illustrate how ambitious plans are being implemented on the ground that will cope with the difficult issues of approaching conservation from a holistic perspective that integrates research, conservation, funding, development, and political agendas. The general aim is to advance the understanding of tropical forest conservation while the specific goal is to provide insights useful in formulating conservation and land-use management policy related to the development of the Chocó-Andean corridor.

1.2 RESEARCH METHODOLOGY AND ORGANIZATION OF THE DOCUMENT

To encompass the geographic magnitude and thematic complexity of my object of study, I have used an embedded case study methodology whereby I integrate qualitative and quantitative information obtained at different times and scales of observation. The embedded case study approach is particularly relevant because an entire eco-region can not be manipulated and controlled in a scientific experiment (Yin 2002). Similar to a case study, the embedded case study approach enables the integration of quantitative and qualitative information into a single research study. Yet it allows the treatment of sub-units with more detailed level of analysis (Scholz and Tietje 2001).

This Chapter 1 provides the background and historical and policy context for the establishment of the Chocó Andean Corridor. Chapter 2 profiles the Chocó Andean Corridor region. Chapter 3 addresses the ecological, socioeconomic, and policy implications of implementing native bamboo projects *Guadua angustifolia* as an integrative biodiversity conservation and climate change mitigation strategy within the

Chocó Andean Corridor. Chapter 4 synthesizes the process, work and lessons learnt while establishing the Chocó Andean Corridor.

1.3 BACKGROUND OF THE PROBLEM

1.3.1 Tropical deforestation and the biodiversity crisis

The destruction of tropical forests is contributing to one of the most serious environmental problems facing humanity in modern times. The massive scale of contemporary biodiversity loss parallels only that of the end of the Cretaceous period, but this time it is believed to result from unsustainable human activities (Pimm et al. 1995). Tropical deforestation is contributing to a major mass extinction (Wilson 1992) as almost half the world's vascular plant species and one-third of terrestrial vertebrates inhabit 25 'biodiversity hotspots'(Brooks et al. 2002, Brooks et al. 2006). Widespread causes of biodiversity loss are habitat transformation and fragmentation (Brooks et al. 2002, Olson and Dinerstein 2002). During the last century, these areas with the highest concentration of biodiversity, which once covered 12% of the earth's land, have decreased to just 1.4% (Brooks et al. 2002). This human-induced biodiversity crisis has sparked efforts to prioritize conservation at global scales because biodiversity is not distributed evenly. Ecoregions of global significance or so-called 'biodiversity hotspots' are identified and ranked by indices that combine concentration of biodiversity and degree of threat (Olson and Dinerstein 2002, Brooks et al. 2006). These global evaluations indicate that tropical forests unequivocally represent terrestrial centers of worldwide conservation concern. It is estimated that about two-thirds of all species occur in the tropics, largely in the tropical humid forests (Pimm and Raven 2000). The Tropical Andes region, for example, contains about a sixth of all plant life in less than one percent of the world's land area (Brooks et al. 2002). But that region is also one of the most threatened because 58% of the world's forest lost between 2000 and 2005 (4.23 million hectares/year) vanished in South America alone (FAO 2006b). Latin America has the highest rates of deforestation in the world: 7.4 million hectares/year, versus 4.1million in Africa and 3.8 million in Asia. Brazil has the most deforestation on the continent, with a loss of at least 1 million hectares/year. In relative terms, however, the situation of Brazil (with 1% loss a year) is better than in such countries as El Salvador, Haiti and

Jamaica (with more than 3% loss a year), or Ecuador, Nicaragua, Honduras and Guatemala (with more than 2% loss a year) (WRI 1992). Plantation forests cover 43.8 million hectares in the tropics, with 32.1 million hectares located in Asia, and 8.6 million hectares in Latin America (mostly in temperate regions). However, the annual plantation rate by no means palliates the effects of deforestation (2.6 million hectares planted versus 15.4 million hectares deforested annually). In Latin America, the gap is immense, with annual deforestation rates 20 times larger than plantation rates. Moreover, plantations are usually composed of eucalyptus or pine, with a low capacity for conserving tropical biodiversity.

1.3.2 Lack of sufficient long-term funding and clear economic incentives for conservation.

There is a widespread lack of both sufficient and long-term funding and clear economic incentives for conservation in the tropics. Tropical governments generally allocate insufficient funds for conservation, and the overseas funding help for conservation is insufficient. Of the $6 billion of annual worldwide conservation funding in the 1990s, approximately 90% originated and was spent in developed countries (James et al. 1999). That remaining 10%, even if applied only to tropical forest conservation, would amount to less than $70 per hectare to halt deforestation and none to provide management of the existing protected areas. Second, conventional conservation is donor-driven (Swingland 2003) and consequently extremely dependent on the politics or the prevailing paradigm of the moment, the bureaucracy surrounding grant giving, the transient interests of donors and the willingness of charitable bodies to dedicate financial support to conservation. These problems are illustrated by the largest conservation fund available for world wide conservation outside of the developed world—the GEF fund (Global Environmental Facility), which pledged $3.13 billion for the 2006 and 2010 period. An air of mystery and uncertainty, as governments' geopolitics and priorities change constantly, surrounds the process of 'replenishment' of the GEF fund every four years. Months before the donors meet, officials of the GEF do not even know if and how much funding will be available. For that reason, no long-term funding commitments are ever made. The average length of project cycles for the GEF is three years, while it takes on average one to three years for a project to be approved (from identification, preparation to approval). The limited funds are often not being spent effectively. Conservation organizations have to meet their own overhead costs, and so the funds that actually are invested in the field are significantly reduced. The larger the organization, the larger the budget they need to run the organizations—often headquartered in expensive cities—and the fewer the funds that are invested in the field in proportion to the total invested. Smaller organizations, on the other hand, have a hard time meeting long-term place-based commitments because they have to continuously adapt their geographic and thematic priorities to obtain funding from the large organizations. A resulting problem of this dynamic is that the average life span of funding cycles for conservation projects is too short (three years). If a donor changes priorities, conservation projects may be left worse off. What is needed is a funding system that does not disenfranchise land stewards, who often are rural people—a system in which forest owners have long-term equitable participation by right, not by patronage. In other words a new system is needed, one that bridges the interests of local communities and external actors through fair and measurable compensations (Wunder 2007).

An early example of such a fair system was thought to be payments for the value of biodiversity (Vogel 1997). Yet prospecting for plants with medicinal value has often violated the intellectual property rights of the indigenous people who discovered the medicinal values (Mittermeier and Bowles 1993). Payment for environmental services provided by biodiversity is another example where compensation might be allocated fairly. However, payments for environmental services that have obvious local value, such as watershed protection, are only practical in very specific locations and only upstream of a very few large cities that actually use the water and where there is the political will to value the service of conservation. A new approach is to attach the value of removing the greenhouse gas, carbon dioxide, to tropical forests through sequestration of carbon. Although carbon sequestration is clearly an important environmental service of tropical forests, the mechanisms for realizing those values in the marketplace are confusing and rudimentary. There are currently many barriers to fully harness the carbon storage potential of conservation projects, such as the expensive transaction costs of climate CO_2 emission reduction projects and the extreme bureaucracy in the process of project evaluation and approval that is exacerbated by policy and scientific uncertainties (GRIEG-GRAN et al. 2005). Despite these problems, there is some optimism that real opportunities to compensate forests stakeholders will arise from the strong connection between the protection of tropical forests, their value for biodiversity, and the climate change mitigation potential of conserving forests (Malhi et al. 2002).

1.3.3 The connection of tropical deforestation and climate change

The clearing and degrading of tropical forests is exacerbating global warming by releasing carbon stored in the aboveground biomass and carbon stored in forest soils and by reducing the potential for storing new carbon. The carbon stored in tropical forests accounts for 20% of the global total; thus forests play an important part in the global carbon (Melillo et al. 1996). In boreal and temperate forests up to 90% of carbon stores are in the soils. In contrast tropical forests carbon stores in the soil and above ground may be higher (Lugo and Brown 1993), though considerably more work needs to be done to confirm the generality of this early research. Therefore, the destruction of tropical forests may result in high carbon losses both above and below ground. The greenhouse gas (GHG) emissions resulting from deforestation are estimated at 1.6 ± 0.4 Gt C/yr, which is about 27% of the global carbon that is released from fossil fuel combustion estimated to be 6 Gt C in 1990 (Malhi et al. 2002, IPCC 2005). Three-quarters of the emissions from deforestation are from the loss of aboveground biomass, and a quarter is due to soil C decomposition (Melillo et al. 1996, Houghton et al. 2001, Malhi et al. 2002).

Trading Carbon Emission Reduction credits from long-term carbon sinks and carbon sequestration projects in high biodiversity areas may create fair payments and incentives for conservation for communities conserving forests (Pfaff et al. 2000, Swingland 2003, de Koning et al. 2005). Despite the growing disappointing results of such types of carbon projects, largely due to poor policy decisions, the global magnitude and overlapping nature of the biodiversity crisis and the climate change crisis obligates us to more deeply investigate the potential for making Conservation Carbon projects work. For that reason, I dedicate the next section to reviewing the climate change policies related to reforestation projects, which could eventually frame conservation carbon projects.

1.4 HISTORICAL CONTEXT

1.4.1 A Historical Sequence of Events that Shaped Conservation Strategies in Latin America

This section reviews the shaping of contemporary conservation thinking in Latin America from one where the creation of protected areas was the central element in conservation policy to a conservation model influenced by science and where human needs, including those of local communities, are key elements of conservation.

Throughout history, the prevailing scientific knowledge, as well as current social values and views about nature, have influenced conservation actions (Figure 1.1). Contemporary conservation has its roots in the scientific findings of the forestry schools of Germany and France of the 18th and 19th century. Alexander Von Humboldt (Sachs 2006) developed bio-geographical concepts and early climate change theories that had tremendous influence on the forestry sector in British India, which tried to keep the 'house-hold' of nature. These ecological ideas in turn influenced the perception of forest conservation in England. American forester Gifford Pinchot, who at the time was studying forestry in Europe, was also deeply influenced by these ecological views. He would then bring them to the United States and develop an ethics of resource conservation, summed up in his slogan 'the greatest good for the greatest number for the longest time,' which is considered today the origins of sustainable development thinking. The social climate of the time was shaped by the influence of social revolutions and the negative impacts of industrialization that led to stripped forests and overcrowded dark polluted cities. One of the significant reactions was a need to connect back to nature at a very deep level. Therefore, those days saw the origin of two schools of thought that still exist in conservation and that prevail today in Latin America. One, a utilitarian view, suggests that we must conserve nature for the services it renders, but the other more romantic view argues that we must conserve nature because of its intrinsic value as proposed by John Muir (Pepper et al. 1984). These early days of environmental awakening resulted in the creation of national parks of spectacular characteristics: Yellowstone National Park, established in 1872, was the world's first national park; then the Sarek park was created in Sweden in 1909, making it the first national park in Europe, and a few parks were created in Latin America including the declaration of National Park for several islands in the Galapagos between 1936 and 1939 in Ecuador (Black 1973), and the Itatiaia Park in 1937 in Brazil, believed then to have the highest mountain peaks of Brazil (UNEP-WCMC 2007).

These first protected areas in the United States were conceived as State land protected for the benefit of future generations, often denying the land tenure rights of indigenous peoples that lived in some of those parks. This conservation model was exported to Asia, Africa and Latin America, and where those national parks were created on indigenous territories they created social conflict and resentment (Colchester 2004).

After World War II, two processes started to develop rapidly and in parallel—a global environmental reawakening and a nascent concern for the development needs of poor nations. They would eventually intertwine and shape today's approach to conservation. The U.S. and Europe experienced an increased environmental awareness, influenced greatly by the fear of a nuclear catastrophe, but also by the progress of scientific research stimulated by the war. The power struggle between the United States and the Soviet Union after the war led the two countries to compete, among other things, for supporters of their economic models among the developing nations, many of which we now know are tropical countries rich in biodiversity. That power struggle was also the origin of development aid. In 1949, at the same time as NATO was created, besides military advice and equipment, President Truman offered a new program for making the benefits of scientific advances and industrial progress available for the improvement and growth of people of the world living in poverty and "whose poverty is a handicap and a threat both to them and to more prosperous areas." He said, "For the first time in history, humanity possesses the knowledge and skill to relieve the suffering of these people." He offered to help nations that would cooperate with the U.S. in the maintenance of peace and security. The objective was to convert thousands of Communist sympathizers. Development aid programs burgeoned during the sixties and seventies. Besides 'food for work' and military assistance programs, Agrarian Reform and Colonization Laws were promoted throughout Latin America coupled with agricultural development assistance.

Partly because donor governments had identified corruption in the use of aid funds and partly because they wanted more control over the projects, a myriad of non-governmental organizations (NGO) both international and national in scope were created to channel aid funds. Various United Nations organizations were created to address technical and development assistance needs at the global scale. The international Food and Agriculture Organization (FAO) was created in the United States in 1943, to become part of the United Nations in 1945. In Paris, the United Nations Education Scientific and Cultural Organization (UNESCO) was conceptualized in 1942, created in 1945, and ratified in 1946. An alliance of non-government organizations and governments concerned for the environment became the International Union for the Protection of Nature, now IUCN or The World Conservation Union, was founded in 1948 in Switzerland. The entire Galapagos archipelago was established as a national park in 1959 under the auspices of the IUCN and UNESCO.

The theory of island biogeography posed in the 1967 by ecologists Robert MacArthur and E.O. Wilson transformed ecology. By applying mathematical models for predicting and explaining the number of species that would exist on a newly created island, they moved ecology from a ‘natural history’ dominated phase to one that tries to understand interconnectedness and ecological processes in nature (MacArthur and Wilson 1967). In the U.S., Rachel Carson's *Silent Spring,* published in 1962, raised the powerful notion that man does not exist apart from nature but is connected to it (Carson 1962). The awareness about the broad destruction of wildlife being caused by highly toxic pesticides such as DDT, which until then had been regarded a postwar ‘miracle’ of modern science, was a turning point for public and private action for the environment, not only in the U.S. but globally.

In 1968 UNESCO organized a ‘Biosphere Conference,’ the first intergovernmental conference examining how to reconcile the conservation and use of natural resources. After this conference, UNESCO launched the ‘Man and the Biosphere’ (MAB) Program in 1970 with the objective of establishing a coordinated World Network of sites representing the main ecosystems of the planet in which genetic resources would be protected and where research on ecosystems as well as monitoring and training work could be carried out. These sites were named as 'Biosphere Reserves' and would be the predecessors of today's eco-regional conservation strategies.

During the 1950s and 1960s, the majority of Latin America had populist governments that promoted nationalistic policies and the development of industrialization that benefited the urban rich and the middle class, but further marginalized rural indigenous people (Boff and Boff 2000). In the 1960s, with the crisis of populism and the developmentalist model, came a strong current of sociological thinking, strongly influenced by Marxist ideas, that tried to explain the social struggles, and that had great influence on the Roman Catholic Church— very specially on the Latin American Catholic Church (Martin 2003). Reinforced by the writings from the Second Vatican Council of the Catholic Church in the late 1960s, there seemed to exist a theological justification for a political dimension to faith, and the obligation of the church to act in favor of the the poor and the oppressed—specially the landless and the marginalized indigenous people (Boff and Boff 2000). This movement, called Liberation Theology, was strong worlwide in the 1960s and 1970s, but despite disapproval of the Pope John Paul II and Pope Benedict XVI—because the movement was used to justify a social revolution through violence (Ratzinger 1987)—is still strong in Latin America (Boff and Boff 2000). Liberation Theology, a phenomenon with various layers and with a spectrum of positions from radical Marxist views that justify violent revolutions to practical actions in favor of the poor and oppressed, influenced the Catholic Church to help indigenous groups throughout Latin America increase their political power, and by that to attain policies that recognize of territorial rights of indigenous people. For example in Ecuador, Monsignor Leonidas Proaño, an idol among indigenous communities of Andean Ecuador, successfully promoted the use of the Quichua language and a respect for their culture, that would take into account indigenous myths and rituals, their oral traditions, their sense of community and their reverence for Mother Earth.

On the other hand, growing worldwide environmental awareness culminated on Earth Day 1970 and the creation of a multiplicity of environmental groups. The Environmental Protection Agency was created in 1970 and environmentally progressive legislation was passed in the United States—the Clean Air Act of 1970, the Clean Water Act of 1972, and the Endangered Species Act of 1973. In 1972 the

Club of Rome published 'Limits to Growth,' which although controversial, created further environmental awareness, as it predicted that economic growth could not continue indefinitely because of unregulated population growth, the limited availability of natural resources, environmental pollution and food shortages. Under the auspices of IUCN and influenced by the environmental trend started in the United States, European and Latin American governments created dozens of national parks in the seventies. The Santa Rosa National Park, Costa Rica's first national park, was established in 1971; while in Bavaria, Germany's first national park was created in 1970.

In 1977, a group of representatives from indigenous people from the Americas took their demands for recognition of their sovereign rights to the Decolonization Committee of United Nations (UN), the UN body responsible with overseeing the granting of independence to colonized peoples. That Committee did not meet their demands, but because of their insistence in 1983 the UN Human Rights Commission summoned a special meeting on Indigenous Peoples at the UN. That meeting resulted in the establishment of a 'Working Group on Indigenous Populations,' and ten years later a 'Declaration on the Rights of Indigenous Peoples' is accepted initiating in 1993 a UN Decade of Indigenous Peoples (Colchester 2004).

During the early 1980s, the agendas of conservation and development aid projects started to merge in the form of Integrated Conservation and Development Projects (ICDP) and Integrated Rural Development projects (IRDP). Scientists coined the term *biodiversity* for the first time. It became clear that some protected areas could not be viable by themselves; buffer zones—areas surrounding protected areas managed to conserve biodiversity by addressing both the impact of local people on the protected areas, and the impact of the protected areas on local people — would be needed. The works of E.O Wilson, D. Simberloff, T. Lovejoy, and D. Janzen were fundamental for the understanding of forest ecology and the need for connectivity and conservation beyond park borders (Wilson and Willis 1975, Simberloff and Abele 1982, Janzen 1983, Lovejoy et al. 1983). Numerous national parks were denominated 'paper parks' because they existed on paper, but were not effectively protected and often they created land use conflicts with local communities (Myers 1981). Either they had been established over indigenous territories or the parks were not effectively protecting areas from colonization and deforesting within park boundaries and its surroundings. To stop being 'paper parks,' national park managers would have to manage beyond the park boundaries and enlist the support of local populations to protect effectively the nature reserves. Involving local people actually meant helping them to find alternative income sources to deforestation, in other words, economic development. On the other hand, the development aid sector was realizing that environmental degradation was in part the culprit for the continued impoverishment of rural people. Thus in addition to promoting income-generating activities, development projects started addressing issues such as soil erosion, forest conservation, agro forestry systems, restoration, and watershed protection. Development aid workers also realized that rural communities not having functional customary laws regulating the use of natural resources and lacking land tenure security led people to overexploit their communal natural resource base (Katz 2000). That was the case for thousands of colonists without local traditions who arrived at forested lands with the hope of claiming a title thanks to Agrarian Reform and Colonization Laws.

The agendas of conservation and development have ended up having to solve the same type of problems, the only difference depending on which type of organization was doing the planning and implementation of the project. Many non-government organizations (NGOs) surfaced to carry out this new type of projects, but also research universities formed consortiums to compete for the projects. Nature conservation organizations, typically staffed by biologists and ecologists would frame the solution one way; development organizations, often staffed by anthropologists, sociologists, foresters or agronomists would frame it in a different way. Models and paradigms emerged in each discipline, and tension became evident between ecologists and anthropologists, between economists and ecologists or anthropologists, between practitioners and researchers. In most cases, however, sound economic and financial advice were often missing, and too often projects were paternalistic had no concern for market development, and did not have sound long-term financial strategies for sustainability as a goal. As a whole, ICDP and IRDP projects were considered highly disappointing. Millions of dollars were spent on foreign and national experts, and thousands of management plans and reports and even peer-reviewed publications were produced, while the livelihood of tropical forest inhabitants was left either worse or unchanged, and deforestation and natural resource degradation continued unabated. The ICDP/IRDP era left a few successes and many lessons learned (Salafsky and Margoluis 1999, Rhoades and Stallings 2001, Salafsky et al. 2001, Browder 2002).

As studies have produced extensive, yet inconclusive wildlife inventories in the tropics, we have learned that biodiversity is concentrated in few hotspots, under tremendous human pressure and inhabited by materially poor rural people. We understand better the need of habitat connectivity. We know that not all habitat patches have the same quality of conditions for different species (Dunning et al. 1992). Not only that, the geometry of the patches also greatly influences the quality of the habitat. Many species migrate altitudinally, others migrate latitudinally, and all need habitat corridors along the way. Advances in computing power and GIS technology are producing better predictive models for species. Thanks to satellite technology, since the 80s, we have witnessed the scale of devastation of tropical forests. This knowledge has led us to realize that the national parks established in the 1970s and 1980s do not necessarily represent the majority of biodiversity in need of protection, that therefore additional protected areas should be established. However, due to population growth and especially due to Agrarian Reform and Colonization Laws, forestland is largely in private hands; therefore establishing more national parks is not necessarily an option. Additionally, the protection of national parks is not a first priority for funding by governments; adding more government protected areas would only put strain on the existing parks.

The Brundtland Commission, also known as the World Commission on Environment and Development (WCED), convened by the United Nations in 1983, indicated that it was necessary that nations establish policies for sustainable development to address the growing concern "about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development." In 1987 the WCED published Our Common Future, which defined sustainable development as "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs"(Brundtland-Commission

1987). That was the conceptual basis for the 1992 Earth Summit and the ensuing Agenda 21, the Río Declaration, the establishment of the Commission on Sustainable Development. Such approaches as bioregionalism, ecoregional conservation, landscape approach, ecosystem approach to conservation, conservation corridors, and watershed management strategies emerged within the last decades as a response to the need of bringing to practice the theoretical constructs of sustainable development by integrating conservation at various scales with the economic development needs of humans.

In 2002, the UN set up a 'Permanent Forum on Indigenous Issues' whose members are made up equally of government delegates and indigenous representatives to guarantee successful co-ordination between the UN agencies dealing with indigenous peoples. Colchester (2004) highlights that as a result of their sustained advocacy, indigenous peoples through various international bodies and regulations now have rights to:

- Self-determination.
- Freely dispose of their natural wealth and resources.
- In no case be deprived of their means of subsistence.
- Own, develop, control and use their communal lands, territories and resources, traditionally owned or otherwise occupied by them.
- The free enjoyment of their own culture and to maintain their traditional way of life.
- Free, prior and informed consent prior to activities on their lands.
- Represent themselves through their own institutions.
- Exercise their customary law.
- Restitution of their lands and compensation for losses endured.

These days, Latin America is also experiencing the influence of the Millennium Ecosystem Assessment (MA) (2001 – 2004). MA was a gigantic effort to integrate worldwide assessments of the earth's ecosystems from existing international environmental research, monitoring, and assessment activities intended to inform decision makers and the public about the links between human well-being, the costs of developing our planet, and the status of ecosystems and their sustainable use. The MA was a U.S. $24.9 million project implemented by the World Resources Institute in collaboration with the United Nations Environmental Program, the United Nations Development Program, the World Bank, the United Nations Food and Agricultural Organization, United Nations Educational, Scientific, and Cultural Organization, the Meridian Institute, the IUCN, and the International Council for Science. MA was designed specifically to help to meet assessment needs of the Convention on Biological Diversity, Convention to Combat Desertification, the Ramsar Convention on Wetlands, and the Convention on Migratory Species (GEF 2000). The assessment concludes that in the past 50 years humans have changed the ecosystems of the earth more rapidly and extensively than in any comparable period in human history, and that substantial development has been achieved at the expense of exhausting our natural and sometimes even harming some groups of people and regions. The MA is slowly becoming influential in national discourses, funding agencies, and research agendas (Carpenter et al. 2006).

1.4.2 A Synopsis of the Development of Conservation Initiatives in Ecuador

The history of the development of conservation initiatives in Ecuador has never been chronicled. For that reason and because such a chronicle places the Chocó-Andean Corridor—the first conservation corridor laid out in Ecuador— in an historical context, this chapter begins with a history of conservation in Ecuador.

It was the mid 1980s, and the conservation movement for mainland Ecuador was about to experience key changes thanks to an explosion of interest in nature from non-governmental environmental organizations (NGO). At the time, only a handful of nature conservation NGOs had been established. Fundación Charles Darwin, the oldest NGO, had been set up in 1959 by the IUCN (World Conservation Union) and UNESCO (the United Nations Educational, Scientific and Cultural Organization) to study and protect the Galapagos archipelago (Black 1973). Fundación Natura[1], founded in 1978 under the auspices of the World Wildlife Fund (WWF) and IUCN, while expressing strong interest in the National Park System, acted primarily in the urban education program, and quickly became well known due to a USAID funded nation-wide urban environmental education program, EDUNAT. Fundación Natura’s Cuenca chapter split to form Tierra Viva in 1984 because Natura sided with industry to build on agricultural land in Cuenca (Meyer 1995). Both opposed land purchase for conservation. Fundación Natura took this position because Ecuador's National Park System was thought to harbor most

[1] Fundación Natura was created by Ministerial Decree No. 7246 (Ministry of Education and Culture), and published in the National Registry No. 635 on July 25 1978.

of Ecuador's biodiversity (Fundacion-Natura 2007) and land purchase was thought to primarily strengthen NGOs (Ruiz 2001, El-Comercio 2003); while Tierra Viva opposed land purchase for conservation with money from foreign sources because it viewed such an approach as selling out the country's sovereignty. Fundación Forestal Juan Manuel Durini[2] had been founded in 1980 as a research and development branch of the largest consortium of timber companies in Ecuador. The Amigos de la Naturaleza Sociedad Francisco Campos, created in honor of a prominent entomologist from Guayaquil from the early 20th century, was focused on research. On the coast, the Fundación Pedro Vicente Maldonado[3], founded in 1984, was concerned with the deterioration of the mangroves, especially along the coast of Guayas province. In 1986, F. Maldonado began collaborating with the largest international multi-institutional program for the conservation of mangroves, the Coastal Resources Management Program (Bodero and Robadue 1995). Also in 1986, a National Council for the Conservation and Research of Birds (CECIA) was formed by a group of ornithologists and birders concerned with the fate of bird conservation (Loor 2007). Also an activist organization started to form, Acción Ecológica that vehemently opposed land purchases for conservation.

As for international conservation NGOs, WWF and IUCN started their presence in Ecuador in 1959 through supporting conservation in the Galapagos through the Charles Darwin Foundation. In 1987 WWF and F. Natura carried out the first debt-for-nature swap in Ecuador. Besides its participation in the creation of the Galapagos National Park, IUCN became more influential in Ecuador as early as the late 1970s, although it established an office in Ecuador only in the 1990s. In the mid 1970s the United Nations Food and Agricultural Organization (FAO) sent experts to Ecuador to help strengthen the forestry system and this effort led to the preparation of a preliminary strategy for the conservation of outstanding wildlife areas (Putney 1976). That was in fact the strategic planning basis for the modern national park system, and indirectly what motivated one of the FAO experts and a prominent Ecuadorian ornithologist

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[2] Corporación Forestal Juan Manuel Durini was created by Ministerial Decree (Ministry of Education and Culture) No. 19745 on October 30, 1980; and later dissolved and created as Fundación Forestal Juan Manuel Durini registered with Ministerial Decree (Ministry of Education and Culture) No. 2423 on May 17 1990.

[3] The Fundación Pedro Vicente Maldonado was created by Ministerial Decree No. 5091 of the Ministry of Education and Culture on 30 July 1984, published in the National Registry No. 4 16 August 1984.

Fernando Ortiz to propose to a group of wealthy and influential Ecuadorians the creation of Fundación Natura (Vreugdenhil 2007). The Nature Conservancy (TNC) had attempted to establish a conservation program in 1984 for the Galapagos National Park, but due to bickering for the funds among the existing organizations (Kakabadse 1989), it wasn't until 1988 that TNC renewed its presence with its interest in helping to establish the Maquipucuna Reserve and a second debt-for-nature swap with Fundación Natura with funds raised by the Missouri Botanical Garden, Charles Darwin Foundation, WWF and TNC.

The Confederación de Nacionalidades Indígenas del Ecuador (CONAIE), founded in 1986, consolidated a several decade process of organization and reaffirmation of the identity of the indigenous culture in Ecuador, with a conservation ethic drawn from deep respect for the 'Pacha Mama' (mother earth) (Lluco -Tixe 2000). The consolidation of CONAIE occurred in parallel with the advancement of the international movement demanding rights for indigenous groups. Thus, the creation of CONAIE was a definite step towards Ecuadorian indigenous groups securing tenure, control, and use of their communal lands, territories and resources, traditionally owned or otherwise occupied by them.

Deforestation was rampant, and there was an obvious relation between the poverty that rural people lived in and their exploitation for land and labor through the mining of natural resources, the spread of plantation monocultures, and failed government policies (Parsons 1957, Norman 1988, Dodson and Gentry 1991, Southgate and Whitaker 1992). FAO, which had maintained their presence since the 1970s helping the forestry sector through the direct implementation of a multi-million, multi-year social forestry project in the degraded Andean region, 'Proyecto de Desarrollo Forestal Participativo en los Andes (DFA)' in early 1990s was influential in helping the government of Ecuador structure a National Forestry Action Plan (PAFE) aimed at finding means to mitigate the deforestation crisis. The PAFE consisted of a portfolio of strategic programs, projects, and donor meetings that for the first time brought together various Ecuadorian NGOs and foreign assistance government agencies from several nations to implement integrated conservation and development projects in the rainforest areas that were undergoing deforestation. The programs and projects in PAFE that attracted international aid agencies to the forestry sector also revealed the lack of coordination and duplication of efforts and the lack of people adequately trained to serve as agro forestry extension workers. The Red Agroforestal Ecuatoriana (RAFE)—a network of international aid agro forestry projects, individuals, and Ecuadorian NGOs—was created as the forum for coordination and to establish guidelines to train the type of extension workers needed to understand the application of ecological principles to forestry management, as well as being respectful of the culture of local and indigenous communities. Several PAFE projects received funding after that initial donor round table. Prompted by an increasing national and international interest in the rich biodiversity of Ecuador, tropical biology schools in Guayaquil, Quito, and Cuenca began producing cadres of tropical biologists better informed about the ecology of the natural areas.

While interest in conservation among Ecuadorians was growing in the 1970s and 1980s, it is noteworthy that on a handful of farms, mostly owned and managed by foreigners from the United States and Europe, the owners had set aside areas of rainforest for conservation, such as in Tinalanda, La Perla, Río Palenque, Palmeras, and DeCoux farms.

During the 1990s there was an explosion of interest in conservation, and now there are over 400 conservation NGOs (Ministerio-del-Ambiente 2006), some with genuine positive proposals, and others 'charlatans' only going after the money (Meyer 1995), but surely the good outnumber the bad. Despite the continued opposition from other organizations, numerous nature conservation NGOs have purchased land for conservation, such as Fundación Maquipucuna, Fundación Jatun Sacha, Fundación Sirua, Fundación Jocotoco, Fundación San Francisco, and Centro de Investigación de Bosques Tropicales. Fundación Maquipucuna and Fondo Ecuatoriano Populorum Progressum (one of the oldest and most prestigious among development-NGOs) have also bought land to transfer to local communities. Besides the newly created nature conservation organizations, many of the former development-NGOs now are also addressing environmental protection issues. Fondo Ecuatoriano Populorum Progressio (FEPP) is the most outstanding example, receiving in 2005 the prestigious United Nations Environmental Program Global 500 Laureate award. FEPP was originally founded as a development NGO by the leadership of the Roman Catholic Church in Ecuador in 1970 as a response to the Papal encyclical Populorum

Progressio of Pope Paul VI, which called for a ‘common fund’ to assist ‘the most destitute’(Fondo-Ecuatoriano-Populorum-Progressio 2007).

Starting in the mid 1990s, all the major international nature conservation organizations established their own offices in Ecuador. The establishment of international organizations was facilitated because the country had an open doors policy (Meyer 1995) and partly in response to the affluence of bilateral and multilateral funds earmarked for Ecuador, as Ecuador has been recognized internationally as a ‘mega-biodiverse’ country which harbors various global conservation priorities.

1.4.3 Fundación Maquipucuna

In the mid 1980s, there was a palpable void of institutions that would take conservation practice into the field and integrate science-based conservation with the needs of people, while breaking free from the conservative strategies of lining up with industry interests and from the radical views that using foreign funds for conservation was selling the country’s sovereignty. It was in this context and after field visits to the decreasing forests of northwest and northeast Ecuador between 1985 and 1986 that, the goals of Fundación Maquipucuna were conceptualized. F. Maquipucuna was initiated by Rodrigo Ontaneda, a young insurance executive from Quito; the author, then an undergraduate genetics student at the University of California at Davis; and Gustavo Morejón, a tropical biology student at the Pontificia Universidad Catolica in Quito. The young founders of Maquipucuna felt challenged to make a difference for the environment by the fact that foreign farmers had appreciated the ecological value of Ecuadorian forests and actually were setting aside land for conservation and that their conservation areas had better infrastructure than all the continental national parks, while Ecuadorian professional conservationists were only talking about conservation. The vision for Fundación Maquipucuna was reinforced by the exchange of ideas of its young founders with people such as Drs. Tom Lovejoy, Peter Raven, Dan Janzen, and Paul Ehrlich during the American Institute of Biological Sciences (AIBS) meeting, in Davis, California, in 1988. There, Dr. Tom Lovejoy gave the keynote speech where he stated that "we must move from thinking of nature as something which is set aside discretely for protection within a human-dominated landscape to thinking of human populations and activities as taking place within a natural landscape. . .

[We need to] create a sense of urgency about biological diversity, climate change and human population. These are problems that grow by increments which may not seem of particularly great consequence but which in aggregate are disastrous."

In 1988, Fundación Maquipucuna[4] was legally established in Ecuador as a grass roots, non-profit, non-governmental, nature conservation organization for integrating the conservation of Ecuador's biodiversity and the sustainable use of its natural resources, education, scientific research, and funding strategies, with the participation of local communities (Fundacion-Maquipucuna 1987). Fundación Maquipucuna was the first organization to purchase land for conservation in Ecuador and to integrate local communities into ecotourism related activities, which has subsequently proven to be one of the most effective means to protect biodiversity.

Fundación Maquipucuna also pioneered conservation involving local communities in southeast Ecuador in the buffer zone of the Podocarpus National Park starting in 1989 with a small grant from the World Wildlife Fund. Through the National Forestry Action Plan (PAFE), F. Maquipucuna received an important grant from the British Government (it was the first time the Overseas Development Administration of the UK, ODA granted funds to an Ecuadorian NGO) to expand the community development program in agroforestry training, as well as help solve land tenure conflicts with the communities in the buffer zone of the Podocarpus National Park.

Fundación Maquipucuna and the Odum School of Ecology at the University of Georgia proposed the Chocó Andean Corridor as a conservation strategy over an east-west altitudinal gradient in 1992 (Justicia 1995) with the ultimate goal of providing continuous habitat from the coast to the Andean summit. The Chocó Andean Corridor was proposed as a matrix of land uses that accommodates conservation and human needs of sustainable economic development. To establish the Corridor, F. Maquipucuna would apply the experience it had obtained by establishing the Maquipucuna Reserve and

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[4] Fundación Maquipucuna was created by Ministerial Decree No. 116 of the Ministry of Agriculture and Livestock (then that Ministry was in charge of conservation), and published by Official Decree No. 919 on April 21 1988.

its community based projects, and the community based conservation work in and around Podocarpus National Park.

1.5 CLIMATE CHANGE POLICY CONTEXT

1.5.1 Policy Background

From the time of the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1990, often referred to as the Kyoto Protocol following the 1997 revision, policy development related to the role of forests in mitigating green house gases (GHG) has been both fast and complex. This section summarizes the main aspects of the international policy framework governing forestry-based GHG mitigation projects. This policy is relevant not only to the development of forest carbon storage projects but also to the use of woody plants that have economic value in addition to carbon storage. In particular, I discuss this policy background in light to develop a major project with native bamboo, as described in Chapter 4.

1.5.2 The United Nations Framework Convention on Climate Change

On 11 December 1990, the 45th session of the UN General Assembly adopted a resolution establishing an overall framework for intergovernmental efforts to tackle the challenge posed by climate change: the Framework Convention on Climate Change (FCCC). The FCCC recognizes that the climate system is a shared resource and that industrialization and other sources of carbon dioxide and other greenhouse gases can affect the stability of the global climate system. The FCCC, presented at the United Nations Conference on Environment and Development (UNCED) in Rio in 1992, entered into force in 1994 and since then over 191 countries have ratified it. Through the convention, governments agree:

a) to gather and share information on greenhouse gas emissions, national policies and best practices,
b) to launch national strategies for addressing greenhouse gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries, and
c) to cooperate in preparing for adaptation to the impacts of climate change (UNFCC 2007f).

1.5.3 The Kyoto Protocol and the policy framework for reforestation and afforestation

A range of policy instruments to facilitate reductions in greenhouse gas (GHG) emissions has been explored and proposed to help Annex I countries[5] meet the commitments required by the UNFCCC. These include direct regulation of emission sources, subsidies for emission reduction projects, taxes on emissions, and tradable emission credits, or 'emissions trading' (ET). These credits, equivalent to the net carbon reduction or sequestration derived from a specific investment, allow investors to use them to lower GHG-related liabilities in their respective home countries. Market-based instruments are included to enable industries to look for cost-effective emission reduction opportunities in a significantly more efficient way than regulatory-led emission reduction procedures. Thus, a company in an Annex I country that is committed, for example, to a reduction of 500 tons of carbon per year could choose to invest in carbon reduction technology and reduce its own emissions, or the company could fund a project in a non-annex I country that would remove at least 500 tons of carbon each year.

The Kyoto Protocol was the outcome of a third Conference of the Parties (COPs)—the governing body of the UNFCC—meeting on December 1997. The protocol strengthened the UNFCC by committing Annex I countries to specific, legally binding targets to limit or reduce their GHG emissions. Only parties to the UNFCC that have also ratified the Protocol are obligated by the Protocol's commitments. The Kyoto Protocol came into force on February 16, 2005, following ratification by Russia on November 18, 2004. As of December 2006, 166 parties had signed and ratified, but 4 countries had signed without intent to ratify the protocol, among them the United States and Australia (UNFCC 2007d). The Kyoto Protocol delineates mechanisms for 39 developed countries and economies in transition (the Annex B countries) to reduce their GHG emissions by an average of 5.2%, based on1990 levels, by the commitment period, 2008-2012 (UNFCC 1998). The Protocol also approved the use of three 'flexibility mechanisms' (Emissions Trading (ET), Joint Implementation (JI) and the Clean Development Mechanism (CDM)) for meeting GHG emission reduction targets and to lower the costs of

[5] Annex I countries are developed countries or economies in transition listed in the UNFCC with emission reduction commitments. The individual targets for Annex I countries are listed in the Kyoto Protocol's Annex B.

reaching those targets. Compliance could be achieved in several ways: by reducing emissions utilizing cleaner technologies, through GHG-sink projects, or by purchasing GHG emission reductions from elsewhere. Certified GHG emission reduction credits are being traded as commodities or can be purchased from projects which reduce emissions in other Annex I countries under the Joint Implementation or from non-Annex I, under the Clean Development Mechanism (CDM). GHG emission reductions can result from projects in the construction, energy, transport, commercial, industrial, and other sectors, but here I focus on forestry and conservation activities.

Another important result of Kyoto was to recognize land use and forestry (LULUCF) activities as valid options for reducing net concentrations of atmospheric GHGs. The language of the Protocol is not conclusive as to the types of land use and forestry activities that are allowed; however, subsequent COPs have clarified what types of terrestrial sinks are accepted as valid mitigation activities for the purposes of the Kyoto Protocol. Unresolved matters such as the definitions of LULUCF activities under the protocol's Article 3.3 and Article 3.4 and the rules for accounting of these activities were resolved and agreed on as part of the Marrakesh Accords of the COP 7 in 2001 (UNFCC 2007e). Sink projects such as avoided emissions from rainforest conservation have not been approved yet, and the technical drawbacks holding up the approval will be considered during the COP 13 in December of 2007 (UNFCC 2007c). To date there are there are at least seven methodologies approved for afforestation and reforestation projects (UNFCC 2007a).

The lingering issues that limit Kyoto's approval of deforestation avoidance include, first, the uncertainty in measuring and predicting deforestation—in other words deforestation projections of 'without-project' baselines are not accurate enough to certify emissions reductions (Brown et al. 2002). Contributing to the uncertainty is the difficulty in gauging the conservation success of projects, and thus to determine and quantify potential leakage (Aukland et al. 2003). In this sense leakage is a term in the Protocol that means that activities implemented to reduce emissions due to avoiding deforestation in one place would drive deforestation elsewhere. The other reason is a political argument that claims that sink projects may induce industrialized countries to delay or avoid actions to reduce fossil fuel emissions

(Fearnside 2001, Brown et al. 2002). Nonetheless, it is expected that progress in remote-sensing and geographic information system technologies coupled to advanced scientifically based monitoring programs, proper analysis at the project design, and economic methods may lead to forthcoming inclusion of conservation within the CDM (Brown et al. 2002, Aukland et al. 2003).

1.5.4 The Clean Development Mechanism (CDM) and the CDM project cycle

Some of the most cost-efficient mitigation opportunities occur in developing countries. Availability of land, low production costs, and fast growth rates are conditions that favor reforestation sequestration projects.

The Clean Development Mechanism (CDM) is the Kyoto flexibility mechanism of relevance to developing countries, while the Joint Implementation (JI) Mechanism facilitates the creation, acquisition, and transfer of emission reductions from projects aimed at reducing emissions at sources or enhancing GHGs removals by sinks between Annex I developed countries. The CDM is designed to assist developing countries (non-Annex I Parties) in making progress towards sustainable development and contributing to the UNFCCC's objectives, while enabling developed countries and economies in transition (Annex I Parties) to achieve their emission reduction targets in a cost-effective manner. Developing countries are supposed to gain the economic, developmental, and environmental benefits from implemented projects that generate Certified Emission Reductions (CERs) for export.

Currently most CDM-approved projects are for the generation of alternative energy (not based on fossil fuels) in developing countries. A relatively small number of reforestation projects have been accepted and the number is not growing as they are with the other type of CDM projects. If deforestation avoidance were approved to create certified emission reductions, those projects would become part of the CDM.

The CDM project cycle

The development of a CDM project is required to follow predetermined steps. Furthermore, tight monitoring and verification of emission reductions from CDM projects is a requirement. I include a brief description of the CDM project cycle in order to provide the policy context for a native bamboo (*Guadua angustifolia*) carbon alternative described in chapter 3.

There are various players in a CDM project. On the one hand, there are two parties or countries involved, one of which is the host country (non Annex I country) where the project will take place. There are also the private entities or project participants, from both the host and the developed country (the project participant from the developed country purchases the certified emission reductions-CERs). Additionally various types of organizations may provide services to a CDM project. Any consulting firm or NGO in the field can typically aid in the preparation of the Project Design Document. However, a specific type of organization called Designated Operational Entity (DOE) is required to participate at different stages of the project cycle. DOEs are organizations authorized by the Conference of the Parties/Meeting of the Parties (COP/MOP) of the UNFCC, based on the recommendation of the CDM Executive Board to validate proposed CDM project activities as well as verify and certify reductions in anthropogenic emissions by sources of greenhouse gases (GHG) and net anthropogenic GHG removals by sinks. Typically, large or international entities already in the business of providing inspection, verification, and quality certification services are becoming DOEs (UNFCC 2007b). There are also Applicant Entities (AE), which perform only some of the tasks that DOEs do until they become approved. A DOE can perform validation or verification and certification of a CDM project activity; however, if the Executive Board approves, a single DOE can perform all these functions within a single CDM project activity.

Project design is the preparation of a project design document (PDD) that describes the project activity; estimates the GHG mitigation potential of the project; identifies the project partners; describes the baseline methodology and monitoring plans and their application; makes a stakeholder evaluation; and describes the socio-economic and environmental impacts of the project. Baseline and monitoring methodologies must be approved by the Executive Board (EB) of the CDM.

Validation is the process of independent evaluation of a project activity by a DOE, and it can take two forms depending on whether the PDD uses an approved baseline and monitoring methodology or proposes a new methodology. Approved methodologies by the Executive Board are publicly available with guidelines for application (UNFCCC 2007a). If a new baseline and monitoring methodology is being proposed, the project proponent has to hire and submit it to the Executive Board of the CDM for approval through a DOE or AE. If the EB approves the methodology, the validation process ends there. If the PDD uses an approved methodology, the DOE must check if the PDD meets the validation requirements, and if it does, it submits it to the EB. Validation of a baseline and monitoring methodology verifies the following:

- Whether the project will result in real, measurable, and long-term environmental benefits additional to the baseline scenario and related to the mitigation of climate change;
- Whether the baseline methodology has already been approved or if it's a new proposed methodology that conforms to all the CDM criteria;
- Whether the project conforms to the sustainable development objectives of the host country and local stakeholders in question; whether the project is compatible with and supportive of national and developmental priorities;
- Whether it has a formal approval by the host country;
- How the project will monitor its GHG and sustainable development achievements (inspection of the monitoring plan);
- How the project will deal with GHG (leakage) and non-GHG externalities, such as deforestation in other areas caused by people from the project that may result affected by the project.

Registration is the official acceptance by the EB of a validated project as a CDM project activity. Registration is the prerequisite for the verification, certification and issuance of certified emission reductions (CERs) related to that project activity. The Executive Board will register a project activity eight weeks after it receives the request for registration unless a Party involved in the project activity or at least three members of the Executive Board request a review of the proposed CDM project activity. The review by the Executive Board relates to issues associated with the validation requirements, and is to be finalized no later than at the second meeting following the request for review, with the decision and the reasons for it being communicated to the project participants and the public. A proposed project activity that is not accepted may be reconsidered for validation and subsequent registration, after appropriate revisions, provided that it follows the procedures and meets the requirements for validation and registration, including those related to public comments (UNFCCC 2007d).

Monitoring: Once the project enters the implementation phase, it has to establish a monitoring program for collection of project-specific data to allow for the calculation of real project achievements. The area needs to be zoned as necessary to calculate the baseline carbon pools, as well as to incorporate the variability of the planting schemes. Carbon-specific data has to be collected for all project-based carbon pools and flows before, during and after; and a database needs to be created by the project, which later will be verified by a DOE. If conservation projects became eligible, additional data would include precise rates and location of deforestation or avoided deforestation.

Monitoring data includes:

- Tree growth, recruitment and mortality, and crown and root development;
- Understory growth and amount of biomass lost through weeding, biomass volume in litter layer and other necromass, and rate of decomposition of necromass in the forest floor;
- Soil carbon, down to 30 cm, and fluctuations during the growth cycle (with particular emphasis on the periods immediately after harvesting and thinning);
- Amounts of wood thinned and harvested, as well as its final uses and losses during the manufacturing process, and records of utilization of residues;
- CO_2 emissions incurred in carrying out the project;
- Leakage (unexpected CO_2 emissions provoked by the project).

Verification/ certification and issuance of credits: Projects need to be independently verified by a DOE before any carbon credits can be issued for trading. Verification will need to ascertain the following:

- That the project has followed the validated Project Design Document;
- The validity of the carbon claims and the calculations used for producing these claims;

- The quality of the data and the procedures used for data collection;
- That the sustainable development indicators proposed in the Project Design Document have been monitored and meet the project's targets.

The successful output of the verification process is the certification of the project that consists of issuing a statement indicating that the project has successfully created a given amount of carbon credits in accordance with the rules of the Kyoto Protocol and the UNFCCC. Based on this certificate, the CDM Executive Board can then issue credits for the project (UNFCCC 2007d).

1.5.5 Growing disappointment and ensuing challenges for the CDM

In the last 10 years great expectations arose among conservationists and rainforest owners and stewards, such as indigenous communities and local conservation NGOs, that the CDM would help fund conservation through avoided emissions and carbon sequestration projects. Land owners hoped this would be the mechanism to generate long term and direct economic incentives for conservation and reforestation that offsets the opportunity costs of foregoing other uses of the land more profitable in the short term. Disappointment with the CDM is growing because—despite the fact that 27% of the CO_2 emissions come from deforestation and degradation of tropical forests and soils and because CDM was created in the name of sustainable development in developing countries and to help poorer countries cope better with the impacts of climate change—we are witnessing a climate change industry that is growing primarily to benefit the rich and the developed world. The strongest impact of climate change will probably be endured by farmers and other rural people in the tropics who are more vulnerable and have less capacity, including access to technology and capital, to adapt to change. Yet, most CDM projects approved and under implementation to date have nothing to do with rural people, with farming, or with forest conservation as it is illustrated in figure 1.2. Of over 1,000 projects registered, only one reforestation project—under the auspices of the World Bank in China—has so far been registered (UNFCCC 2007c). Nearly half are large scale alternative energy—such as wind towers and hydroelectric plants—CDM projects implemented by large companies in developing countries and often even run by expatriates from the developed world. When they are not alternative energy generation projects, they are reduced emissions from waste handling and disposal projects from large-scale poultry or other large-scale industrial or farming operations.

Rainforest land owners, such as indigenous communities or owners of smaller parcels of land that could undergo reforestation are not able to set up CDM projects because of the very high costs of transaction of those projects. Similarly, the costs of properly designing and implementing carbon emission reduction projects for the voluntary market are also too high. Even most of the non-profit local nature conservation organizations (NGOs) that own private nature reserves, often of thousands of hectares, can not afford the costs of transactions to set up CDM projects. The transaction costs to prepare the project design document (PDD), to develop the methodology to generate carbon credits, to negotiate the projects with both the CDM board and with prospective investors, to design a monitoring program, and verification add up to very high sums of money that could only be internalized by large scale projects (Michaelowa et al. 2003). Under current estimates of world market prices for greenhouse gas emission permits, projects with annual emission reductions of less than 50,000 t CO2 equivalent are unlikely to be viable; for micro projects transaction costs can reach several hundred [Euro] per t CO2 equivalent (Michaelowa et al. 2003). There are several reasons why the costs of transaction end up being so high. One reason is that the magnitude of the global climate change dilemma requires timely, precisely measurable, and thus credible emissions reductions resulting from the projects. Secondly, the investors of the projects demand guarantees for their investment, whether because they plan to sell the credit certificates or because they are companies that must comply with emission reduction caps of their countries. The third reason is the information required by the project calls for knowledgeable people with access to advanced technology to assess baselines (emissions without project), for designing and implementing monitoring carbon emission, for quantifying leakages (unintended emissions that result because of the project), as well as for quantifying the emission reductions. Finally, these projects require that the people responsible for the project be legally accountable for their emission reduction commitments and that there be realistic enforcing mechanisms in place. Consequently, the setting up of

CDM projects is much more complex than it was originally thought, and that complexity has increased the ensuing frustration among conservationists as well as land owners of rainforests.

If CDM is in effect going to work for rainforest conservation and small landowners, key things need to happen. We need to design CDM projects whereby transaction costs are reduced, at the same time that accountability can be enforceable, and we are able to quantify precisely both the baseline as well as the reduction of carbon emissions. The quantification of forests carbon content by combining the use of high resolution images and randomized carbon field sampling, coupled with models of land use change promise to help in the determination of realistic baselines. Models of land use change should be done in a participatory manner, with the involvement of relevant stakeholders, e.g. land owners and local authorities. Modeling land use change in a participatory way implies involving local stakeholders in the process of determination of the weight of factors that drive deforestation. That would result in greater local understanding of the strict demands of quantification and monitoring, and therefore more buy-in to the project. An increased understanding also would likely generate respect for the project guidelines and would open up opportunities to engage local authorities into the monitoring process.

1.5.6 Applicable International standard definitions of forest

The definition of forest does not include land that is predominantly under agricultural or urban land use or tree stands in agricultural production systems, for example in fruit plantations (FAO 2006b). Forest is determined both by the presence of trees and the absence of other predominant land uses. The UNFCC uses the Food and Agriculture Organization (FAO) standard definitions of forest (FAO 2006a, UNFCCC/CCNUCC 2006):

> Forest is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 metes at maturity *in situ*. A forest may consist either of closed forest formations where trees of various storys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest.

Furthermore, relative to the bamboo project discussed later, forests also include areas with ***bamboo*** and palms provided that height and canopy cover criteria are met.

A country's designated national authority (DNA), typically the Minister of Environment, for the CDM decides the parameters it has chosen for the definition of 'forest' to be used for the purposes of hosting project activities under the CDM. Ecuador's DNA has chosen a 30% cover or higher to define forest.

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1800's	Humboldt
1800's	Pinchot – 'Conservationist' vs. Muir – 'Preservationist'
1872	Yellowstone National Park – displacement of local and indigenous peoples
1930's	Scenic National Parks established in Europe & Latin America
1945	End of WW II
1945	Creation of United Nations' FAO & UNESCO
1948	Creation of IUCN – Word Conservation Union in Switzerland
1949	President Truman - NATO & Beginning of development aid programs
1960's	Liberation Theology in the Latin American Catholic Church
1962	Rachel Carson's Silent Spring
1967	R.H. MacArthur and E.O. Wilson - Theory of Island Biogeography
1970	First Earth Day
1970	UNESCO – Man and the Biosphere Program – 'Biosphere Reserves'
1970's	Boom of National Parks in Latin America and Europe sponsored by IUCN and FAO
1972	Club of Rome - 'Limits to Growth'
1977	Indigenous Peoples demand rights at Decolonization Committee of United Nations (UN)
1980's	E.O. Wilson, T. Lovejoy - 'Biological diversity' and 'Biodiversity'
1980's	International Conservation and Sustainable Development Projects (ICDP's)
1983	UN Human Rights Commission summoned a special meeting on Indigenous Peoples
1987	Brundtland Commission – 'Our Common Future' & 'Sustainable Development'
1990	United Nations Framework Convention on Climate Change (UNFCCC)
1992	Earth Summit – Rio Declaration and UN Commission for Sustainable Development
1993	UN Decade of Indigenous Peoples initiates with Declaration on the Rights of Indigenous Peoples
1997	Kyoto Protocol
2004	Millennium Ecosystem Assessment

Figure 1.1 Milestone events that have influenced modern conservation in Latin America.

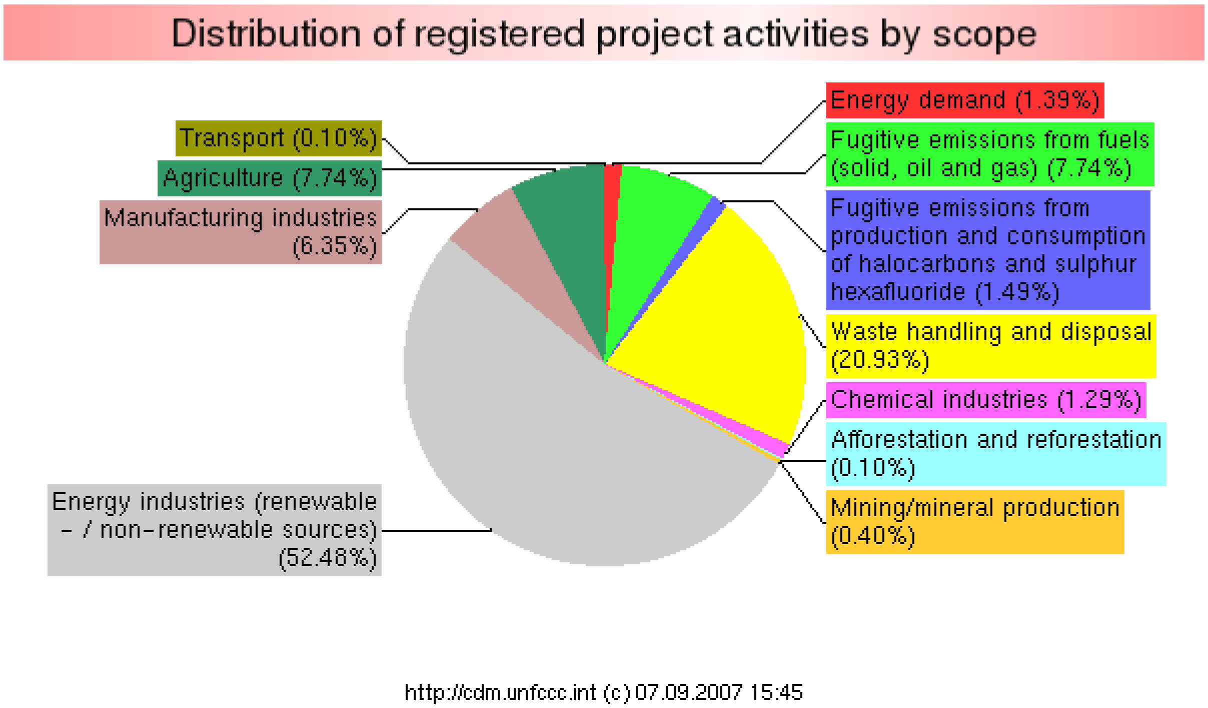

Figure 1.2 Distribution of Clean Development Mechanism (CDM) registered projects showing how afforestation and reforestation projects have the least significant participation in the CDM climate change mitigation projects.

CHAPTER 2

THE CHOCO ANDEAN CORRIDOR REGION OF NORTHWEST ECUADOR

2.1 INTRODUCTION

Even by neotropical standards, the lowland Chocó and Andean slopes of Northwest Ecuador contain extraordinary levels of biodiversity and endemism (Table 2.1). Protecting the biodiversity of this region ranks as a top global priority for nine international conservation organizations (Redford et al. 2003, Harris et al. 2005, Brooks et al. 2006). In 1992, the Maquipucuna Foundation initiated the Chocó Andean Corridor project with the ultimate goal of providing continuous habitat from the coast to the northwestern Andean summit (Figure 2.1). The Chocó Andean Corridor spans two of World Wildlife Fund's Global 200 Ecoregions: the lowland Chocó-Darien Moist Forests that stretch from Panama, western Colombia, and Western Ecuador and the Northern Andean Montane Forests (Dinerstein et al. 1995, Olson and Dinerstein 2002). Similarly, the Chocó Andean Corridor extends over two of Conservation International's biodiversity hotspots; the lowland forests of the Chocó are part of the Tumbes-Chocó-Magdalena hotspot while its Andean forests above 900 m belong to the Tropical Andes hotspot (Conservation-International 2006). The Chocó Andean Corridor also falls within BirdLife International's Chocó Endemic Bird Area (EBA) and has some geographical overlap with the North Central Andes EBA in the Cotacachi area. BirdLife International includes within the Corridor 19 of the total 114 of areas recognized as Important Bird Areas (IBAs) in all Ecuador (Aves-y-Conservacion 2007).

By the early 90's, the lowland rainforests of Western Ecuador below 900 m had virtually disappeared (Dodson and Gentry 1991). Currently the only large remaining forest tracts are located in the Chocó Andean Corridor, but are gravely threatened by advancing deforestation (Dushku and Justicia 2003).

The following section is a description of the environment, the people, and the institutions of the Chocó Andean Corridor region. Its diversity in every sense obligates us to study and understand the region as a whole, before we can propose biodiversity conservation and sustainable development policies. The state of natural, human, social and man-made capital in the region is both the foundation for conservation and sustainability and the threats to biodiversity conservation. This section is not an exhaustive treatment of each topic. Rather, it is an attempt to show the relationships of different topics conventionally treated as independent subjects. Natural capital here is used as a metaphor for the biophysical basis (geographical and geological conditions, soils, vegetation, and fauna) for the production of ecosystem services such as productivity, water cycling, erosion prevention, oxygen production, carbon storage, pollination, seed dispersal, and the maintenance of biodiversity. Human capital refers to education, health and other basic indicators of individual development. Social capital refers to the cultural heritage, local social organization and institutions active or influential in the region. Man-made capital refers to the infrastructure and investment available for economic development of the region.

2.2 NATURAL CAPITAL

2.2.1 Geography

The Chocó Andean corridor of Northwest Ecuador extends from the western crest of the Andes Mountains down to the mangroves at sea level. It covers a significant part of the Pacific Coastal region of Ecuador which is generally defined as the lower, western slopes of the Andes below 1,000 m elevation, and the Andes Mountains above 1,000m. With over 3 million hectares, the area is approximately the size of the country of Belgium. Located between 01°28'N North, 00°35'S South, 80°07'W West, and 77°42'W East, the area traverses 25 counties (municipalities, as used in Ecuador) within the provinces of Esmeraldas, Imbabura, Carchi, and Pichincha. The area protects five large river systems flowing to the Pacific. From north to south, these river systems are the Chota-Mira-Mataje, Santiago-Cayapas, Rio Verde, and the Guayllabamba-Esmeraldas. Due to the unique geological history, location with respect to global atmospheric circulation currents and coastal currents, the Chocó Andean corridor covers an altitudinal continuum that embraces a variety of ecosystem types, from the tallest mangrove stands in the world, wetlands, rainforests, dry forests, cloud forests, elfin forests, and paramo. There is some presence of taxa normally considered lowland in the mountains (Webster and Rhode 2001) and typically highland taxa are found at elevations lower than their expected ranges (Jørgensen and León-Yánez 1999). This is the only section along the Andes where there is a forest connection between paramo and Pacific mangrove ecosystems. The only other place in South America with a paramo to mangrove connection is the Sierra Nevada de Santa Marta in the Colombian Caribbean of the Atlantic.

Although the lower part of the Chocó Andean Corridor is similar to the Chocó region of Colombia and Panama (Webster and Rhode 2001), there are significant differences. In particular, the Ecuadorian Chocó Andean region has an unusually high level of plant endemism (> 25%) (Baslev 1988). Therefore, the region merits its own holistic conservation strategy and should not to be treated as the ignored southern tail end of the Chocó region.

2.2.2 Geology

The geological history of the region is expected to have influenced the distribution of plants and other species; yet this topic has been relatively ignored (Neill, 1999). Hence, this is just a brief description of the orogenesis of the region highlighting events that are believed to have had the greatest impacts on biodiversity. The Chocó Andean region is contained within the Western Tectonic Realm of the Northern Andean Block - the Andes of Ecuador, Colombia, and Venezuela. The tectonic assembly of this block and the uplift of the northern Andes of Colombia and Ecuador-the youngest section of the Andes - began approximately 20 - 25 million years ago (Zeil 1979). It is the result of the prolonged and continued interaction of three lithotectonic plates: the South American moving west-northwest, the Pacific (Farallón-Nazca) moving east, and the Caribbean (Cediel et al. 2003). The current height of the Andes cordillera was reached during the mid to late Tertiary (25–2.5 million years ago) and resulted from intensive volcanic activity on top of uplifted basal rocks of the cordillera (Zeil 1979). In addition to the main north-south cordillera, the tectonic activity has produced a lower coastal cordillera that reaches as high as 600 m and runs on an east to west direction on both sides of the Esmeraldas River. The rise of the Andes resulted in climatic variations as well as in the isolation of the wildlife populations of the west of the Andes from those of the Amazon, and to a lesser extent from the south. In contrast, the Andes facilitated the exchange of wildlife between North America and South America through the Panama stretch when the Pleistocene glacial expansions lowered sea levels. Haffer (1969) through modeling the distribution of neotropical birds, and Brown (1974) by modeling the distribution of Heliconius butterflies, hypothesized that the Chocó may have been one of the wildlife refuges during the drier periods of the Ice Age that started 2.5 million years ago and terminated approximately 10,000 years ago. Therefore, the combined effects from the biotic exchange with North America, the isolation from the Amazon, local migration barriers from the irregular terrain that resulted from plate tectonic movement, and the relatively warmer climate are expected to have accelerated the process of speciation and contributed to the high levels of biodiversity in the region.

2.2.3 Climate

Although the Chocó Andean Corridor region is predominantly warm-humid, an especially diverse array of weather regimes exists in the region. These diverse weather patterns are due to the interaction of northern warm and southern cold coastal currents with the equatorial Intertropical Convergence Zone (ITCZ) as well as the climatic effects produced by the irregular topography of the western Andes and the smaller coastal range. The ITCZ is a belt of low pressure around the earth's equatorial region produced by solar heating forcing moist air to rise. The 'solar equator' is at the latitude having the maximum solar heating and represents the middle of the ITCZ. The 'thermal equator' in northwestern Ecuador moves to about 10°N at the June solstice, to about 5°S latitude at the December solstice. The ITCZ increases rain and cloudiness in the Corridor around December and to a lesser extent in June, following the location of the solar equator. Additionally, temperature and rain, specially near the coast are influenced by the cold coastal Humboldt current that flows north from Chile to Ecuador, and turns eastward at about the equator, where it meets the warm equatorial current that flows southward from the Gulf of Panama. The warm current brings moist air to coastal areas throughout the year, but accentuates rainfall from December to April, and diminishes between August and November, when the cold current dominates. The southern tip of the corridor is generally dryer because the Humboldt Current cools the marine air, thus it does not generate precipitation, while the northern part is cloudy and foggy even during the dryer months. The presence of the irregular terrain of the Andes is responsible for a 'rain shadow' effect that occurs in several places where the warm moist air moves inland and collides with mountain ridges of the coast and of the Andes, discharges the moisture and proceeds as dry air. Every 3 to 8 years ENSO (El Niño-Southern Oscillation) events result from major temperature fluctuations in surface waters of the tropical Eastern Pacific Ocean. During warm water El Niño events rainfall increase along the Ecuadorian coast; however, in the Chocó Andean Corridor coast the increase is not nearly as strong as in southern Ecuador, Peru and Chile.

The following information was obtained by geographic information system (GIS) analysis of rainfall, temperature, elevation and political division information of the Corridor (Fundacion-Maquipucuna 2002, Hijmans et al. 2005b, Souris 2007). The wettest area of the Corridor receives 5038 mm of annual rainfall, and occurs in the *Parroquia Chical*, on the border of the province of Carchi and Esmeraldas along the border with Colombia at about 600 m. The driest spot has annual average rainfall of 460 mm and occurs in the *Parroquia Salinas* of Imbabura in the 'rain shadow' of the Andes Mountains at about 1750 m. Thus, over a relatively short distance, rainfall may differ nearly eleven fold. While seasonal precipitation over the corridor varies largely from the convergence of trade winds and oceanic currents, temperature is highly correlated with changes in elevation. The coldest average annual temperature of 1°C is found on the summit of the Cotacachi volcano at 4887 m in the Imbabura province, while the areas inland of the mangroves of the San Lorenzo County at 26°C have the warmest annual temperatures. Diurnal temperature ranges increase with elevation from about 5.6°C in the Muisne area at sea level, to a maximum diurnal range on the slopes of the Andes in the province of Pichincha at about 1600 m, where the difference is above 13°C in some places such as around the towns of Mindo and Nanegal. Daily temperature fluctuations diminish above 3500 m. Figures 2.2 through 2.4 illustrate the main climatic fluctuations in terms of diurnal and annual temperature, annual rainfall and seasonality.

2.2.4 Soils

Soil characteristics influence the distribution of plant diversity and therefore of wildlife in general. Unlike most old tropical regions, the Andean slopes have soil with relatively large amounts of available phosphorus derived from volcanic activity. In tropical forests, many tree species have improved phosphorus uptake (among other things) through a strong mutualism between their roots and mycorrhizal fungi, particularly arbuscular mycorrhizae. Trees in some families, for example, the species rich Lauraceae, typically have an obligate mutualism with mycorrhizae. These mutualisms do not seem to be nearly as strong in the upper Corridor. Perhaps due to the long history of relatively high levels of available phosphorus in the upper Chocó Andean Corridor, many forest trees have relatively weak association with mycorrhizae (Eckert 1998). Thus, the volcanic history has likely affected an important relationship between mycorrhizae and their normal tree hosts.

Another important influence on Andean habitats is the high frequency of landslides that result from the poorly consolidated surface soils, high rainfall and steep slopes. In these vulnerable landscapes, poor land management further increases the risk of landslides. The significance of these landslides is apparent even in protected areas. The forest seen from the road that borders the steep southern side of the Maquipucuna Reserve shows many patches of young forest, a clear indication of past landslides. Thus, landslides influence the spatial heterogeneity of Andean slope forests.

Soils can also pose fundamental resources as well as limitations for human economic productivity – a pre-condition for sustainable development. When the quality of soils is beneficial both for human use and as well as for wildlife, conflicts between conservation interests and economic interests may intensify. The impact of climate, parent material, slopes, thick layers of ash deposited over long periods of volcanic activity up to the present , organisms, and vegetation have all played roles in shaping the soil types characteristic of the region. Even though the Chocó Andean Corridor mostly consists of young soils of volcanic origin, it has a variety of soil subtypes with a wide range of utility for agricultural or other types of human uses. Soils of twenty-three subgroups in fifty-three combinations within five different orders are present in the Chocó Andean Corridor region. The principal orders include Andosols, Alfisols, Entisols, Inceptisols, Mollisols and Histosols. Based largely on soil characteristics such as soil texture, fertility, salinity, depth available for plant growth, erodability, floodability, toxicity (Al), pH, organic matter content, phreatic level of water, drainage capacity, and stone content, the Ecuadorian government has produced a map of recommended uses. This map has been the basis for government political decisions for land use (MAG-IICA-CLIRSEN 2002). According to the government's land use classification, about 500,000 ha of forest by the year 2000 is at risk from government policies if the government enables deforestation based on official classification of these forested hectares as land with good agricultural potential. On the other hand, there are about 680,000 ha of already deforested areas that also have poor agricultural use value where policies should favor reforestation. Table 2.2 summarizes the potential conflicts that would arise if the government put into effect policies to implement the recommended zoning based on soil use classification as well as opportunities for restoration.

2.2.5 Vegetation

Plant diversity and endemism

Vascular plants make up the structure and most of the primary productivity of forests and are therefore a fundamental component of the natural capital of forested areas. The Corridor region is a global center of high plant diversity and includes many threatened plant species. I examined 37,000 plant collection records from the TROPICOS database of the Missouri Botanical Garden—including collections from L. Sodiro, Acosta-Solís, Harling, Cañadas, P. Jørgensen, T. Croat, S. Lægaard, B. Øllgaard, A. Gentry, C. Dodson, D. Neill, C. Cerón, V. Zack, and H. Balslev—and collections made by Dr. Grady Webster (University of California-Davis) during 10 years of field work. This information yielded a plant richness of 8,081 species for the Ecuadorian Chocó Andean region. This number of species is about 10% of all the species recorded from the Neotropics (Barthlott 2005). The plant richness of the Chocó Andean region represents over 50% of the 15,306 plant species in the latest Catalogue of the Vascular Plants for Ecuador (Jørgensen and León-Yánez 1999). The Chocó Andean Corridor contains 83% of the all the plant families found in Ecuador. Orchidaceae and Asteraceae are the most species-rich families of the 273 families in the Flora of Ecuador (Jørgensen and León-Yánez 1999), and they are also the most species-rich families of the 227 families found in the Chocó Andean Corridor. Ecuador has 2,110 plant genera and the highest number of species are found in Pleurothallis, Epidendrum, Lephantes, Miconia and Anthurium(Jørgensen and León-Yánez 1999). The Chocó Andean Corridor has 1,655 (78.4% of Ecuador's) genera. Anthurium, Monstera, Piper, Epidendrum, Solanum, Peperomia are the most species-rich genera in the Corridor, although the number of genera in the orchid family is likely larger because the collection records for approximately 150 species of orchids now known to exist at the Maquipucuna Reserve (Reynolds 2004) were not part of the collection records analyzed (Webster and Rhode 2001). As indicated in table 2.3, the elevation range between 900 m and 2000 m has the highest total number of plant species (3,007) and of threatened plant species (186). The density of collections in Ecuador generally is, on average, 200 per 100 km^2 (Jørgensen and León-Yánez 1999), while with 37,000 collections, the Chocó Andean Region has a collection effort of only 123 collections per 100 km^2 and thus has not been as extensively explored as other areas of Ecuador. The number of species is estimated to increase significantly when the entire area is inventoried (Jørgensen and León-Yánez 1999, Webster and Rhode 2001).

The area also harbors high degrees of endemism with an estimated 25% of the flora endemic to the region (Baslev 1988, Borchsenius 1997). Analyzing the plant database for the Corridor with the IUCN red list of endangered species (IUCN 2006), I obtained 468 endangered plant species for the Corridor (Appendix A-List of IUCN red listed plant species of the Chocó Andean Corridor). That is, the Chocó Andean Corridor harbors 23% of Ecuador's IUCN red listed plant species. As seen in table 2.3, the elevation range between 900 m and 2000 m has the highest number threatened plant species (186), which is a result analogous to the highest species richness found in that same elevation range. An alarming finding is that of the 468 threatened plant species in the Corridor (Figures 2.5 and 2.6), 386 species have been collected outside protected areas, and half of that had not been collected in any protected area. Only 72 threatened species have been collected within reserves of the National Park System, and a quarter of those species were not collected anywhere else. Overall, private protected areas such as protective forests managed by non-profit organizations or grass roots groups and indigenous territories seem to be doing a better job at protecting threatened plant species with 209 species collected inside such private protected areas, and almost a third of the species not collected anywhere else. In addition, there are significant differences between the species found in better-collected areas that are almost adjacent to each other, thus hinting at the high degrees of endemism. For example, the *Maquipucuna* Reserve (75 threatened plant species) and the *Pululahua* Geobotanical Reserve (36 threatened plant species), about 10 km apart from each other, only have in common 13 threatened plant species. Finally, the *Cotacachi-Cayapas* Ecological Reserve (RECC) (29 threatened plant species), which is supposed to be the pillar for biodiversity protection in Northwest Ecuador seems to have only small overlap with closeby private protected areas:

- RECC shares 3 threatened species with the 82 threatened plant species of the *Awá* territory.
- RECC shares 5 threatened species with the 47 threatened plant species of the *Golondrinas* Protective Forest.
- RECC shares 2 threatened species with the 75 threatened plant species of the *Maquipucuna – Guayllabamba* Protective Forest.
- RECC shares no threatened species with the 9 threatened plant species of the territory of the *Comuna Rio Santiago Cayapas*.
- RECC shares no threatened species with the 12 threatened plant species of the *Awacachi* corridor.

It is worth noting that the *Cotacachi Cayapas* Reserve has not been as extensively inventoried as other areas, thus further collections may indicate higher representation of threatened species than currently estimated with available collection records. However, the comparison of adjacent well-collected areas indicates that there is great species variation even within very short distances. Therefore, even though these observations are about the location of collections of threatened plant species and not their distribution—which we do not know— these results warrant careful spatial coverage of future collections, both inside and outside areas of the National Park System.

Vegetation types

The most current classification was developed by R. Sierra et al. (1999), who derived the new classification using floristic and climatic information, as well as remote-sensing (Landsat) images, integrated in a geographic information system (GIS) with information at 1:1,000,000 and 1:250,000 scales. Though still preliminary, the Ministry of the Environment of Ecuador has adopted this classification for purposes of conservation planning (Sierra et al. 2002). The scale of resolution of this classification is still coarse for local planning, but it is the most detailed that is available. Two-thirds of the vegetation types identified by Sierra et al. for Ecuador are in the Chocó Andean region. A conservation prioritization approach based on threshold minimum representative areas for each vegetation type has been suggested (Sierra et al. 2002); however, strategies to conserve altitudinal connectivity should complement with such an approach, which will be fundamental to protect species in a future of climate and landscape change. Below are synthesis of the predominant vegetation types combining Sierra et al.'s (1999) and Harling's (1979) previous classification for the vegetation types of Ecuador.

Mangroves and Dwarf mangroves

Mangroves represent the dominant vegetation of the estuaries of the Mataje, Santiago and Cayapas Rivers and numerous human communities make a living from artisanal harvest of shellfish, primarily oysters and shrimp that live among the mangrove roots. There are six different species of mangroves, most commonly *Rhizophora harrisonii* and *R. mangle*; some of which reach over 30m (Sierra 1999). One mangrove is endemic. *Pelliciera rhizophorae* is only found in the Chocó Andean mangroves. Inland, there are dwarf mangrove formations with tree heights less than 5 meters.

Coastal lowland inundated forest (guandal)

These fresh-water swamps (guandal) remain inundated several months of the year and are characterized by a few tree species such as *Campnosperma panamense* and *Otoba gracilipes*. They can be found in the lower basin of the Santiago River, landward from the true mangroves up to 100m in the Esmeraldas Province *(Neill 1999, Sierra 1999)*.

Coastal Lowland Evergreen Forests

Coastal lowland rain forests are found in the region below 300 m elevation (Sierra 1999). The only relatively large areas of this type of forest in Ecuador are in the Esmeraldas and Pichincha provinces in the lands of the parroquia Concepcion, Comuna Rio Santiago Cayapas, between the Santiago and Cayapas rivers, and various indigenous Chachi Centers south of the Cayapas River. These forests, characteristized by a tall canopy height of 30 m or taller and high species diversity are considered the true southern extension of the Colombian Chocó region of the Pacific coast and share many species with the northern Chocó, though they also have a significant element of endemic species (Neill 1999).

Large parts of this vegetation type are dominated by *Wettinia quinaria* (Neill 1999, Sierra 1999), the Tagua palm (vegetable ivory) that was likely managed and densities possibly enriched over a century ago (Local inhabitants, per. comm.). In some places, more than half of the trees will consist of this palm. A good example of this is found in the lower Santiago river basin. Other common species are: *Brosimum utile ('Sande'), Guarea polymera ('Tangare'), Otoba gordoniifolia ('Carachacoco'), Humiriastrum procerum ('Chanul')(Sierra 1999).*

Coastal lowland semideciduous forests

This vegetation is found up to 300 meters along the drier southern coast of Esmeraldas Province and is characterized by tall trees to 20 meters. Non-tree shrubs often have thorns, and common semideciduous trees such as *Ceiba trichistandra* ('*Ceibos*') and fine hardwoods such as *Tabebuya crysantha, and T. bilbergii* ('*Guayacanes*') with epiphytes such as bromeliads in the crown of trees (Neill 1999, Sierra 1999).

Coastal foothill evergreen and Coastal Evergreen Lower Montane Forests

There is a coastal range that reaches and elevation ca. 600 m. Part of this coastal range goes in an east-west direction and is not protected, thus most of the vegetation has been either degraded or transformed into pastures. The other part, a cordillera that runs parallel to the coastline, is partially protected by the Mache-Chindul Reserve. Typical cloud forest vegetation can found as low as 400 m (Parker & Carr, 1992). Trees can reach heights of 20 meters.

Western Andes Foothill Evergreen, Lower Montane Evergreen, and Montane Cloud Forests

These vegetation types according to Sierra et al. (1999) correspond to three elevation ranges 300 - 1300m, 1300 – 1800m, and 1800 – 3000m respectively. In Harling's (1979) vegetation classification, lower montane rain forest is present between about 700 and 2500 m elevation, while upper montane rain forest occurs from 2500 m elevation to the upper limit of closed forest, which is variable, but frequently at 3400 – 3600 m. These vegetation types, which are found both on the eastern and western sides of the

Andes, contribute largely to the highest degrees of biodiversity and endemism that characterize the Tropical Andes hotspot (Barthlott 2005). These forests appear to be most diverse at mid-elevations (Gentry's 'mid-elevation bulge' (Gentry 1988)). An indication of this mid-elevation species richness is the plant diversity of the Maquipucuna Reserve between 1000 – 2800m where more than 1900 species have been recorded, which correspond to approximately 10% of Ecuador's total plant diversity (Webster and Rhode 2001). Still, more quantitative studies are necessary to fully explore the flora below 900 meters in the Chocó Andean region. Most of what we know for this lower elevation comes from studies done outside of the Chocó Andean Region, in the south west part of Ecuador in places such as Rio Palenque, Jauneche, Centinela, and Tenefuerte (Dodson and Gentry 1991), or in southwest Colombia (Gentry 1986). More recently, there are plant inventories not yet published from the Bilsa and Mache Chindul Reserves in central west Ecuador (Neill 2007). There are only some collections in the lowlands of the Chocó Andean region from the Endesa Reserve (Jorgensen and Ulloa, 1989).

'Cloud forests' are present above 1550m. These forests are characteristic by nearly constant high atmospheric humidity, frequent fog- and mist-associated horizontal precipitation, and dense loads of vascular epiphytes as well as non-vascular bryophytes on tree branches and trunks (Webster and Rhode 2001, Küper et al. 2004). Forests above 1000 meters within the Cotacachi Reserve have not been well studied and should be the focus of future inventories.

Floristic studies of Lower Montane Evergreen and Montane Cloud Forests have been carried out extensively at the Maquipucuna Reserve (Webster & Rhode, in press). Common canopy tree species on the western slopes include *Ruagea glabra*, *R. pubescens*, *Dussia lehmannii*, *Meriania tomentosa*, *Cinchona pubescens*, *Roupala obovata*, and *Nectandra acutifolia*.

Western Andes Upper Montane Evergreen Forests

As altitude increases, the height of the tree canopy decreases drastically and in some places, such as in the Siempre Verde Reserve we can find 'elfin forests.' Tree growth is stunted, trees become more twisted, and species richness of trees decreases (Valencia et al., 1998). Harling (1979) referred to this vegetation as 'upper montane rain forest.' This vegetation type corresponds to the upper limit for forest, or in Spanish, *ceja andina* (‘eyebrows of the mountains’)(Barthlott 2005). Several floras and checklists characterize these upper montane forests (Ulloa and Jorgensen 1993, Jorgensen and Ulloa 1994, Fehse et al., 1998).

Paramo

The paramo is generally considered to be a grassland above 3400m but there is some discussion about the origin of these grasslands. The highlands of Ecuador have been occupied by humans for at least 7,000 years, and it is possible that continual anthropogenic disturbances, especially fires, have frequently altered this vegetation (Keating 2007). The finding of small trees at elevations as high as 4100 m, and the existence of the influence of continuous fire, has led to a theory that if fires were suppressed, woody vegetation would invade the grass páramo and replace it with a continuous upper montane woodland of *Polylepis* and other small trees (Keating 2007). Thus, whether or not paramo is a ‘natural’ ecosystem or an anthropogenic creation is still debated (Luteyn 1999), but paramo ecosystems are part of the livelihood of highland peoples of the Corridor. Given the high number of endemic herbaceous species in the páramo (Jørgensen and León-Yánez 1999), it is evident that paramo, in some form, has been present in the northern Andes for thousands of years. Paramo vegetation is generally present from 3400 m, above the tree line, up to about 4,500 m. There are three types of paramo vegation, determined largely by altitude and water deficiency due to freezing temperatures. ***Grass paramo*** consists on bunch- or tussock-forming grasses, mostly species of *Calamagrostis* as well as *Festuca,* interspersed with tall composites such as *Espeletia and Puya* and a diverse assemblage of herbaceous plants. Thousands of hectares of this vegetation type can be found in the Carchi province. ***Shrub and cushion páramos*** occur as heterogeneous patches, with bare sandy soil exposed between the plants at elevations above the grass páramo, from 4,000 to 4,500 m. Cushion plants are adapted to nightly frosts. Characteristic cushion and shrub taxa include *Chuquiraga jussieui*, *Pernettya prostrata*, *Baccharis latifolia*, and *Gynoxys buxifolia*. **Desert paramo** vegetation is found from about 4,500 m up to the lower limit of the snow line. As glaciers retreat, it is expected that there will be plant colonization and such studies will be important to monitor the impacts of climate change.

2.2.6 Fauna

Faunal diversity and endemism, as expected, are very high. The Chocó Andean Corridor of northwest Ecuador includes approximately 30% of the Chocó Endemic Bird Area (EBA) identified by Birdlife International, and has some geographical overlap with the North Central Andes EBA in the Cotacachi area. The Chocó EBA supports 830 bird species, and the largest number of restricted-range birds of any EBA in the Americas, over 50 species being endemic to the area (Conservation-International 2005). BirdLife International has designated 20 Important Bird Areas (IBA) within the Chocó Andean Corridor region (Aves-y-Conservacion 2007).

Mammal diversity and endemism are also significant, with 142 mammal species, of which 15 (10.6%) are endemic to the region (Conservation-International 2005). In the Maquipucuna Reserve alone, with only 6,000 ha, preliminary surveys have found 45 mammal species, or 17% of the entire country's inventory (Fundacion-Maquipucuna 1995). The decreasing presence of Mountain Lions (*Felis concolor)*, and Ocelots (*Leopardus paradalis*) indicates the high degree of pressure that these ecosystems are undergoing. However, mountain lions also tend to decline as forests become more closed, probably because deer, their principal prey, also decline. While a large number of nectivore and fruitivore bats, as well as the large number of bird species and their distributions indicate the existence of altitudinal connectivity.

The potential for development of ecotourism in the Corridor is particularly high due to the region's spectacular bird diversity and its charismatic mammals, such as: Spectacled Bears (*Tremarctos Ornatus*), Ant eaters (*Tamandua mexicana*), Pygmy Anteater (*Cyclopes didactylus*), large Armadillos (*Dasypus novemcinctus*), Three toed sloth (*Bradypus variegatus*), Paca (*Agouti paca*), Kinkajus (Potus flavus), Coati (Nasua narica), Reed brocket deer (*Mazama americana*), and Peccaries (*Pecari tajacu*) (Fundacion-Maquipucuna 1995, Municipio-de-San-Lorenzo-del-Pailón 2003).

Knowledge of Ecuadorian amphibians is fragmented and limited. The diversity is expected to be high, particularly in the mid elevations. Several endemic species are known from single locales, such as the Dendrobatidae frog *Colostethus maquipucuna*; while amphibian diversity around the area of Lita and in the basins of the river Cayapas and Santiago merit special conservation attention (Gagliardo 2005). The entire Chocó is estimated to have 350 species of amphibians, 60% of which are expected to be endemics (Conservation-International 2005). As with many higher elevation tropical locales in Latin America, the chytrid fungal disease may be affecting amphibian populations in the upper Corridor.

2.3 HUMAN CAPITAL

The people of the Chocó Andean Corridor are from diverse ethnic origins, from Quichua Andean indigenous communities that inhabited the highlands for thousands years, to indigenous nationalities and African descendants, and colonists from other parts of the country and Colombia. The northwestern lowlands are home to Chachi, Epera, and Awá indigenous communities. Afro-Ecuadorian communities have inhabited the lowlands of the Esmeraldas province since 1553 (Municipio-de-San-Lorenzo-del-Pailón 2003). *Colonos* are people who have emigrated from other regions and have settled mainly in the mid-elevations. In the past 20 years, *colonos* began settling in the northern lowlands, sometimes with conflicting land use with Chachi, Awá and AfroEcuadorians. More recently, there is a wave of migration resulting from the armed conflict in Colombia. *Colono* establishment in the mid-elevations and elsewhere was the result of an Agrarian Reform and Colonization Law (Blankstein and Zuvekas Jr 1973), which was in effect until 1991. Under this policy, *colonos* formed cooperatives to occupy the land, 50% of which they had to clear in order to show ownership and thereby acquire a land title to the land. Each member maintained individual rights for one plot of 50 to 200 has. Today, *colonos* continue to settle the area, sometimes claiming individual tenure rights to already occupied land, and are often associated with land traffickers and speculators that affect indigenous communities and protected reserves, both private and governmental.

Chachi, Awá and AfroEcuadorians have a strong conservation ethic. For example, for Afro descendants the land is a vital space where 'life is reproduced and culture is maintained.' Without the forest ('*monte'*), the rivers and the land, AfroEcuadorians say they are nothing (Municipio-de-San-Lorenzo-del-Pailón 2003) In contrast, *mestizo* c*olonos* arrived with the tenure requirement need and the mentality or ethos to clear as much forest as possible. *Colonos* have a work ethic that differs from the

Afro-Ecuadorian and indigenous communities; working hard for a *colono* often means clearing as much forest as possible and cultivating as much land as possible.

Approximately 225,000 people, with an average population density of 0.14 persons per hectare, inhabit the *parroquias* (the smallest political division in Ecuador) where there at least some forest remains (Instituto-Nacional-de-Estadistica-y-Censos 2001). In surrounding deforested areas and cities (within a 100 km range of the forest), there are over 1,225,000 people. The rural inhabitants of the Corridor are young and the population is growing rapidly; 40% of the inhabitants are children 14 years or younger, thus future demographic pressure on land use in the Corridor will grow. Towns are small —with an average of 50 families each—and isolated. Generally, there is a larger central town in each *parroquia* ('*cabecera parroquial'*) with an average of 3,000 people.

Lack of educational opportunities hinders human development, and the local communities' opportunity to adapt to economic pressures from the global or even national society. Because villages are small and isolated, the lack of schooling opportunity for children, as well as other basic services such health centers and clean drinking water are major hardships for local communities and real constraints for projects that aim at improving their livelihoods by generating sustainable economic opportunities. Small villages have on average 40 to 60 children of school age, and if they are lucky, the government will assign one teacher for every 20 – 30 children to teach all grades 1 – 6th. There will normally be no school materials or any additional resources to aid teaching, thus education is severely deficient. Less than 1% of the population achieves a college education, 25% reach some year of high school, and 75% have some elementary school education (Instituto-Nacional-de-Estadistica-y-Censos 2001, Municipio-de-San-Lorenzo-del-Pailón 2003).

Due to isolation and material poverty that characterize most rural communities of the Chocó Andean Corridor, people's health and nourishment have decreased significantly during the last two decades as subsistence farming and fishing opportunities have decreased (Municipio-de-San-Lorenzo-del-Pailón 2003). Because people in the Corridor often express a love for their land and because the population is young, there are opportunities for sustainable development. However, the challenges are significant especially in some areas of the Corridor, such as the lowlands of San Lorenzo and Eloy Alfaro, which are extremely poverty stricken and where infant mortality at 0.87%, is 66% higher than the national average (Municipio-de-San-Lorenzo-del-Pailón 2003).

2.4 SOCIAL CAPITAL

Indigenous Awá and Chachi, and Afro Ecuadorian communities have a strong conservation ethic and traditionally strong social organizations with clear hierarchical structures and democratic representation. Another indigenours group, the Epera, is a very small group of 255 people with little published about them. To these indigenous groups, the jungle is their home; it is their supermarket and pharmacy; and it is their church and classroom. They depend on the forest's resources for food, shelter, and cultural continuity. To Afro Ecuadorian communities, the forest is also inspiration for their rich musical heritage (Municipio-de-San-Lorenzo-del-Pailón 2003).

The Awá indigenous nation, which dwells in approximately 101,000 hectares in the northern lowlands of the Corridor along the Colombian border in various municipalities of the provinces of Esmeraldas and Carchi, has the strongest organization and leadership. Organized into 22 groups within an Awá Federation, they have progressed towards securing communal ownership and conservation of their 'territory' (Municipio-de-San-Lorenzo-del-Pailón 2003).

The Epera live on lands without specific designated territory. They live in various communities of the Municipalities of Eloy Alfaro and San Lorenzo, and are represented by an incipient National Organization of the Epera Nationality of Ecuador (ONAEE) (Municipio-de-San-Lorenzo-del-Pailón 2003).

The Chachi communities are scattered in 29 Chachi Centers occupying approximately 105,500 ha throughout the northern part of the Corridor, in the municipalities of Eloy Alfaro, San Lorenzo, Rio Verde, Quininde and Muisne in the Esmeraldas Province. The Chachi are represented by the Federación Ecuatoriana de Centros Chachi del Ecuador (FECCHE)(Municipio-de-San-Lorenzo-del-Pailón 2003).

Afro-Ecuadorians have very sophisticated organizational structures. A *Confederación Comarco Afro-Ecuatoriana del Norte de Esmeraldas* is a national umbrella organization run by a Regional Council of *Palenques* (traditional forms of organization of Afro descendants that group smaller communities), which represents 7 *Palenques.* There are also two large associations of communities, the *Comuna Playa de Oro,* and the largest, *Comuna Río Santiago Cayapas* (CRSC). CRSC has a '*Cabildo'*, which is a governing board elected each year by popular election to represent the different communities, and which is registered at the Ministry of Agriculture. There are Afro-Ecuadorian communities in the Municipalities of San Lorenzo, Eloy Alfaro, and Rio Verde in small communities spread over 110,000 ha. African descendants have struggled as a group, because they had to overcome a stigma of slavery and abuse, although Ecuador abolished slavery in 1851. Yet, the government of Ecuador granted large areas of their territory to companies such as 'Ecuador Land Mining Company' as payment to the debt acquired by Ecuador from England during the Independence War.

In contrast to indigenous groups and African descendants, *colonos* don't share a consistent land ethic. As they come from different locales, such as Manabi, Loja and other provinces of the Sierra, and Santo Domingo and Quininde, they tend to be more individualist, their community organization is weak, and thus *colonos* are less inclined to look for the common good. However, *colonos* are more market oriented and when the communities have good individual leaders; community-based ecotourism projects have been successful in some of the mid-elevations forests near the Maquipucuna, Mindo and Intag areas.

Indigenous and AfroEcuadorian groups argue that timber and oil palm companies bribe and deceive community leaders (Cantincus 2002) which has resulted in corruption, a debilitation of the social structure, and, in several cases, leaders selling their community's timber and land to *colonos* and timber and oil palm companies. The process of sale of some of the land of the AfroEcuadorian Comuna Río Santiago Cayapas sadly illustrates this. Paradoxically, shortly after 6,000 ha had been legalized in the name of conservation for 200 families with the aid of the USAID funded SUBIR (Sustainable Uses of Biodiverstiy) project and the international development organization CARE, a handful of people said to represent the 200 families were already negotiating the land and receiving advanced payments from different potential buyers. Five years later, the sale of the land to a timber company is completed, and a large part of the payment went to pay debts acquired by the handful of negotiators, while many of the 200 family owners who refused to sell their part were obligated to leave the area with a minimal payment (Kowler 2007). In an increasingly globalized society, it is important that ancestral communities preserve their cultural heritage as the framework of reference for future sustainable management, including ecotourism among other possible sustainable alternatives. This should be an active focus of attention of conservation and development interventions because strong pressures from economic interests such as timber companies and oil palm companies, as well as land traffickers are eroding that cultural heritage. One example is the unfortunate trend of corruption among leaders of many of the ancestral communities in the region. The paradox of the plenty, or 'resource curse' as coined by Richard Auty (1997) is evident in the region. The abundance of timber, ores, fishery, and fertile land instead of providing dignifying livelihoods to local people, has impoverished the majority, and only benefited a few (Municipio-de-San-Lorenzo-del-Pailón 2003).

In addition to the intrinsic systems of social organization, the area has seen a long history of development and conservation projects, both government and private, with a range of intervention strategies, which have left a mixed legacy from strengthened organizations, to communities with too many organizations and too little purpose, to communities accustomed to paternalistic approaches. Conservation and development policies should keep in mind that a homogeneous treatment across-the-board could lead to the failure of development initiatives and to the weakening of social structures. Strong organizations with strong leaderships are indispensable conditions for successful conservation and sustainable development projects, very especially in areas where communities are isolated. However, 'over organization' resulting from the saturation of development and conservation interventions can be as deleterious as the lack of organization.

2.5 MANUFACTURED CAPITAL

The economic activity of the region varies largely depending on climate, relief, and location in reference to roads and markets. In the northern lowlands, farming is mostly for subsistence and to a lesser extent for the market. Subsistence farming takes place on riverbanks and includes plantain, banana, corn, papaya, citrus, passion fruit, and other local fruits. For the market, they produce cacao, tagua, pepper, and oil palm. Additionally, in the lowlands where rivers are large and near the coast, there is artisanal fishing, and collection of shellfish in the mangroves and estuaries. Timber harvesting for the market is predominant in the lowlands, while in the mid-elevations timber harvests are more for the production of charcoal. Neither of these timber-harvesting activities seems to help people earn enough money to save surplus income. In 2007 local people received USD $1.5 for every cubic meter of timber wood, that is about USD $17 per tree. Of those earnings two thirds simply cover expenses for the timber cutter and the timber companies are the only ones that make a profit (El-Comercio 2007).

Even though pasture is a predominant land use of the corridor, and there are thousands of hectares of pastures, only in the lowlands of the *Rio Verde*, *Pedro Vicente Maldonado*, and *Los Bancos* is cattle-raising a significant economic activity. In other regions, pastures often contain few or no cattle. In the mid-elevations, ecotourism has flourished over the past decade, particularly closer to large cities like Quito, Otavalo, and Ibarra. Additionally, in the mid-elevations there is a mix of subsistence farming of plantain, corn, citrus and other fruits, and the cultivation of sugar cane for the production of alcohol and raw sugar.

Shade-grown coffee has been cultivated for decades in the region; however, with the global drop in coffee prices farmers reduced significantly the area under coffee cultivation in the late 1990s. Since the year 2001, the Chocó Andean Corridor initiative provided new coffee plants, reforestation trees, technical assistance, organic certification, and marketing to coffee farmers in the mid-elevations of the Pichincha province. Farmers of the Intag area in the Imbabura province are also producing shade-grown coffee. Shade-grown Chocó-Andes™ coffee has earned two national coffee quality prizes and if market increases for gourmet, shade-grown coffee farmers are eager to increase the area under cultivation.

Outside of small agriculture, capital-intensive industrial activities include sawmills, shrimp farms, oil palm refineries, and oil palm, heart of palm, and banana plantations. Most of the scant productive infrastructure in the area is the property of wealthy investors from large cities such as Quito and Guayaquil. Much of this infrastructure uses obsolete technology; for example, local people related to the oil palm business complain that the current infrastructure does not guarantee safe working conditions

(Municipio-de-San-Lorenzo-del-Pailón 2003). The infrastructure investments made by the government are very limited and focus on basic services and roads for areas that already have more productive infrastructure.

Creating successful mechanisms that focus investments on enabling local forest communities to accumulate manufactured capital is an essential, yet overlooked, condition for sustainable development. A minimum base of manufactured capital is a requirement so that people that live in forest communities can produce sustainably and do not have to mine their natural resource base for income. One would expect see infrastructure and capital investments resulting from hundreds of millions of dollars of revenue from the exploitation of natural resources over the past two hundred years, and hundred millions more invested in development and conservation projects over the past three decades. However, at least in the Corridor area, material wealth has not accumulated, net export of raw materials has increased, and the region is progressively becoming poorer, on top of a degrading natural resource base.

The focus of conservation and development investments typically has not been the creation of man-made capital. Only the few material investments made in infrastructure, coupled with enough training and the availability of markets, have yielded visible man-made capital that has stayed for the benefit of the areas. Most development and conservation projects have produced large amounts of reports and studies, management plans, and training workshops often disassociated with a sustainable process of infrastructure development and production, and frequently promoting agroforestry practices without markets. International companies, non-government organizations, and technicians - outsiders to the area - have been able to accumulate capital more easily as development and conservation projects have had to pay competitive salaries based on education, experience, and market value. This is in contrast to low capital formation by locals. The longest Conservation and Development SUBIR project funded at 20 million dollars by USAID occurred over 10 years in the lowlands of the Corridor. SUBIR listed as their accomplishments: “Identifying target aid areas; developing inter -organizational structures; obtaining land title to 10,000 ha near Playa de Oro and 14,000 ha in other communities; completing the first natural resource management plan in Ecuador; developing more than 130 agroforestry plots in 20 communities;

and assisting community forestry initiatives that enabled local communities to receive a 60% increase in the price paid for timber cut in natural forests, develop community and regional management plans for 300,000 ha of unprotected Ecuadorian Chocó; establish forest management plans for at least 20 communities bordering the RECC; train a cadre of young professionals and local parabiologists to carry on activities after the close of Phase III, and…strengthening three conservation organizations"(CARE et al. 1998, ARD 2000). Four years after the end of the SUBIR project at least 5,500 ha of the land titled has already been sold to timber companies. Another 18,000 thousand are being negotiated; no agroforestry plots are visible, timber continues being cleared, locals complain that prices of timber are too low, and other international conservation projects are facilitating, again, the development of forest management plans and community management plans in the same region. The investments made to build a lodge in Playa de Oro, and train the locals in ecotourism despite the modest investment made, are the only man-made capital visible as legacy of the SUBIR project in the field. The other visible capital outcome of the project is three well established (with equipment and trained personnel) national conservation NGO's in Ecuador that continue doing studies and managing conservation projects in other parts of the country (Rhoades and Stallings 2001). A comparable monetary investment to the establishment of the Playa de Oro ecotourism project is a modest $300K investment funded by the Ecuadorian-Canadian Fund to establish infrastructure and human capacity to improve cacao production in the northern part of Esmeraldas. Funds went to a local association of cacao producers APROCANE. Three years after the initial funding ended, the cacao facilities continue to process cacao from over 400 cacao producers, the organization is exporting cacao to Europe at almost twice the original price, and is opening a new larger processing center to serve about 5 times as many cacao producers (Kowler 2007).

2.6 THREATS TO CONSERVATION

Habitat transformation is the main cause of biodiversity loss in the Chocó-Andean region, and the degree of transformation of native forests in the region is alarming. Native forests declined from 1.6 million hectares in 1991, to 1.4 million hectares in 1994, to 1 million ha by the year 2000. With a 4% annual deforestation rate, deforestation in the Corridor exceeds the national average of 1.49 – 1.6%

published previously (CLIRSEN 1991, INEFAN-OIMT 1994, MAG-IICA-CLIRSEN 2002, FAO 2006b, Sanchez 2006).

Four causes intertwine to drive deforestation in the region: increased demand of timber in the urban area (Sierra 2001, Wunder 2001), local impoverished communities' need for an income (Sierra and Stallings 1998), and flawed government policies that have failed to recognize the ecological value of the areas and the weak conservation ethics of the *colono* communities. Government agencies have promoted policies that encouraged the exploitation of natural resources, and a land tenure system that has disenfranchised ancestral inhabitants of the forests, stimulated land trafficking and speculation, and encouraged deforestation in areas not suitable for agriculture. One example is the promotion of monocultures such as African oil palm (Southgate and Whitaker 1992).

Government policies fail to recognize the ecological value of the areas outside the national protected area system, and the notion of sustainable development is a discourse not put into practice. The Ministry of Environment is the lowest in the hierarchy of Ministries, behind Agriculture, Commerce, and Energy and Mines, which is reflected in its scant budget and the lack of influence on policies about land use outside protected areas. On the other hand, there has been a disregard and lack of valuation of the conservation ethics of the indigenous communities. In their need to participate in the market economy, ancestral communities have lacked economic alternatives to non-sustainable timber harvesting or land conversion; and in fact in numerous areas they have cultivate and treated the land just like *colonos*. *Colonos* have arrived with a hard work ethic to transform as much forest as possible and turning the land into monocultures or pastures. The situation is exacerbated by lack of productive infrastructure, technical assistance, limited access to credit, access to markets, and insecure land tenure, which encourage people to see forests as short-term cash sources. In the lowlands, deforestation is driven by the steady increase of commercial logging and transformation of forests into African oil palm, and heart of palm plantations, and shrimp farms. Indigenous communities and AfroEcuadorianos are actually active agents, clearing the forest for labor pay and timber sales to companies. In the mid-elevations, deforestation is driven mainly by the expansion of colonization and the ensuing charcoal production, establishment of pastures, and land speculation and mining. These threats to biodiversity are confounded by the under-representation of ecologically critical areas in the National Protected Areas System (Sierra et al. 2002).

Commercial logging, expansion of African oil palm plantations, and colonization are processes well illustrated along the new road from San Lorenzo to Ibarra. Non-agricultural cooperatives have claimed land titles of communal lands traditionally held by Awá, Chachi or Afro-Ecuadorian groups. These cooperatives re-sell the land to incoming colonists, in return for harvesting the timber. Then community leaders sell the timber to the large timber companies, although timber companies also buy the timber directly from the land-holders in exchange for supposedly opening roads, establishing schools, or creating health centers. African oil plantations are expanding rapidly in the area, and oil palm interests are lobbying for a 50,000ha exclusive oil palm zoning government decree in the San Lorenzo County (Municipio-de-San-Lorenzo-del-Pailón 2003). Plantation investors have the capital and political influence to buy tenure rights from non-agricultural cooperatives, indigenous groups, and Afro-Ecuadorian communities. With the recent global market interest in bio-diesel fuels, the market value of palm oil is increasing. Ironically, the growth of bio-fuels to address global climate change could result in deforestation with almost certain large carbon dioxide emissions.

Over 90% of land outside government protected areas is either under private ownership or claimed ownership for communal rights, because parts of this landscape have been occupied continuously since pre-Conquest times, patterns of settlement changed and intensified dramatically since World War II (Parsons 1957). However, one major threat for the conservation of the Chocó Andean region is the lack of legalized land tenure. Extraction of timber has increased dramatically due to Agrarian Reform and Colonization policies over the past 40 years facilitated by large-scale road construction projects, to encourage distribution of ‘lazy’ lands – lands that are not fulfilling their productive potential - whether of government or private ownership. A wave of colonization by *colonos* arrived from other parts of rural Ecuador claiming title to formerly communal land, and securing legal tenure as cooperatives (Justicia 2000). The application of an Agrarian Reform and Colonization Law has been flawed; consequently, uncertainties concerning rules of colonization and land tenure have resulted in a *de facto* 'uncleared is unclaimed' land claim approach where land is cleared just for the sake of securing a land title (Blankstein and Zuvekas Jr 1973). Subsidies to dairy production further encouraged forest clearance for grazing land (Southgate and Whitaker 1992).

Finally, associated with deforestation, and fragmentation, there is the phenomenon that I call ‘settlement sprawl’. Even where indigenous groups claim communal property of the land, their communities consist of small 30 – 50 families, and each family claims possession of about 50 hectares; thus the location of small indigenous communities is just as spread out as colonist’s sprawled settlements. ‘Settlement sprawl’ leads to village isolation, which increases significantly the costs for governments providing basic services, thus exacerbating rural marginalization. People in isolated villages pressure for the improvement of roads, and as a result, more deforestation occurs as more settlers are attracted to the area. ‘Settlement sprawl’ also increases the cost of establishing conservation and sustainable development projects; and it is a serious barrier for communities to participate in the market. ‘Settlement sprawl’ results from policies that obligated people to clear the land to show ownership and the government’s lack of agro ecological and urban zoning.

I prepared the following synopsis of threats to the different ecosystems obtained by cross tabulating (using ArcGis 9.2) the vegetation map of Sierra (1999) with the land use map of 2002 (Sierra 1999, Fundacion-Maquipucuna 2002) in addition to observations made during many visits to the region.

Threats to mangroves are over fishing of shellfish, mollusks, and shrimp larvae; deforestation; and habitat transformation into shrimp ponds. The original area of mangrove in the region was ca. 42,000 ha. Commercial shrimp production for export in the area started in the 1970’s. Now, there are large areas of mangroves transformed into shrimp ponds, in spite of Ecuadorian laws that prohibit clearing of mangroves. About 40% of the mangrove area had been transformed as of 2002, and only a fifth of the mangrove areas destroyed (17,000 ha), appear as shrimp ponds officially registered with the government. Additionally, locals cut mangroves for timber, charcoal, and the bark for its tannins, causing additional damage to this ecosystem. Little is known of the impact of this destruction in both the ecology of the estuaries, as well as the uplands to which these mangrove areas were once connected through lowland forests; therefore, no limits have been set as to how much fishing can take place in the mangroves.

Most of the coastal lowland inundated forest (guandal) has been logged or transformed into oil palm and pastures. Some Afro-Ecuadorian communities struggle to cultivate rustic cacao in these swampy areas along the Santiago River.

Coastal Lowland Evergreen Forests were originally the most abundant vegetation of the Corridor. However, of the original 1,190,000 ha as of 2002, only 14% remain and most of the transformation has occurred within the last 60 years due to logging, establishment of pastures, the establishment of banana plantations, and now for plantations of oil palm.

The threat to Western Andes Foothill Evergreen, Lower Montane Evergreen, and Montane Cloud Forest ecosystems is deforestation for the establishment of pastures and sugar cane, charcoal making, and several other cash crops in a lesser scale. Also, these areas are located near the larger cities located in the Inter Andean valleys such as Quito, Otavalo, Ibarra and Tulcan, therefore land is becoming a commodity in high demand and that is driving land trafficking and speculation. In the area of Intag in the province of Imbabura, there is an imminent risk of land loss and river pollution due to the establishment a large-scale copper mining operation. On the limit between the protected forests Guayllabamba and Mindo and traversing the southern part of the Corridor, a new heavy crude oil pipeline caused minimal damage during construction, but poses a latent risk of contamination to rivers that run near the Maquipucuna Reserve and in the Guayllabamba Protected Forest. Artisanal charcoal production in the montane cloud forests is a serious threat to the forests in Guayllabamba Protected Forest. As of 2002, only 28% of Western Andes Foothill Evergreen forests remained intact of the original ca. 700,000 ha. Of the 340,000 ha of Lower Montane Evergreen Forests, 32% remain intact, and 42% of the 295,000 ha of Montane Cloud forests.

2.7 THE CONSERVATION LANDSCAPE

Before widespread, informed conservation and development actions can take place there must be a common understanding of who the stakeholders are, and what are their motivations, their approaches to conservation and development, and their impact. A Corridor stakeholder assessment was carried out in preparation for an award from the Global Environmental Facility/World Bank. More than 350 stakeholders —people, groups or institutions whose actions relate, positively or negatively, to the conservation or development of the Chocó Andean Corridor region— were identified. As the previous sections suggest, the conservation landscape was found to be extremely complex, with incredibly high levels of conflicts of interests and political differences to the point of making it nearly impossible to think of an institutional working group for the region (Stallings 2001). There is an extremely large level of organized activity in the regions with the common objective of conservation and sustainable development. However, in most cases and with very few exceptions, groups and organizations are not collaborating or coordinating actions. There are large environmental groups siding with the timber and oil palm industries, which in turn creates opposition and distrust at the local level, and among NGOs. In addition, the assessment found marked jealousy and distrust from indigenous and farmer groups towards non-government organizations and governments. There is rivalry among some indigenous and AfroEcuadorian organizations. In the many cases where there exist second tier and third tier organizations, grassroots organizations complain that, large organizations do not represent their interests, while large organizations complain that grassroots leaders make decisions without consulting the higher levels. Central and local governments feel distrust and jealousy of non-government organizations. Over 70 different grassroots and larger organizations represent Indigenous nationalities, AfroEcuadorians, and *colonos*. Another 70 or so non-government organizations, national and international, as well as bilateral and multilateral aid projects are also active through out the region. Government projects and activities from at least five Ministries—Environment, Tourism, Agriculture, Mining, Education and Health—from both the central government and from each of the 4 provincial governments are taking place in numerous communities along the Corridor. Each of the 162 *Parroquias* and 25 Municipalities represent the local governments. In contrast to the large number of social, conservation, and government organizations, the number of organizations that very effectively represent the industrial sector is very small. There are two timber associations, one oil palm producer associations, one shrimp culture organization, one national mining association. The conclusion is that it is very difficult to coordinate actions at every level of organization, yet communication and collaboration are necessary to avoid duplication of efforts and reinventing the wheel, and to facilitate synergy of activities carried out with the limited funding available.

A number of eco-regional conservation strategies exist in the region. Fundación Maquipucuna and the Institute of Ecology (now Odum School of Ecology) at University of Georgia proposed the Chocó Andean Corridor as a conservation strategy over an east-west altitudinal gradient from the Andes mountains to the sea in 1992 (Justicia 1995). In 1994, the British Rainforest Concern also adopted the strategy as their working framework, which then joined in 2001 and 2002 by Flora and Fauna International and the local NGO SIRUA to plan the Awacachi Corridor (one of the main routes of the proposed Chocó Andean Corridor). The eco-regional strategies of the large international conservation organizations can be described in two ways, how they have classified the areas, and where they actually invest funds in the field. The Chocó Andean Corridor region falls into two of Conservation International 'biodiversity hotspots' the Tumbes-Chocó-Magdalena and the Tropical Andes. In 2001, Conservation International (CI) initiated the Chocó-Manabi Corridor as their field strategy for the conservation of the Tumbes-Chocó-Magdalena Hotspot (up to 1000 meters), thus missing the Tropical Andes areas of Northwest Ecuador; recently CI reviewed the limits (Conservation-International 2005, 2006) to also include the northwestern Tropical Andes. CI funds a few projects north of the Cotacachi Cayapas Reserve (CCER) — land purchase of the Awacachi Corridor—, and southeast of the Cotacachi Cayapas Reserve — work with some Chachi indigenous communities. The Chocó Andean Corridor falls into BirdLife International's Chocó Endemic Bird Area (EBA), additionally it has declared 19 Important Bird Areas (IBAs) which together cover the majority of the Corridor, but its emphasis in the field is mainly on the IBA Mindo (Aves-y-Conservacion 2007). The Chocó Andean Corridor falls into four of World Wildlife Fund's (WWF) Global 200 Ecoregions, the Chocó-Darién Moist Forests, the Northern Andean Montane Forests, Northern Andean Paramo and South American Pacific Mangroves (Olson and Dinerstein 2002). For WWF the conservation status of the Chocó-Darién Moist Forests is relatively stable and intact (WWF 2006a), the Northern Andean Montane Forests are critically endangered (WWF

2006b), and for the others the conservation status is not listed. In the field, WWF helps the Awá indigenous group to protect their territory. Of all the eco-regional conservation strategies for Northwest Ecuador, the Chocó Andean Corridor is the only home-grown initiative and the only one that aims at the protection of ecological processes in an altitudinal gradient.

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Table 2.1 Chocó Andean Corridor threatened plant species in relation to top countries per number of plants listed in the IUCN Red List of Threatened Species. **IUCN Red List Categories**: **EX** - Extinct, **EW** - Extinct in the Wild, **CR** - Critically Endangered, **EN** - Endangered, **VU** - Vulnerable, **LR/cd** - Lower Risk/conservation dependent, **NT** - Near Threatened (includes LR/nt - Lower Risk/near threatened), **DD** - Data Deficient, **LC** - Least Concern (includes LR/lc - Lower Risk, least concern), **na –** This information was not downloaded. Extracted from the summary country totals (Plants) (IUCN 2006).

	EX	**EW**	**Sub - total**	**CR**	**EN**	**VU**	**Sub - total**	**LR/ cd**	**NT**	**DD**	**LC**	**Total**
Ecuador	1	0	**1**	240	669	923	**1,832**	1	263	239	148	**2,484**
Chocó Andean Corridor	na	na	**na**	15	112	225	**352**	na	104	12	na	**468**
Malaysia	1	1	**2**	186	99	403	**688**	113	70	32	280	**1,185**
Indonesia	1	2	**3**	113	70	204	**387**	9	78	49	170	**696**
China	3	1	**4**	73	172	197	**442**	5	47	19	111	**628**
Brazil	5	1	**6**	46	117	219	**382**	22	66	37	86	**599**
Mexico	0	2	**2**	40	75	146	**261**	8	23	21	87	**402**
United States	23	7	**30**	104	64	75	**243**	4	23	3	83	**386**
Peru	1	0	**1**	9	15	252	**276**	4	38	19	40	**378**
India	7	2	**9**	45	113	89	**247**	1	22	18	68	**365**
Madagascar	0	0	0	61	98	118	**277**	0	31	16	39	**363**
Colombia	3	0	**3**	31	86	108	**225**	4	43	12	47	**334**

Table 2.2 Matrix of potential conservation conflicts and opportunities obtained by cross-tabulating the government recommended uses from Proyecto MAG-IICA-CLIRSEN (2002) and land use classification of 2000 (CLIRSEN). Conflicts would arise if the government put into effect policies to implement the recommended zoning based on soil use classification as well as opportunities for restoration. Shaded area in the Forest column is at risk; shaded area in Non-forest column represents opportunities of reforestation projects.

Gov. recommended uses	Forest (ha)	Non-forest (ha)	n/d (ha)
1 Forest	758,987	680,539	4,017
2 Non Agriculture or Pasture	48,364	18,444	3,033
3 Agriculture - strongly limited	65,742	202,883	1,312
4 Agriculture - important limitations	40,167	240,345	492
5 Agriculture - slight limitations	27,461	100,089	164
6 Agriculture - ideal	36,314	300,595	5,492
7 Pasture	329,695	283,380	3,525
8 Urban	-	7,869	82
9 W/R/S/S	-	10,656	2,213

Table 2.3 Number of threatened plant species in the Chocó Andean Corridor at specified altitudes in relation to total number of species and collection effort. The sum of the total number of species is greater than 8801 because there is overlap between altitudinal ranges.

Number of threatened species < 300m	**93**
Records of threatened species	309
Total records collected < 300m	5,786
Area (100 Km2)	123
Collection effort/100km2	47
Total # of species	**1,890**
Number of threatened species between 300 - 900 m	**139**
Records of threatened species	451
Total records collected between 300 - 900 m	6,727
Area (100 Km2)	64
Collection effort/100km2	105
Total # of species	**2,166**
Number of threatened species between 900 - 2000 m	**186**
Records of threatened species	543
Total records collected between 900 - 2000 m	10,050
Area (100 Km2)	55
Collection effort/100km2	184
Total # of species	**3,007**
Number of threatened species between 2000 - 3000 m	**170**
Records of threatened species	453
Total records collected between 2000 - 3000 m	8,555
Area (100 Km2)	47
Collection effort/100km2	181
Total # of species	**2,515**
Number of threatened species > 3000 m	**102**
Records of threatened species	226
Total records collected between > 3000 m	5,942
Area (100 Km2)	27
Collection effort/100km2	221
Total # of species	**1,502**

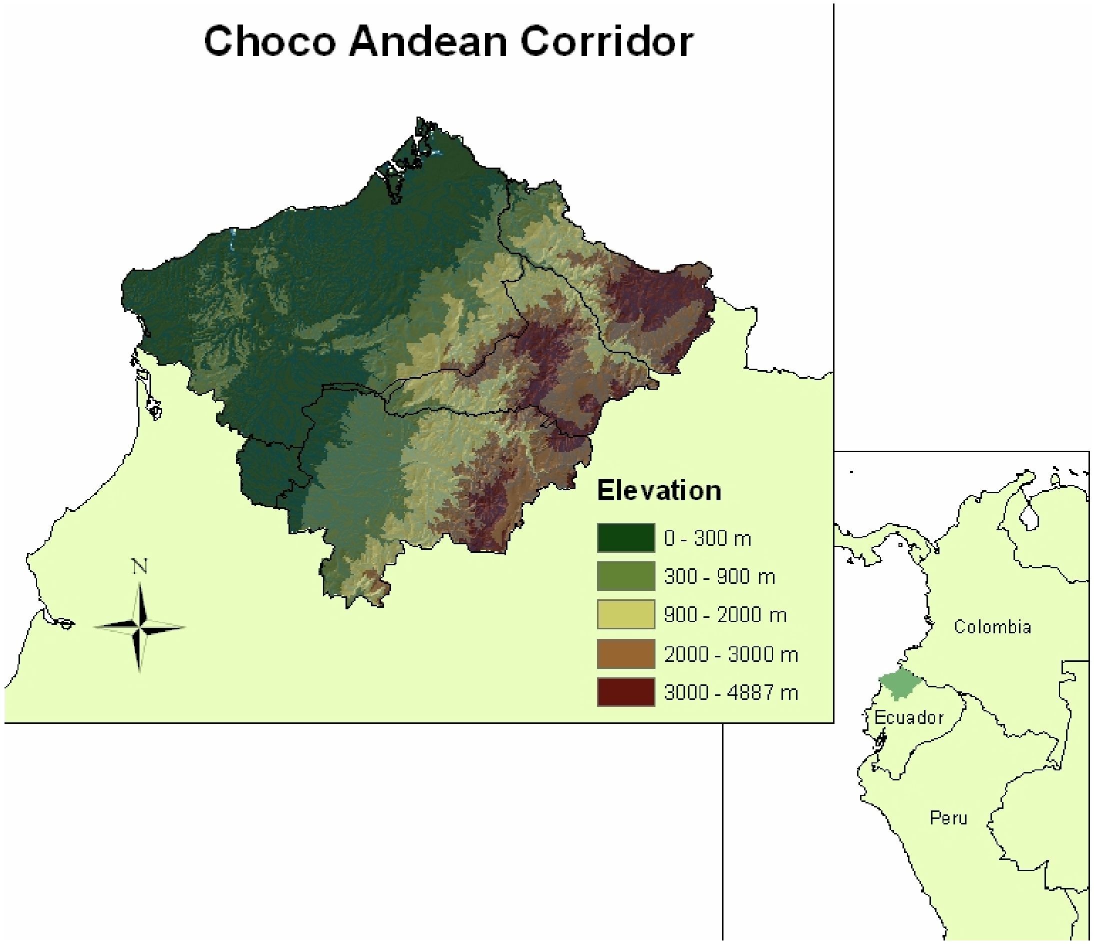


Figure 2.1 The Chocó Andean Corridor in Northwest Ecuador

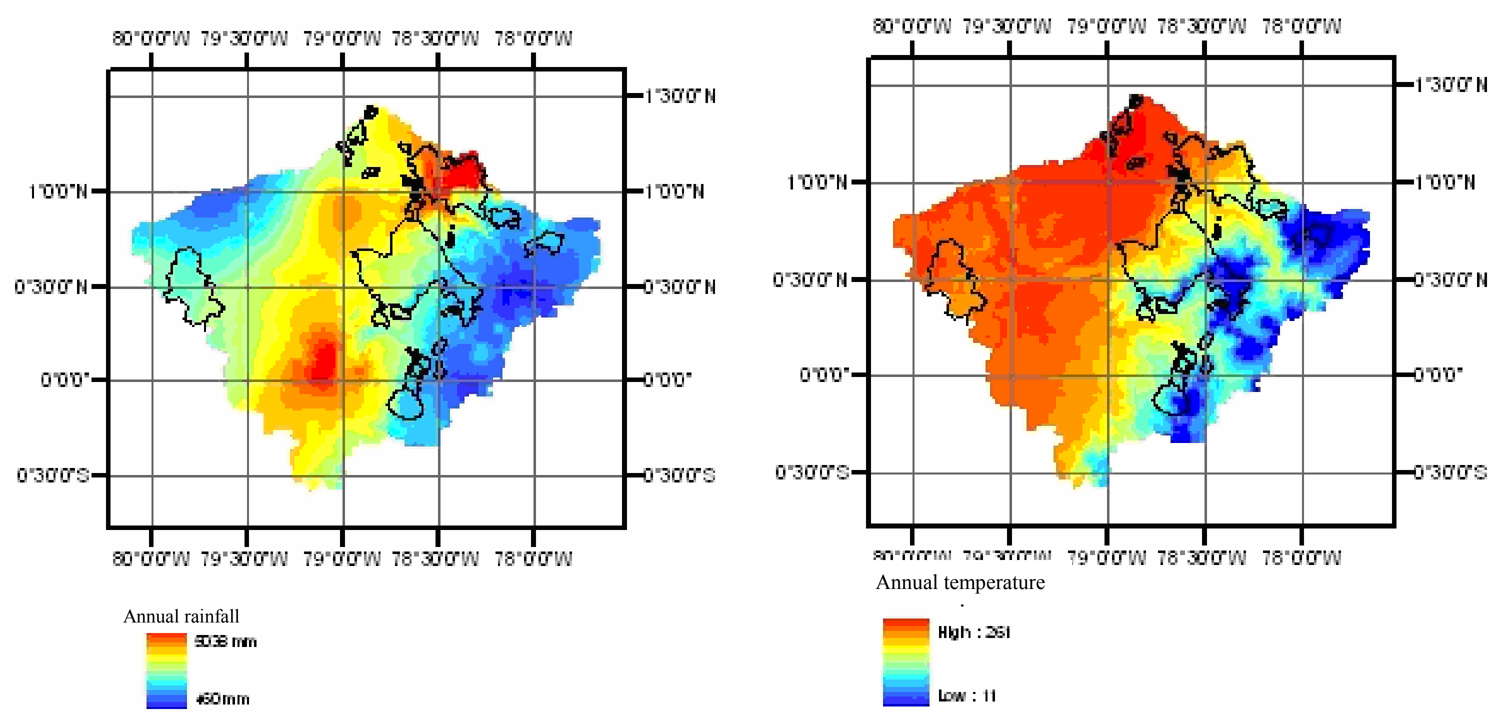


Figure 2.2 Main climatic fluctuations in the Chocó Andean Region of Northwest Ecuador in terms of annual rainfall (5038mm – 460mm) and annual temperature (26.1°C – 1.1°C).

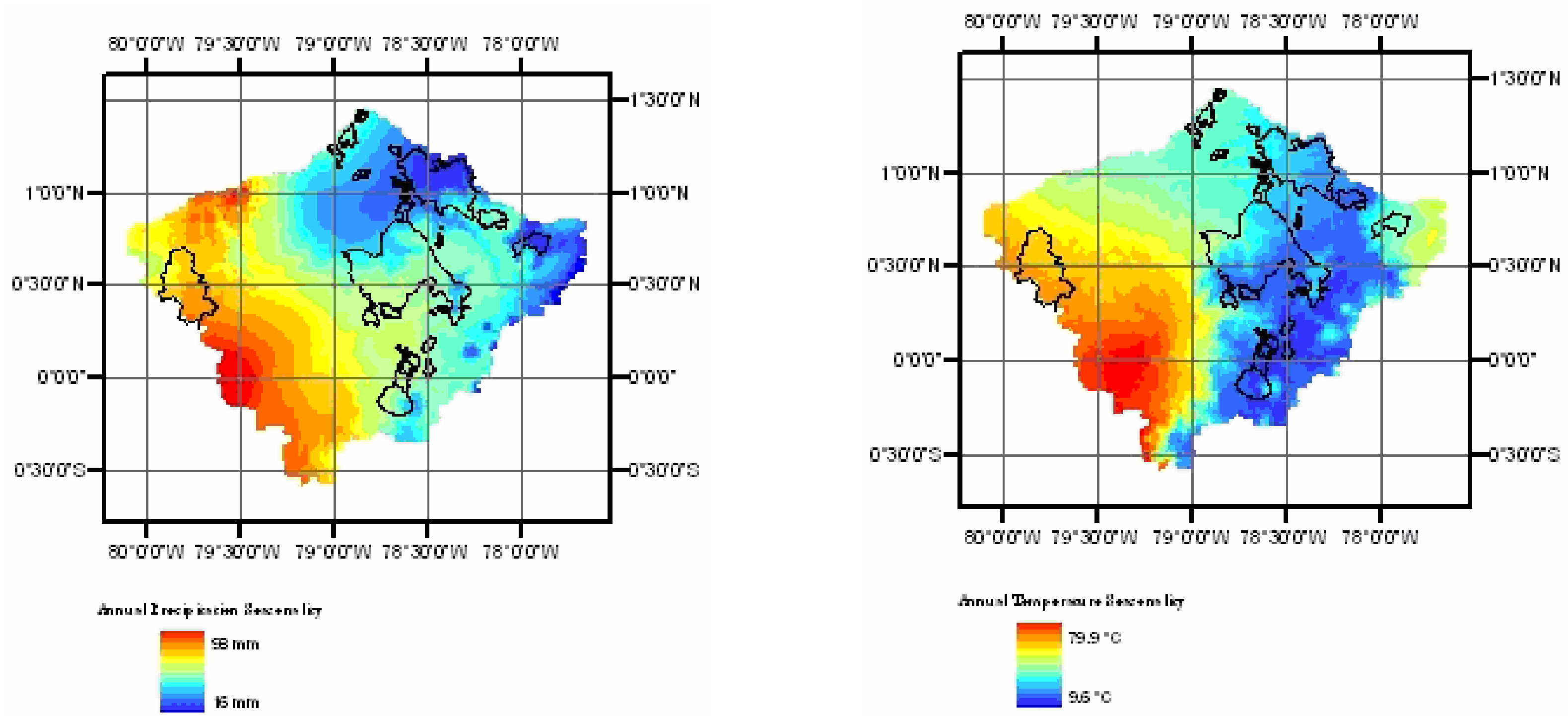


Figure 2.3 Main climatic fluctuations in terms of annual rainfall seasonality (coefficient of variation) (58mm – 16mm) and annual temperature seasonality (standard deviation *100) (79.9°C – 9.6°C) in the Chocó Andean Region of Northwest Ecuador.

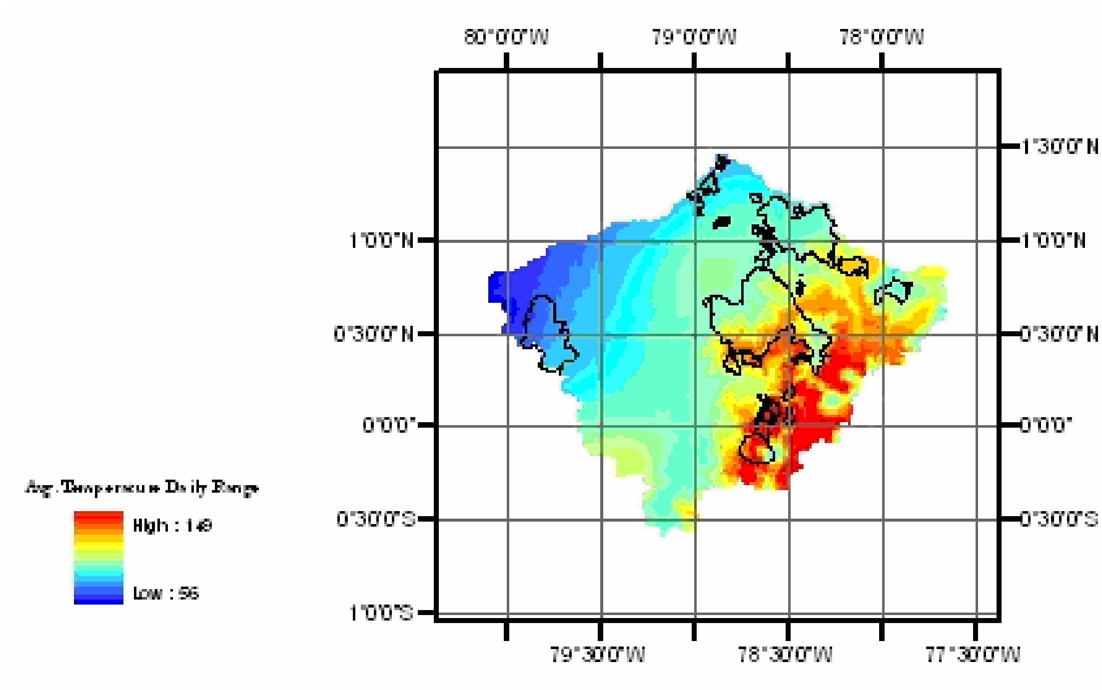


Figure 2.4 Main climatic fluctuations in the Chocó Andean Region of Northwest Ecuador in terms of average diurnal range 14.9 °C – 5.6 °C (mean of monthly (max temp - min temp)).

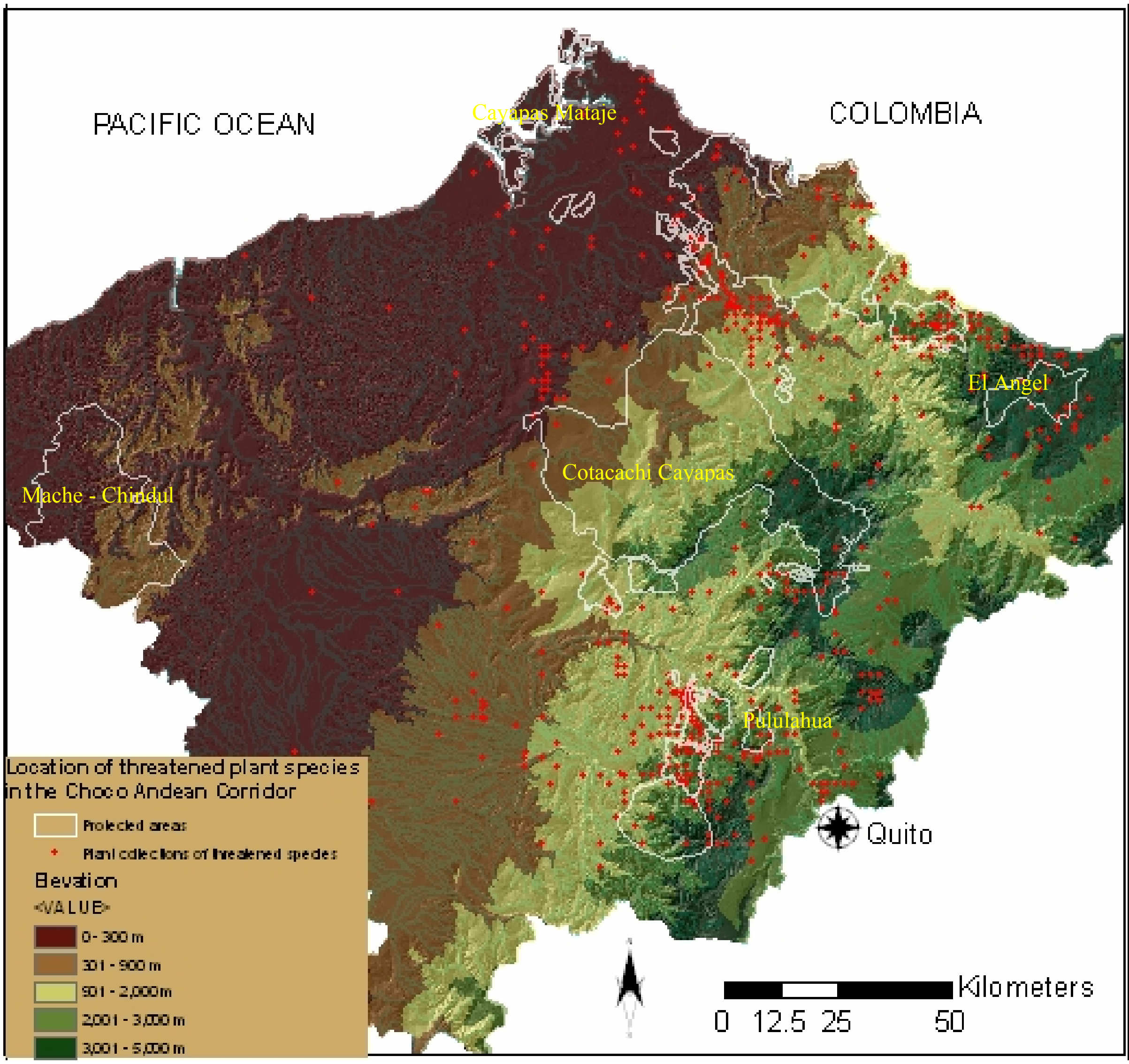
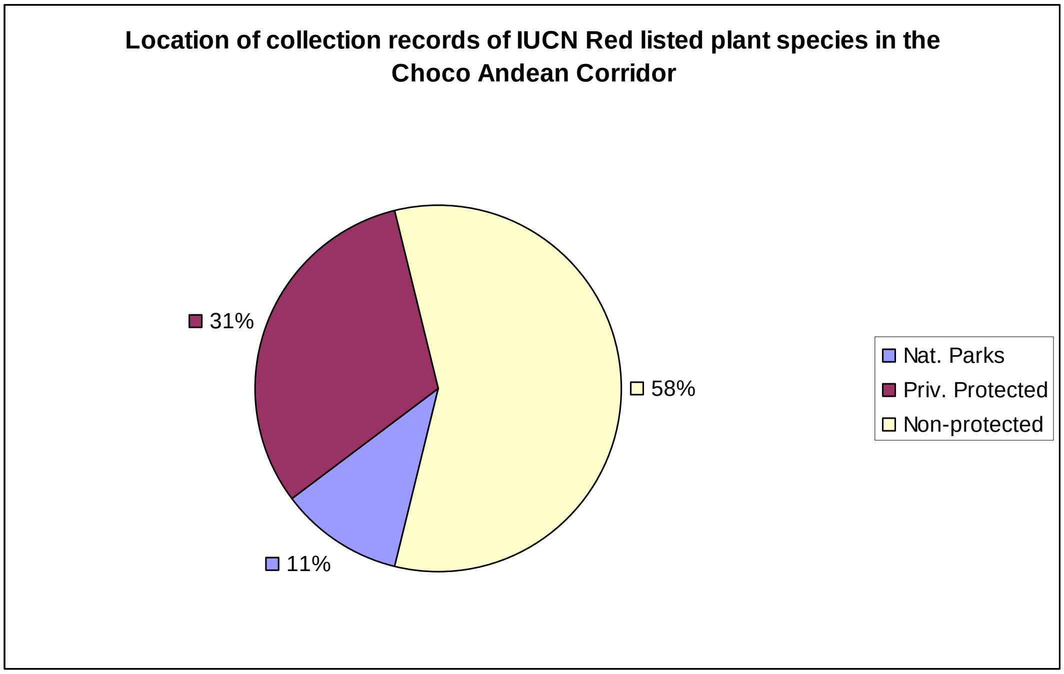


Figure 2.5 Location of plant collections of threatened plant species (IUCN red listed) in the Chocó Andean Region of Northwest Ecuador showing protected areas, both private and from the National Park System. The areas labeled in yellow belong to the National Park System. The map shows that there are significantly more threatened plant species collections outside the National Park System than in private protected areas (areas delineated in white without a label) or outside any protected area.



Location of collection	# Species	% of species	Uniqueness fraction
Nat. parks	72	11%	24%
Priv. protected	209	31%	29%
Non-protected	386	58%	53%

Figure 2.6 Locations of collection records of IUCN Red listed plant species and their uniquess concerning location of collection in protected areas of the National Park System (Nat. parks), private protected areas (priv. protected) and non-protected areas (non-protected). For example collections in non-protected areas having a uniquess fraction of 53%, means that of the 386 threatened species collected on non-protected areas, 53% of the species were not collected in any protected area.

APPENDIX A

List of threatened plant species of the Chocó Andean Corridor in Northwest Ecuador

List of threatened plant species (except least concern) according to the IUCN's Red List of Threatened species generated for the Chocó Andean Corridor (from the TROPICUS database 1936 - 2006 for the plants of Ecuador, the Tucker Herbarium for the plants of the Maquipucuna Reserve 1989 - 1992), and the IUCN Red List of Plants for Ecuador for all years through 2007. IUCN Red List Categories: CR - Critically Endangered, EN - Endangered, VU - Vulnerable, NT - Near Threatened (includes LR/nt - Lower Risk/near threatened), DD - Data Deficient.

Family	**Scientific name**	**Elev_range**	**Conservation status**	**# of georeferenced records**
Acanthaceae	*Aphelandra albinotata*	300 - 900	VU	1
	Justicia ianthina	< 300	NT	3
	Pseuderanthemum subauriculatum	< 300	NT	1
Acanthaceae Total				5
Actinidiaceae	*Saurauia adenodonta*	900 - 2000	NT	4
	Saurauia lehmannii	900 - 2000	NT	1
Actinidiaceae Total				5
Amaryllidaceae	*Bomarea glaucescens*	> 3000	NT	2
	Bomarea graminifolia	> 3000	CR	1
	Eucharis astrophiala	300 - 900	EN	2
	Eucrosia dodsonii	900 - 2000	VU	1
	Phaedranassa cinerea	> 3000	VU	1
		2000 - 3000	VU	1
	Phaedranassa viridiflora	2000 - 3000	EN	1
Amaryllidaceae Total				9
Anacardiaceae	*Tapirira rubrinervis*	300 - 900	EN	3
		900 - 2000	EN	1
Anacardiaceae Total				4
Annonaceae	*Annona oligocarpa*	< 300	EN	1
	Unonopsis magnifolia	< 300	VU	2
Annonaceae Total				3
Apocynaceae	*Allomarkgrafia ecuatoriana*	< 300	VU	1
		> 3000	VU	1
	Mandevilla dodsonii	300 - 900	EN	1
	Prestonia rotundifolia	< 300	EN	1
		300 - 900	EN	1
Apocynaceae Total				5

Araceae	*Anthurium angustilaminatum*	900 - 2000	NT	1
	Anthurium aristatum	2000 - 3000	NT	2
		900 - 2000	NT	11
	Anthurium auritum	900 - 2000	VU	1
	Anthurium balslevii	< 300	VU	2
		300 - 900	VU	27
	Anthurium cabuyalense	300 - 900	VU	1
	Anthurium dolichophyllum	300 - 900	VU	3
	Anthurium esmeraldense	< 300	VU	1
		300 - 900	VU	4
	Anthurium falcatum	< 300	NT	2
		300 - 900	NT	1
	Anthurium furcatum	< 300	NT	1
		300 - 900	NT	2
	Anthurium gualeanum	> 3000	VU	1
		2000 - 3000	VU	1
	Anthurium hebetatilaminum	300 - 900	VU	4
	Anthurium jaramilloi	300 - 900	VU	16
	Anthurium jimenae	2000 - 3000	VU	3
		300 - 900	VU	5
		900 - 2000	VU	1
	Anthurium leonianum	900 - 2000	VU	1
	Anthurium maculosum	300 - 900	NT	1
	Anthurium magnifolium	300 - 900	VU	9
	Anthurium nemorale	< 300	VU	1
	Anthurium nigropunctatum	< 300	NT	10
		300 - 900	NT	13
	Anthurium oxyphyllum	< 300	VU	1
		300 - 900	VU	1
		900 - 2000	VU	5
	Anthurium pallatangense	2000 - 3000	NT	3
		900 - 2000	NT	1
	Anthurium pedunculare	< 300	VU	10
		300 - 900	VU	10
		900 - 2000	VU	1
	Anthurium polyneuron	900 - 2000	DD	1
	Anthurium punctatum	< 300	VU	1
	Anthurium rimbachii	< 300	VU	3
		300 - 900	VU	10
	Anthurium saccardoi	< 300	EN	6
		300 - 900	EN	2
	Anthurium silanchense	300 - 900	VU	2
	Anthurium sparreorum	< 300	NT	1
	Anthurium subcoerulescens	< 300	VU	1

	Anthurium tenuifolium	< 300	EN	2
		2000 - 3000	EN	1
		900 - 2000	EN	5
	Chlorospatha besseae	300 - 900	EN	3
	Dracontium croatii	300 - 900	EN	4
		900 - 2000	EN	1
	Philodendron balaoanum	< 300	CR	1
	Philodendron hooveri	< 300	VU	1
		300 - 900	VU	5
		900 - 2000	VU	9
	Philodendron musifolium	< 300	VU	8
		2000 - 3000	VU	2
		300 - 900	VU	3
		900 - 2000	VU	3
	Philodendron pogonocaule	< 300	CR	5
		300 - 900	CR	6
	Philodendron ventricosum	900 - 2000	EN	1
	Stenospermation gracile	< 300	VU	2
		900 - 2000	VU	2
	Stenospermation hilligii	300 - 900	VU	3
	Xanthosoma eggersii	< 300	EN	1
		300 - 900	EN	8
Araceae Total				260
Araliaceae	*Oreopanax corazonensis*	900 - 2000	EN	2
	Oreopanax grandifolius	2000 - 3000	NT	1
		900 - 2000	NT	4
Araliaceae Total				7
Arecaceae	*Aiphanes chiribogensis*	300 - 900	VU	3
		900 - 2000	VU	2
	Bactris setulosa	< 300	NT	3
		300 - 900	NT	3
		900 - 2000	NT	1
	Ceroxylon alpinum	2000 - 3000	EN	1
		900 - 2000	EN	3
	Phytelephas aequatorialis	< 300	NT	7
Arecaceae Total				23
Asclepiadaceae	*Cynanchum nielsenii*	> 3000	VU	1
	Cynanchum stenospira	2000 - 3000	VU	1
	Matelea harlingii	2000 - 3000	VU	1
Asclepiadaceae Total				3
Asteraceae	*Achyrocline hallii*	> 3000	VU	2
	Aequatorium jamesonii	> 3000	VU	3
	Ageratina dendroides	2000 - 3000	VU	1
	Aristeguietia cacalioides	2000 - 3000	NT	1
	Ayapana ecuadorensis	900 - 2000	VU	1
	Baccharis arbutifolia	> 3000	NT	5
	Baccharis klattii	> 3000	NT	3

Clibadium harlingii	2000 - 3000	VU	2
Clibadium manabiense	< 300	VU	2
	300 - 900	VU	1
Clibadium napoense	< 300	VU	1
Clibadium websteri	2000 - 3000	EN	1
Critoniopsis palaciosii	2000 - 3000	VU	5
Critoniopsis sodiroi	2000 - 3000	NT	8
	900 - 2000	NT	1
Cronquistianthus niveus	> 3000	VU	12
	2000 - 3000	VU	3
Dendrophorbium onae	2000 - 3000	NT	1
Dendrophorbium tipocochensis	2000 - 3000	NT	2
Diplostephium macrocephalum	> 3000	NT	1
Gnaphalium dysodes	> 3000	NT	1
Gnaphalium ecuadorense	2000 - 3000	EN	1
Grosvenoria rimbachii	> 3000	VU	8
Hebeclinium obtusisquamosum	300 - 900	VU	1
	900 - 2000	VU	2
Idiopappus saloyensis	2000 - 3000	EN	2
Jalcophila ecuadorensis	> 3000	NT	1
Kingianthus paniculatus	> 3000	NT	1
	2000 - 3000	NT	3
Llerasia assuensis	> 3000	NT	1
Loricaria antisanensis	> 3000	NT	1
Mikania cuencana	900 - 2000	DD	2
Mikania iodotricha	> 3000	NT	1
	2000 - 3000	NT	2
Munnozia pinnatipartita	900 - 2000	NT	1
Mutisia microcephala	> 3000	VU	2
Mutisia microphylla	> 3000	VU	3
Oligactis pichinchensis	> 3000	NT	1
	2000 - 3000	NT	4
Pappobolus juncosae	900 - 2000	VU	1
Pentacalia campii	> 3000	NT	2
Pentacalia carchiensis	300 - 900	VU	1
Pentacalia corazonensis	> 3000	VU	1
Pentacalia floribunda	2000 - 3000	VU	2
Pentacalia hillii	> 3000	VU	1
Pentacalia luteynorum	> 3000	VU	1
	2000 - 3000	VU	2
Pentacalia palaciosii	2000 - 3000	VU	2
	900 - 2000	VU	1
Plagiocheilus peduncularis	> 3000	VU	1
Senecio iscoensis	> 3000	DD	1
Stevia crenata	> 3000	VU	1

		2000 - 3000	VU	1
	Verbesina rivetii	> 3000	VU	2
		2000 - 3000	VU	1
	Werneria graminifolia	> 3000	VU	1
Asteraceae Total				116
Begoniaceae	*Begonia exalata*	2000 - 3000	VU	1
	Begonia harlingii	2000 - 3000	EN	1
		900 - 2000	EN	2
	Begonia secunda	900 - 2000	VU	2
	Begonia sodiroi	2000 - 3000	NT	1
		300 - 900	NT	1
		900 - 2000	NT	1
	Begonia truncicola	2000 - 3000	VU	1
Begoniaceae Total				10
Berberidaceae	*Berberis hyperythra*	2000 - 3000	DD	1
Berberidaceae Total				1
Bignoniaceae	*Calceolaria gossypina*	> 3000	EN	1
	Calceolaria helianthemoides	2000 - 3000	NT	1
Bignoniaceae Total				2
Bombacaceae	*Huberodendron patinoi*	< 300	VU	6
		300 - 900	VU	3
	Matisia alata	< 300	EN	3
		300 - 900	EN	1
	Matisia coloradorum	900 - 2000	EN	3
	Matisia grandifolia	< 300	EN	3
		300 - 900	EN	1
	Matisia palenquiana	< 300	EN	1
	Pseudobombax millei	< 300	DD	1
Bombacaceae Total				22
Brassicaceae	*Draba aretioides*	> 3000	EN	4
		2000 - 3000	EN	1
	Draba extensa	> 3000	EN	1
	Draba obovata	> 3000	NT	1
	Eudema nubigena	> 3000	EN	2
	Lepidium quitense	2000 - 3000	VU	1
Brassicaceae Total				10
Bromeliaceae	*Greigia atrobrunnea*	2000 - 3000	VU	1
	Guzmania aequatorialis	> 3000	VU	1
		2000 - 3000	VU	4
	Guzmania albescens	300 - 900	EN	3
		900 - 2000	EN	1
	Guzmania alborosea	< 300	VU	1
		300 - 900	VU	6
		900 - 2000	VU	3
	Guzmania barbiei	900 - 2000	DD	1
	Guzmania corniculata	300 - 900	VU	1
	Guzmania fosteriana	300 - 900	NT	4

	900 - 2000	NT	4
Guzmania fuquae	300 - 900	EN	5
Guzmania fusispica	2000 - 3000	VU	1
	900 - 2000	VU	5
Guzmania harlingii	< 300	VU	1
	300 - 900	VU	3
	900 - 2000	VU	1
Guzmania hirtzii	> 3000	VU	1
	2000 - 3000	VU	1
	900 - 2000	VU	1
Guzmania inexpectata	300 - 900	VU	1
Guzmania kentii	2000 - 3000	VU	2
	900 - 2000	VU	1
Guzmania pseudospectabilis	900 - 2000	VU	5
Guzmania roseiflora	900 - 2000	EN	1
Guzmania sieffiana	300 - 900	VU	2
Guzmania teuscheri	900 - 2000	NT	3
Guzmania xanthobractea	300 - 900	NT	1
	900 - 2000	NT	12
Pepinia hooveri	2000 - 3000	EN	5
	900 - 2000	EN	5
Pitcairnia ferrell-ingramiae	< 300	VU	3
	300 - 900	VU	18
	900 - 2000	VU	5
Pitcairnia pavonii	> 3000	NT	1
Pitcairnia simulans	< 300	NT	1
	300 - 900	NT	2
	900 - 2000	NT	2
Pitcairnia sodiroi	2000 - 3000	NT	15
	900 - 2000	NT	6
Pitcairnia stevensonii	300 - 900	VU	4
Puya angelensis	> 3000	EN	1
	2000 - 3000	EN	1
Puya sodiroana	2000 - 3000	VU	5
Racinaea inconspicua	2000 - 3000	EN	1
Racinaea quadripinnata	2000 - 3000	NT	2
Racinaea tandapiana	2000 - 3000	VU	3
	900 - 2000	VU	4
Tillandsia emergens	> 3000	VU	2
	2000 - 3000	VU	4
Tillandsia indigofera	2000 - 3000	EN	1
	900 - 2000	EN	2
Tillandsia polyantha	> 3000	EN	3
	2000 - 3000	EN	5
Tillandsia pretiosa	300 - 900	VU	4
	900 - 2000	VU	5
Tillandsia sceptriformis	2000 - 3000	NT	1

	Tillandsia sodiroi	2000 - 3000	VU	1
	Tillandsia spathacea	2000 - 3000	NT	3
	Vriesea boeghii	2000 - 3000	NT	1
	Vriesea drewii	2000 - 3000	EN	1
	Vriesea limonensis	2000 - 3000	VU	1
	Werauhia diantha	300 - 900	EN	1
		900 - 2000	EN	3
	Werauhia paupera	300 - 900	VU	5
		900 - 2000	VU	4
Bromeliaceae Total				208
Brunelliaceae	*Brunellia acostae*	2000 - 3000	VU	5
Brunelliaceae Total				5
Campanulaceae	*Burmeistera brachyandra*	< 300	VU	6
		300 - 900	VU	1
	Burmeistera crispiloba	2000 - 3000	VU	5
		300 - 900	VU	2
		900 - 2000	VU	11
	Burmeistera holm-nielsenii	2000 - 3000	EN	6
		300 - 900	EN	1
		900 - 2000	EN	1
	Burmeistera huacamayensis	2000 - 3000	EN	1
	Burmeistera loejtnantii	> 3000	VU	2
	Burmeistera racemiflora	900 - 2000	VU	1
	Burmeistera resupinata	2000 - 3000	EN	1
	Burmeistera truncata	900 - 2000	VU	1
	Centropogon aequatorialis	2000 - 3000	EN	4
		900 - 2000	EN	3
	Centropogon arcuatus	2000 - 3000	VU	1
	Centropogon balslevii	2000 - 3000	EN	3
	Centropogon chiltasonensis		EN	1
		2000 - 3000	EN	2
	Centropogon dissectus	> 3000	NT	5
		2000 - 3000	NT	1
	Centropogon llanganatensis	2000 - 3000	NT	3
		900 - 2000	NT	1
	Centropogon medusa	> 3000	EN	1
	Centropogon rimbachii	2000 - 3000	EN	1
	Centropogon rubrodentatus	2000 - 3000	VU	5
	Centropogon sodiroanus	2000 - 3000	NT	4
		900 - 2000	NT	4
	Centropogon subandinus	2000 - 3000	NT	10
	Centropogon trachyanthus	900 - 2000	VU	2

	Siphocampylus furax	2000 - 3000	EN	2
		900 - 2000	EN	1
	Siphocampylus rupestris	> 3000	EN	1
		300 - 900	EN	1
Campanulaceae Total				95
Capparaceae	*Podandrogyne brevipedunculata*	< 300	EN	4
		300 - 900	EN	6
		900 - 2000	EN	2
Capparaceae Total				12
Caricaceae	*Carica pulchra*	2000 - 3000	NT	1
Caricaceae Total				1
Cecropiaceae	*Cecropia maxima*	2000 - 3000	VU	2
		900 - 2000	VU	3
Cecropiaceae Total				5
Chrysobalanaceae	*Licania grandibracteata*	300 - 900	VU	2
		900 - 2000	VU	2
	Licania longicuspidata	< 300	EN	2
		300 - 900	EN	1
		900 - 2000	EN	5
	Licania megalophylla	300 - 900	EN	1
Chrysobalanaceae Total				13
Clethraceae	*Clethra crispa*	> 3000	NT	1
Clethraceae Total				1
Clusiaceae	*Clusia polystigma*	< 300	VU	1
Clusiaceae Total				1
Connaraceae	*Connarus ecuadorensis*	< 300	CR	1
Connaraceae Total				1
Cycadaceae	*Zamia gentryi*	300 - 900	VU	1
	Zamia roezlii	< 300	NT	4
		300 - 900	NT	2
Cycadaceae Total				7
Cyclanthaceae	*Asplundia cayapensis*	< 300	VU	2
		300 - 900	VU	1
	Asplundia domingensis	300 - 900	EN	1
	Asplundia fagerlindii	300 - 900	NT	4
		900 - 2000	NT	1
Cyclanthaceae Total				9
Cyperaceae	*Uncinia ecuadorensis*	> 3000	VU	1
	Uncinia lacustris	> 3000	EN	1
	Uncinia subsacculata	> 3000	VU	1
Cyperaceae Total				3
Dichapetalaceae	*Stephanopodium longipedicellatum*	< 300	VU	1
		900 - 2000	VU	1
Dichapetalaceae Total				2
Dioscoreaceae	*Dioscorea rimbachii*	> 3000	NT	1
Dioscoreaceae Total				1

Dryopteridaceae	*Diplazium divisissimum*	900 - 2000	VU	1
	Tectaria chimborazensis	900 - 2000	DD	1
Dryopteridaceae Total				2
Elaeocarpaceae	*Vallea ecuadorensis*	2000 - 3000	NT	1
Elaeocarpaceae Total				1
Ericaceae	*Macleania loeseneriana*	> 3000	VU	7
		2000 - 3000	VU	3
		900 - 2000	VU	1
Ericaceae Total				11
Euphorbiaceae	*Acalypha dictyoneura*	2000 - 3000	NT	1
	Alchornea leptogyna	900 - 2000	NT	1
	Alchornea sodiroi	2000 - 3000	VU	2
		900 - 2000	VU	1
	Croton coriaceus	> 3000	VU	2
		2000 - 3000	VU	4
		900 - 2000	VU	1
	Croton elegans	2000 - 3000	VU	4
		900 - 2000	VU	3
	Croton menthodorus	2000 - 3000	NT	7
		900 - 2000	NT	1
	Croton pavonis	900 - 2000	EN	5
	Croton pycnanthus	2000 - 3000	NT	3
	Croton sordidus	2000 - 3000	VU	1
	Croton wagneri	2000 - 3000	NT	4
		300 - 900	NT	1
		900 - 2000	NT	2
	Euphorbia jamesonii	900 - 2000	VU	1
Euphorbiaceae Total				44
Fabaceae	*Abarema ganymedea*	< 300	VU	1
	Bauhinia haughtii	< 300	EN	1
	Bauhinia pichinchensis	< 300	VU	4
		300 - 900	VU	6
		900 - 2000	VU	3
	Coursetia dubia	2000 - 3000	NT	7
		900 - 2000	NT	1
	Coursetia gracilis	> 3000	VU	1
		2000 - 3000	VU	5
		300 - 900	VU	1
		900 - 2000	VU	2
	Erythrina megistophylla	> 3000	NT	1
		900 - 2000	NT	13
	Erythrina schimpffii	900 - 2000	NT	1
	Inga carinata	< 300	EN	1
	Inga multicaulis	300 - 900	EN	2
		900 - 2000	EN	1
	Inga silanchensis	< 300	VU	3
		300 - 900	VU	4
		900 - 2000	VU	2

	Lupinus nubigenus	> 3000	EN	1
	Lupinus smithianus	> 3000	DD	2
	Senna scandens	300 - 900	EN	1
	Swartzia haughtii	< 300	VU	16
		300 - 900	VU	1
	Swartzia littlei	< 300	EN	2
	Zapoteca aculeata	2000 - 3000	EN	1
Fabaceae Total				84
Flacourtiaceae	*Banara regia*	900 - 2000	EN	5
	Banara riparia	< 300	EN	4
		300 - 900	EN	1
	Casearia mexiae	2000 - 3000	EN	3
Flacourtiaceae Total				13
Gentianaceae	*Gentianella jamesonii*	> 3000	EN	3
Gentianaceae Total				3
Geraniaceae	*Geranium chimborazense*	> 3000	VU	1
Geraniaceae Total				1
Gesneriaceae	*Alloplectus herthae*	2000 - 3000	DD	9
		900 - 2000	DD	24
	Alloplectus penduliflorus	900 - 2000	VU	1
	Besleria miniata	< 300	DD	1
	Besleria modica	2000 - 3000	NT	1
	Columnea asteroloma	900 - 2000	CR	1
	Columnea eubracteata	2000 - 3000	VU	4
	Columnea manabiana	< 300	CR	2
	Columnea mastersonii	2000 - 3000	VU	4
		300 - 900	VU	1
		900 - 2000	VU	13
	Columnea ovatifolia	2000 - 3000	VU	2
	Columnea rileyi	900 - 2000	VU	2
	Columnea rubribracteata	< 300	VU	1
		300 - 900	VU	1
	Cremosperma reldioides	300 - 900	VU	1
		900 - 2000	VU	2
	Drymonia chiribogana	900 - 2000	VU	3
	Drymonia ecuadorensis	300 - 900	EN	1
		900 - 2000	EN	3
	Drymonia laciniosa	< 300	EN	5
		300 - 900	EN	2
	Gasteranthus carinatus	900 - 2000	EN	2
	Gasteranthus crispus	900 - 2000	EN	1
	Gasteranthus lateralis	2000 - 3000	VU	1
		900 - 2000	VU	5
	Gasteranthus trifoliatus	900 - 2000	VU	1
	Monopyle sodiroana	< 300	EN	12
		300 - 900	EN	5
	Paradrymonia binata	300 - 900	EN	5
		900 - 2000	EN	1

	Paradrymonia fuquaiana	300 - 900	VU	1
	Paradrymonia hypocyrta	300 - 900	EN	1
		900 - 2000	EN	1
Gesneriaceae Total				120
Heliconiaceae	*Heliconia gaiboriana*	900 - 2000	VU	1
	Heliconia sclerotricha	900 - 2000	NT	6
	Heliconia virginalis	900 - 2000	VU	3
Heliconiaceae Total				10
Hernandiaceae	*Hernandia lychnifera*	< 300	EN	1
Hernandiaceae Total				1
Juglandaceae	*Juglans neotropica*	2000 - 3000	EN	1
		900 - 2000	EN	2
Juglandaceae Total				3
Lamiaceae	*Clinopodium mutabile*	2000 - 3000	NT	1
	Lepechinia paniculata	2000 - 3000	VU	1
Lamiaceae Total				2
Lauraceae	*Nectandra guadaripo*		VU	1
		< 300	VU	11
		300 - 900	VU	13
		900 - 2000	VU	1
	Nectandra obtusata	> 3000	NT	2
		2000 - 3000	NT	5
		900 - 2000	NT	12
	Ocotea benthamiana	> 3000	VU	1
		2000 - 3000	VU	6
	Ocotea pachypoda	2000 - 3000	CR	2
	Ocotea rugosa	2000 - 3000	NT	5
		900 - 2000	NT	2
	Persea nudigemma	> 3000	VU	1
		900 - 2000	VU	1
	Pleurothyrium giganthum	900 - 2000	EN	1
Lauraceae Total				64
Lecythidaceae	*Eschweilera rimbachii*	< 300	VU	4
		300 - 900	VU	4
		900 - 2000	VU	7
	Grias multinervia	< 300	VU	3
		300 - 900	VU	6
		900 - 2000	VU	1
	Gustavia dodsonii	< 300	EN	7
		300 - 900	EN	3
	Gustavia pubescens	900 - 2000	VU	1
Lecythidaceae Total				36
Malvaceae	*Wercklea intermedia*	< 300	VU	1
Malvaceae Total				1
Marantaceae	*Calathea ischnosiphonoides*	900 - 2000	EN	3
	Calathea plurispicata	900 - 2000	NT	1
Marantaceae Total				4

Marcgraviaceae	*Marcgraviastrum gigantophyllum*	900 - 2000	VU	1
	Marcgraviastrum sodiroi	300 - 900	EN	1
		900 - 2000	EN	2
Marcgraviaceae Total				4
Melastomataceae	*Axinaea quitensis*	2000 - 3000	NT	2
	Axinaea sclerophylla	2000 - 3000	VU	3
	Axinaea sodiroi	2000 - 3000	EN	2
	Blakea eriocalyx	2000 - 3000	EN	2
		900 - 2000	EN	18
	Blakea involvens	300 - 900	EN	1
	Blakea jativae	< 300	EN	5
		300 - 900	EN	1
		900 - 2000	EN	3
	Blakea oldemanii	2000 - 3000	VU	1
	Blakea rotundifolia	2000 - 3000	VU	6
		300 - 900	VU	1
		900 - 2000	VU	5
	Brachyotum gleasonii	> 3000	VU	3
	Brachyotum gracilescens	> 3000	VU	2
	Clidemia acostae	300 - 900	VU	2
	Clidemia caudata	300 - 900	NT	1
		900 - 2000	NT	1
	Clidemia ecuadorensis	< 300	CR	2
	Clidemia purpurea	< 300	VU	5
		300 - 900	VU	1
	Huilaea ecuadorensis	2000 - 3000	VU	2
	Meriania pichinchensis	900 - 2000	VU	1
	Meriania rigida	900 - 2000	VU	1
	Miconia brevitheca	< 300	NT	1
		300 - 900	NT	6
		900 - 2000	NT	9
	Miconia dapsiliflora	2000 - 3000	VU	1
		900 - 2000	VU	3
	Miconia explicita	300 - 900	VU	1
	Miconia guayaquilensis	< 300	EN	1
	Miconia idiogena	> 3000	VU	1
	Miconia littlei	900 - 2000	CR	3
	Miconia lugonis	< 300	NT	2
	Ossaea palenquensis	900 - 2000	EN	1
	Ossaea sparrei	900 - 2000	VU	2
	Tibouchina gleasoniana	2000 - 3000	VU	6
	Topobea asplundii	< 300	VU	1
	Triolena pedemontana	< 300	VU	9
		300 - 900	VU	5
Melastomataceae Total				123

Meliaceae	*Carapa megistocarpa*	< 300	EN	5
		300 - 900	EN	1
		900 - 2000	EN	4
	Guarea cartaguenya	< 300	VU	1
		300 - 900	VU	16
		900 - 2000	VU	3
	Guarea polymera	< 300	VU	24
		300 - 900	VU	4
	Trichilia primogenita	300 - 900	VU	5
		900 - 2000	VU	3
Meliaceae Total				66
Monimiaceae	*Siparuna croatii*	900 - 2000	VU	4
	Siparuna guajalitensis	2000 - 3000	VU	3
		900 - 2000	VU	2
	Siparuna multiflora	< 300	VU	5
		300 - 900	VU	5
		900 - 2000	VU	4
	Siparuna palenquensis	300 - 900	EN	1
	Siparuna piloso-lepidota	> 3000	NT	2
		2000 - 3000	NT	27
		900 - 2000	NT	5
Monimiaceae Total				58
Moraceae	*Ficus lacunata*	2000 - 3000	VU	2
	Naucleopsis chiguila	< 300	VU	1
		300 - 900	VU	3
	Sorocea sarcocarpa	< 300	EN	15
		300 - 900	EN	2
Moraceae Total				23
Myrsinaceae	*Ardisia flavida*	300 - 900	VU	1
	Geissanthus ecuadorensis	900 - 2000	VU	1
	Geissanthus fallenae	2000 - 3000	EN	2
		900 - 2000	EN	3
	Geissanthus pichinchae	> 3000	NT	1
		2000 - 3000	NT	17
		900 - 2000	NT	1
	Geissanthus vanderwerffii	2000 - 3000	NT	1
	Myrsine sodiroana	2000 - 3000	VU	1
Myrsinaceae Total				28
Myrtaceae	*Eugenia valvata*	> 3000	NT	1
		2000 - 3000	NT	5
Myrtaceae Total				6
Olacaceae	*Heisteria asplundii*	2000 - 3000	NT	1
		300 - 900	NT	2
		900 - 2000	NT	5
	Minquartia guianensis	< 300	NT	8
		300 - 900	NT	1
Olacaceae Total				17

Oxalidaceae	*Oxalis rufescens*	> 3000	VU	1
Oxalidaceae Total				1
Passifloraceae	*Passiflora anfracta*	< 300	EN	1
	Passiflora discophora	300 - 900	EN	1
	Passiflora eggersii	900 - 2000	VU	1
	Passiflora jamesonii	> 3000	VU	2
	Passiflora montana	2000 - 3000	EN	1
	Passiflora sodiroi	2000 - 3000	NT	1
	Passiflora trochlearis	300 - 900	VU	2
Passifloraceae Total				9
Piperaceae	*Peperomia crispa*	2000 - 3000	VU	2
		900 - 2000	VU	1
	Peperomia inconspicua	2000 - 3000	VU	1
		900 - 2000	VU	1
	Peperomia pachystachya	2000 - 3000	EN	2
	Peperomia scutellariifolia	900 - 2000	VU	2
	Piper brachystylum	300 - 900	EN	2
		900 - 2000	EN	1
	Piper hylophilum	300 - 900	VU	1
		900 - 2000	VU	2
	Piper saloyanum	900 - 2000	EN	1
	Piper schuppii	2000 - 3000	VU	1
	Piper sodiroi	2000 - 3000	VU	4
		900 - 2000	VU	2
Piperaceae Total				23
Poaceae	*Aristida guayllabambensis*	2000 - 3000	VU	3
		900 - 2000	VU	5
	Aulonemia longiaristata	2000 - 3000	NT	2
	Calamagrostis aurea	> 3000	VU	3
	Calamagrostis carchiensis	> 3000	VU	2
	Chusquea maclurei	2000 - 3000	VU	6
	Festuca glumosa	> 3000	NT	4
	Paspalum azuayense	2000 - 3000	EN	1
	Pharus ecuadoricus	300 - 900	EN	1
Poaceae Total				27
Polemoniaceae	*Cobaea campanulata*	2000 - 3000	EN	1
Polemoniaceae Total				1
Polygalaceae	*Monnina obovata*	2000 - 3000	VU	1
	Monnina sodiroana	2000 - 3000	EN	2
		900 - 2000	EN	7
Polygalaceae Total				10
Pteridophyta	*Alsophila esmeraldensis*	< 300	EN	1
		300 - 900	EN	5
		900 - 2000	EN	2
	Blechnum floresii	900 - 2000	EN	3
	Blechnum monomorphum	> 3000	VU	1
		2000 - 3000	VU	1

	Campyloneurum oellgaardii	900 - 2000	VU	1
	Ceradenia semiadnata	> 3000	VU	1
	Cyathea bipinnata	300 - 900	VU	3
		900 - 2000	VU	1
	Cyathea corallifera	> 3000	NT	1
		900 - 2000	NT	1
	Cyathea cystolepis	2000 - 3000	DD	1
		900 - 2000	DD	3
	Cyathea halonata	900 - 2000	VU	2
	Cyathea heliophila	2000 - 3000	EN	5
	Cyathea hemiepiphytica	300 - 900	VU	4
		900 - 2000	VU	1
	Cyathea punctata	300 - 900	VU	3
	Diplazium chimboanum	2000 - 3000	VU	1
	Diplazium divisissimum	300 - 900	VU	3
		900 - 2000	VU	6
	Diplazium melanosorum	2000 - 3000	NT	3
	Diplazium oellgaardii	300 - 900	VU	11
		900 - 2000	VU	6
	Diplazium palaviense	< 300	VU	2
		300 - 900	VU	1
	Diplazium pulicosum	2000 - 3000	NT	1
	Diplazium rivale	900 - 2000	VU	1
	Elaphoglossum antisanae	> 3000	VU	4
	Elaphoglossum isophyllum	> 3000	EN	2
	Elaphoglossum oleandropsis	300 - 900	VU	1
	Elaphoglossum spectabile	> 3000	EN	1
	Elaphoglossum yatesii	> 3000	VU	2
	Hecistopteris pinnatifida	300 - 900	VU	1
	Huperzia ascendens	> 3000	VU	2
	Huperzia llanganatensis	> 3000	VU	2
	Huperzia polydactyla	> 3000	NT	6
	Huperzia talpiphila	> 3000	VU	2
	Hymenophyllum cristatum	2000 - 3000	NT	1
	Polybotrya andina	300 - 900	VU	4
	Polystichum bonapartii	2000 - 3000	VU	1
	Selaginella sericea	2000 - 3000	NT	2
		900 - 2000	NT	3
	Thelypteris aculeata	900 - 2000	VU	1
	Thelypteris elegantula	2000 - 3000	VU	2
	Thelypteris fluminalis	300 - 900	NT	1
	Trichomanes paucisorum	< 300	VU	1
		300 - 900	VU	14
Pteridophyta Total				128
Rosaceae	*Lachemilla jamesonii*	> 3000	VU	1
	Lachemilla rupestris	> 3000	VU	2

	Polylepis incana	> 3000	VU	14
		2000 - 3000	VU	1
	Polylepis pauta	> 3000	VU	21
	Polylepis reticulata	> 3000	VU	1
Rosaceae Total				40
Rubiaceae	*Arachnothryx chimboracensis*	900 - 2000	CR	1
	Coussarea pilosiflora	300 - 900	NT	1
	Ladenbergia pavonii	2000 - 3000	NT	2
		900 - 2000	NT	7
	Ladenbergia rubiginosa	300 - 900	CR	1
	Manettia pichinchensis	> 3000	NT	3
	Palicourea anderssoniana	900 - 2000	VU	2
	Palicourea asplundii	900 - 2000	VU	1
	Palicourea calothyrsus	2000 - 3000	VU	6
	Palicourea calycina	> 3000	VU	1
	Palicourea fuchsioides	> 3000	EN	1
	Palicourea holmgrenii	2000 - 3000	NT	5
	Palicourea sodiroi	2000 - 3000	VU	1
		300 - 900	VU	1
		900 - 2000	VU	3
	Pentagonia involucrata	< 300	EN	3
		300 - 900	EN	2
	Psychotria rimbachii	300 - 900	EN	1
		900 - 2000	EN	3
	Rustia alba	2000 - 3000	VU	1
		900 - 2000	VU	2
	Sabicea pyramidalis	300 - 900	VU	1
Rubiaceae Total				49
Rutaceae	*Erythrochiton giganteus*	> 3000	EN	1
Rutaceae Total				1
Sapindaceae	*Allophylus dodsonii*	< 300	EN	1
	Paullinia navicularis	2000 - 3000	VU	1
	Talisia bullata	< 300	CR	1
		900 - 2000	CR	1
Sapindaceae Total				4
Sapotaceae	*Pouteria capacifolia*	300 - 900	CR	1
	Pouteria collina	300 - 900	VU	5
		900 - 2000	VU	5
Sapotaceae Total				11
Scrophulariaceae	*Calceolaria pedunculata*	> 3000	VU	4
		2000 - 3000	VU	3
Scrophulariaceae Total				7
Selaginellaceae	*Selaginella sericea*	900 - 2000	NT	4
Selaginellaceae Total				4
Solanaceae	*Brugmansia aurea*	> 3000	VU	1
		2000 - 3000	VU	2
	Brugmansia versicolor	< 300	NT	2

		300 - 900	NT	1
		900 - 2000	NT	5
	Cuatresia harlingiana	< 300	NT	3
		> 3000	NT	1
		900 - 2000	NT	4
	Markea spruceana	300 - 900	VU	1
	Solanum cajanumense	300 - 900	NT	1
	Solanum chimborazense	900 - 2000	EN	1
	Solanum dolichorhachis	< 300	CR	2
	Solanum fallax	900 - 2000	NT	1
	Solanum interandinum	> 3000	VU	3
		2000 - 3000	VU	5
Solanaceae Total				33
Sterculiaceae	*Herrania balaensis*	< 300	EN	2
Sterculiaceae Total				2
Symplocaceae	*Symplocos carmencitae*	> 3000	EN	1
		2000 - 3000	EN	3
Symplocaceae Total				4
Theaceae	*Freziera rufescens*	2000 - 3000	VU	2
	Freziera tomentosa	2000 - 3000	NT	1
		900 - 2000	NT	1
Theaceae Total				4
Thymelaeaceae	*Daphnopsis grandis*	900 - 2000	EN	2
	Daphnopsis macrophylla	2000 - 3000	NT	3
	Daphnopsis occulta	900 - 2000	CR	1
	Daphnopsis zamorensis	900 - 2000	DD	1
Thymelaeaceae Total				7
Tropaeolaceae	*Tropaeolum asplundii*	2000 - 3000	VU	2
Tropaeolaceae Total				2
Urticaceae	*Pilea napoana*	2000 - 3000	VU	1
	Pilea schimpfii	300 - 900	VU	1
		900 - 2000	VU	1
	Pilea serratifolia	2000 - 3000	NT	1
Urticaceae Total				4
Valerianaceae	*Valeriana asterothrix*	> 3000	NT	1
Valerianaceae Total				1
Verbenaceae	*Aegiphila ferruginea*	> 3000	NT	4
		2000 - 3000	NT	3
	Aegiphila monticola	2000 - 3000	EN	2
	Aegiphila schimpffii	< 300	EN	2
		300 - 900	EN	3
		900 - 2000	EN	1
	Citharexylum rimbachii	2000 - 3000	VU	1
Verbenaceae Total				16
Viscaceae	*Dendrophthora sumacoi*	> 3000	VU	1
	Dendrophthora tenuifolia	2000 - 3000	VU	1
	Phoradendron canzacotoi	2000 - 3000	VU	1
Viscaceae Total				3

Zingiberaceae	*Renealmia dolichocalyx*	300 - 900	NT	1
		900 - 2000	NT	2
	Renealmia oligotricha	> 3000	VU	1
		900 - 2000	VU	2
	Renealmia sessilifolia	2000 - 3000	NT	1
		900 - 2000	NT	12
Zingiberaceae Total				19

CHAPTER 3

BAMBOO (GUADUA ANGUSTIFOLIA): ITS POTENTIAL FOR GREENHOUSE GAS REDUCTION, CONSERVATION AND SUSTAINABLE DEVELOPMENT IN THE ECUADORIAN CHOCO ANDEAN CORRIDOR

3.1 INTRODUCTION

The Chocó Andean corridor in northwestern Ecuador bridges two of the earth's most biodiverse and threatened regions, the Chocó and the Tropical Andes. Endangered by population growth spreading from the coastal and Andean population centers of Ecuador, this region is under intense land-use pressure. *Guadua angustifolia* Kunth (*Guadua* hereafter) is a tall, erect and large diameter woody bamboo plant that is an integral element of the natural rainforests of northwestern South America with possible natural populations in Central America (Humboldt et al. 1971, Judziewicz and Clark 1991). Stands of this native, non-invasive, clump-forming bamboo have historically been cleared to make room for banana plantations and pasture lands throughout western Ecuador. There, it was found over extensive areas (Judziewicz and Clark 1991, Parsons 1991, Young and Judd 1992), and today continues to be cleared in parallel with the advance of deforestation throughout northwestern Ecuador. This unique woody grass species, not only forms an ecosystem upon which many other organisms depend (Kosei 1979, Vélez 2003, Bystriakova et al. 2004, BirdLife-International 2007), but is also of material importance for locals who use it in construction, furniture and a myriad of other uses (Parsons 1991, FAO 2004), and of huge potential value for industrialization and the substitution of timber products (van der Lugt et al. 2006), and the production of fibers for clothing. Our field data shows that *Guadua* stores comparable amounts of carbon to hardwood tropical forests (Gornall 2001), and that *Guadua* stores more carbon than pastures in their root system and the soil (Tian et al. 2007), and therefore it could be used in reforestation projects for carbon sequestration.

Unfortunately, *Guadua* is one of the major victims of the massive deforestation of western Ecuador and wild stands may be on the road to endangerment in Ecuador. The current distribution of *Guadua* in Ecuador is not known and there is a widespread mistaken perception that the plant is abundant. People seem commonly unaware that the current apparent abundance is only a small fraction of what historical accounts say about the distribution of the plant. There is also lack of awareness among farmers about its management, thus stands are over-harvested and used without the appropriate technique to avoid fungal rot of the culms. Finally, a lack of economic and environmental policies regarding the exploitation of *Guadua* produces a bad combination of low prices and overexploitation (Cleuren and Henkemans 2003, Klop et al. 2003, FAO and INBAR 2006).

Creative alternatives to deforestation in the Chocó-Andean region are needed. Carbon-emissions trading could be part of one and is becoming an incentive for tropical forest protection and for the services they provide: biodiversity protection and carbon sequestration (Energy Information Administration 1998, Swingland 2003). To be a viable incentive for conservation however, carbon emissions trading needs to address at least three root causes of deforestation- the increasing demand for tropical timber, a poverty cycle where rural inhabitants make a living cutting trees due to a lack of economic alternatives to deforestation (Southgate 1997) and weak land tenure in poor communities. Here I present several arguments for why and under what conditions *Guadua* has good potential to be a creative and key element for integrating conservation and sustainable development in the Chocó Andean region of Ecuador. The arguments should also be valid for the Chocó Andean region of Colombia and other regions in Latin America where the plant is found or where it has been naturalized. *Guadua* forests harbor important levels of biodiversity. It is a native species and, unlike some introduced Chinese bamboo, it is not invasive. It is an important substitute for tropical timber with a harvest time 4 to 7 times shorter than hardwoods. Its carbon content per hectare is comparable to that of native hardwoods and contains higher soil carbon levels than pastures. Additionally Guadua supplies raw material for several industries. It could supply sustainable building material for the huge housing deficit in the developing world. Because small farmers can grow it with minimal investments, through a systematic plan for its production and industrialization, *Guadua* can become an instrument to fight poverty. Thus reforesting with *Guadua* may offer authentic win-win opportunities for conservation and sustainable development.

3.1.1 Chapter Structure

A summary of recent developments in international climate change policy in relation to forestry and land use activities, which are also relevant to bamboo promotion, is provided in the introductory chapter. I start this chapter with a literature review of the state of knowledge about *Guadua angustifolia*. Then, I elaborate the core part of the technical analysis framed by four questions:

1. Does Guadua contribute to the conservation of biodiversity?
2. What are the areas most suitable for Guadua?
3. Would *Guadua* land use sequester and store more Carbon than predominant pastureland use?
4. Would reforesting with *Guadua* sequester more Carbon than traditional Clean Development Mechanism (CDM) reforestation projects within the Kyoto Protocol?

3.2 BAMBOO, GUADUA, AND SUSTAINABLE DEVELOPMENT

3.2.1 Bamboo and Sustainable Development

Bamboos are forest grasses that have served humanity for millennia. There are thousands of documented uses for bamboo, from food to shelter, to religious uses, to crafts and furniture. Bamboo is deep-rooted in cultures and one of the oldest materials used for the construction of houses and other structures in countries like China, Japan, India, Indonesia, Ecuador, and Colombia, to name a few (McClure 1966, Parsons 1991, Bharadwaj et al. 2003, Cleuren and Henkemans 2003, Hunter 2003, Bystriakova et al. 2004). Bamboo can grow with minimal care and resources, and for that reason is the local resource of choice for poor people in many countries of the developing world. Because of its apparent infinite abundance it has received negligible industrialization effort and still has poor market value, earning bamboo the appellative of "poor man's timber" (Bystriakova et al. 2004). However, the production of bamboo has proven to benefit small farmers (Ruiz-Perez et al. 1999, El-Comercio 2002) and to generate significant employment. In India alone, bamboo generates jobs of close to 70 million workdays before primary processing and 120 million workdays for weaving structures in the production of silk (Adkoli 1998, 2002, Paudel and Loboikov 2003).

Bamboo can play a crucial role in providing a solution to the global shelter deficit and access to shelter is a pre-condition to sustainable development. While over one billion people world-wide already live in bamboo houses (De Flander 2005), there is another billion people who don't have access to safe and healthy shelter and the number is increasing dramatically with population growth (INBAR 2007). The vast shelter problem in the developing countries has resulted in the propagation of slums and squatter settlements. To improve housing conditions to acceptable levels some 95000 new urban housing units would have to be constructed each day in developing countries (INBAR 2007). Thus, the International Network on Bamboo and Rattan (INBAR) has initiated a global bamboo-housing program to provide homes to the millions of people who are either homeless or live in substandard houses.

The use of bamboo to reduce the use of cement and to substitute for the use of timber, would reduce the fossil fuel energy demand of construction, and would reduce the pressure on old growth tropical forests. As an alternative to tropical timber, bamboo has the potential to contribute more widely and thus relieve the pressure on tropical forests for housing, furniture, fuel, and paper pulp. In China, where there are over 2.6 million hectares and 5 billion green culms (canes) of *Phyllostachys pubescens* (*Moso bamboo*), the invention and production of plybamboo (plywood made of bamboo) has played an important role in poverty reduction in the rural economy of the south of China (Shenxue 1998). Although additional research is still needed to incorporate woody bamboos into mainstream construction, there is already sufficient progress to indicate that it is feasible. In fact, the preparation of an international building code with bamboo is underway (Janssen 2002). The use of structural bamboo poles in bamboo homes in Hawaii complies with the International Building Codes from the US NGO ICC Evaluation Service accredited by the American National Standards Institute (Bamboo_Technologies 2007), while in Europe the use of bamboo in construction is an area of active research (De Flander 2005, van der Lugt 2005).

Woody bamboo projects can meet all the eligibility criteria of the *Clean Development Mechanism* as described in Chapter 1. First, bamboo is a fast growing renewable resource that is ready for first harvest after 3 to 5 years depending on the species and locale. Mature culms can be harvested each year, while the younger culms remain in place with no need of re-planting (McClure 1966). In contrast, to use tropical timber from a plantation one has to wait at least twenty to twenty five years for the fastest growing species, after which the area is cleared. To illustrate this contrast, a study in Costa Rica indicated that a 70-hectare bamboo plantation would be sufficient to build 1000 bamboo houses per year. If these houses were built with timber, 600 hectares of natural forest would have to be destroyed each year (INBAR 2007). Second, little energy input other than hand labor is needed for the production of bamboo and building with bamboo is energy efficient, almost carbon neutral (van der Lugt et al. 2006). When viewed with respect to the load bearing capacity of the material, the ratio of energy for production to the unit stress under normal use is significantly lower for bamboo (30 MJ/m^3 per N/mm^2) than for other common building materials (Janssen 1981). In comparison, concrete, steel and timber require 240, 1500 and 80 MJ/m^3 per N/mm^2 respectively (Janssen 1981). Third, there is a large potential for economic development. Farmers can grow small plantations of just one hectare and get enough bamboo culms each year for many uses, including building a typical rural house. The capital returns per hectare can be higher and more sustainable for bamboo than for wood (Ruiz-Perez et al. 1999, El-Comercio 2002). Fourth**,** bamboo is a light and flexible construction material proven to withstand earthquakes better than some traditional more rigid construction material. The industrialized use of bamboo for construction and for biofuel is feasible (Dagilis and Turcke 1998, El-Bassam et al. 1998, Anwar et al. 2004, Becker et al. 2004, INBAR 2007) opening the possibilities for the participation of large numbers of bamboo producers to supply a large potential market. Finally, if used in durable constructions that can be certified to last at least three decades, modern technology that integrates geographic positioning system (GPS), bar code technology and database management, can trace and account for the fate of carbon, thereby meeting criteria of the Clean Development Mechanism.

A major problem of using bamboo in construction is that, just as timber, without preservation it may not withstand wood degrading organisms (Saenz Aponte 2002). However, substantial research work has been carried out in bamboo producing countries in Asian and Latin America and the service life of bamboo has been increased (Gutiérrez 1998, 2002, Liese et al. 2002, Bharadwaj et al. 2003, Bystriakova et al. 2004). The author has seen bamboo construction in the highlands of Calacalí in the Chocó Andean Corridor that has lasted over 100 years, indicating bamboo durability with adequate preservatives. In our work, we have used non-toxic borate solutions to preserve bamboo in the humid environment of the Corridor. For the several years that our preserved bamboo has been in use, we see little evidence of fungal rot. However, a longer time is needed to fully evaluate this preservative in the conditions of the Corridor.

3.2.2 Characterization of Guadua angustifolia Kunth

Guadua angustifolia Kunth, one of about 1,575 species of bamboo worldwide, belongs to the subfamily Bambusoideae, of which there are about 1,200 species (Ohrnberger 1999). *Guadua angustifolia* Kunth belongs to genus Guadua, family Gramineae (Poaceae), order Cyperales, class Liliopsida (monocot), and phylum Tracheophyta (flowering). There are more than 30 species of the genus Guadua in the Americas, most commonly in the lowland Amazon. Four species occur in Ecuador, but the other three lack the size and strength, and hence the utility of *Guadua angustifolia* (Judziewicz and Clark 1991, Parsons 1991). There are two subspecies belonging to the *Guadua angustifolia* complex, namely subspecies *angustifolia* Kunth and *chacoensis* (Young and Judd 1992, Judziewicz et al. 1999) distributed from southern Mexico to northern Argentina, but there are gaps in the distribution (Judziewicz and Clark 1991, Young and Judd 1992). *Guadua angustifolia* subspecies *angustifolia* is predominantly found in northwestern South America (Figure 3.1); its distribution in the Amazon is poorly known; and it's hypothesized that Guadua may have been extirpated from some areas in Central America as *Guadua* land was equated with good banana land, or dramatically reduced due to climatic changes (Young and Judd 1992). In Costa Rica *Guadua* is believed to have been introduced (Londoño 2002). In Ecuador there are two varieties of *Guadua angustifolia* Kunth, a thorny variety that is called "caña brava" and a thorn-less variety called “caña mansa” but both are still classified as *Guadua angustifolia* Kunth (Young and Judd 1992).

Propagation is mainly vegetative through the rhizome system because the discontinuities in flowering and seed production can take more than 35 years, but it is impossible to predict when flowering will occur (Young and Judd 1992). Seed dispersal vectors or distances have not been studied (Young and Judd 1992). When bamboos flower, they generally flower synchronously over large areas and die. There are several hypotheses to explain the complicated phenomenon of flowering in the bamboos. Predator satiation from the vast amounts of seeds produced at once, parasite avoidance, gap creation and energy portioning during the life cycle of the plants competing with trees have been proposed as hypotheses to explain the cyclical, synchronous, and monocarpic flowering behavior of bamboos (Clark 1996). Because large scale die-offs of *Guadua* would create significant economic hardships, it is important to understand what controls bamboo flowering and death. It may also be important to increase genetic diversity among stands and thereby perhaps maintain more stands following flowering events.

McClure (1996) identified two rhizome systems among bamboo species: pachymorph and leptomorph as shown in figure 3.2. *Guadua* has pachymorph rhizomes with a sympodial branching pattern that has a main rhizome, fine roots, and lateral buds. *Guadua* is an erect, robust, non-aggressive bamboo that occurs in small discrete clumps of 0.5 ha on average (Morales and Kleinn 2004) under natural conditions.

Guadua's optimal growth conditions are found between 500 and 1500 meters, at temperatures between 18 and 24 °C, in slightly acidic soils, with rainfall between 1500 mm and 2500 mm per year (Londoño 1998, Riaño et al. 2002, Morales and Kleinn 2004), but it adapts well to the extreme high rainfall conditions of Ecuador and Colombia's rainforests (Londoño 1998). In Honduras it is found near swamps and along rivers (Young and Judd 1992). It seems that in areas where rainfall is lower *Guadua* still does well in wet soils, and where rainfall is above the optimal, it does best on well drained soils (Young and Judd 1992, Londoño 1998). The diameter of *Guadua* varies according to soils and climate, although the exact relationship has not been established (Londoño 1998, Kirkby 2003, Kleinn and

Morales-Hidalgo 2006). Fine textured soils on steep sites seems to improve its physical and mechanical properties (Camargo 2006).

In a natural stand one finds culms at different stages of development, shoots, young, mature, old, and dead (Figure 3.3). In an ideal plantation the distribution should be 10% new shoots, 30% young culms, 60% mature and over mature culms and no dry or dead culms and with a density between 3000 and 8000 culms per hectare (Riaño et al. 2002). Since *Guadua* reproduces primarily through rhizome propagation, at least 66% of the plant biomass must remain intact in order for the plant to survive (Londoño 1998). Culms achieve maximum diameter very soon after sprouting, and reach their full height in 180 days (Londoño 1998). Only then do branches and leaves begin to develop and the culms start to shed the culm leaves that envelop the young culms (Londoño 1998). The maximum and mean diameter for culms varied in the different regions studied. In the Peruvian forest of Madre de Dios maximum and mean diameter was found to be 18.36 and 7.91 ± 0.11 cm, respectively, while in the coffee region of Colombia *Guadua* the average diameter is 10.8cm (Kirkby 2003, Morales and Kleinn 2004), in Ecuador at the Maquipucuna Reserve the average diameter at breast height is 10.54 ± 2.39 cm. *Guadua* does not have vascular cambium because it is a monocot, therefore the culms only grow longitudinally and unlike trees there is no radial accumulation of cells and thus the diameter changes little during the life of the culms, and only tapers towards the tips (Judziewicz et al. 1999). Therefore culm diameters are less associated with age than with culm density (Londoño 1998). The average length of mature *Guadua* culms at the Maquipucuna Reserve is 20.07 m ± 3.12 m.

3.2.3 Ecological relevance of Guadua

The first Europeans explorers of the western part of modern Colombia and Ecuador noted the amazing abundance and luxuriant growth of the giant, clump-forming "canes" and described for the first time, what is today known as *Guadua angustifolia* Kunth (Humboldt et al. 1971). *Guadua* stands, are likely to be important components of the pristine forests of the region. Yet, the relevance of *Guadua* for biodiversity has been poorly documented. A related species, *Guadua weberbaueri* in the Amazon provides important habitat for several bird species, some of which may be entirely restricted to these

Guadua stands (Parker et al. 1997 , Oppel et al. 2004). The now endangered Recurve-billed bushbird (*Clytoctantes alixii*) is dependent on *Guadua* and uses its specialized keel-shaped bill to split open bamboo shoots in search of insects (BirdLife-International 2007). Other ornithological accounts for *Guadua angustifolia* also indicate that is an important resource for birds in the Tropical Andes and Chocó (Vélez 2003, Cortes-Herrera et al. 2004). The forests in which *Guadua* stands are common also support a great diversity of invertebrates (Louton et al. 1996, Davidson et al. 2006), amphibians (Louton et al. 1996), and mammals (Olmos et al. 1993 , DeLuycker 1995). In particular, *Guadua* seems an important part of the diet for primates such as wild black-capped capuchin (*Cebus apella*) and black howler monkey (*Alouatta palliata*) (Kosei 1979, Estrada 1984, Damián 1990, DeLuycker 1995). It is plausible that the decrease in *Guadua* may be a factor in accelerating the decline of populations of these primates. Furthermore, it has been hypothesized that rapid growth of woody Guaduas could alter normal forest succession (Griscom and Ashton 2003), and thus may contribute to high levels of beta diversity. Some have even proposed that the original abundance of *Guadua* could contribute to high levels of endemism (Bystriakova et al. 2004), though the ecological mechanism is unclear.

Other ecological functions of *Guadua* are to help soil stabilization and reduce erosion on hill slopes and river banks (Bystriakova et al. 2004), and to influence soil moisture (Londoño 1998). In the Maquipucuna area, each single mature culm or cane of *Guadua* can hold from 6.76 to 22.07 liters of water (Ardani and Unda 2007). Thus with a conservative estimate of 1400 mature culms per hectare, one would expect *Guadua* to hold from 10,000 to 30,000 liters per hectare, water. The fate of this internal reservoir of water needs investigation.

3.2.4 The socio-economic relevance of Guadua

Guadua has particularly high social and economic importance for Ecuador and Colombia where there has been a long cultural tradition, from pre-Columbian times, of using this type of bamboo for construction, tools, fencing posts, baskets, and public works such bridges and gabions to dam rivers and streams (Parsons 1991). For example, the native cultures of the Magdalena River Valley in Colombia made extensive use of *Guadua* (Judziewicz and Clark 1991). Construction in the city of Guayaquil, the main port of Ecuador, made extensive use of Guadua until the beginning of the 20th century. The entire rural coastal region of Ecuador still relies on *Guadua* for housing. In recent years, the Ecuadorian banana industry, to meet European "greening" environmental standards, has increased the use of bamboo poles (Parsons 1991, Cleuren and Henkemans 2003, Klop et al. 2003, van der Lugt 2005). Figure 3.4 illustrates some of the traditional and modern uses of *Guadua*.

Unfortunately, the contemporary perception of *Guadua* in Ecuador is also that of the "poor man's timber" because cheap and poor quality rural bamboo houses are ubiquitous in the landscape of coastal Ecuador (Parsons 1991). That perception is reinforced by the fact that the largest single buyer of *Guadua* for construction is a non-profit organization based in Guayaquil that makes houses for the poorest of the poor out of wood and bamboo (Klop et al. 2003). Sadly, a very large number of Ecuadorians still don't realize that *Guadua* is a type of Bamboo, as "Bamboo" is regarded as the elegant and exotic plant from Asia (Parsons 1991). Largely because *Guadua* is poorly valued, major commercial plantations are using introduced bamboos from Asia such as *Bambusa vulgaris, B. tuldoides* (used for banana plantations), and *Phyllostachys aurea*(for use in producing crafts in the Amazon and the coast), *Phyllostachys pubescens,* and *Dendrocalamus asper* (Chinese giant bamboo) (FAO and INBAR 2006). Of these exotic bamboos, the genus Bambusa and Dendrocalamus have sympodial rhizome systems so they grow contained in clumps, while plants of the genus Phyllostachys have monopodial rhizome systems that run horizontally under the ground to form large groves and the plant can easily become invasive (Stapleton 1996).

Fortunately, the perception is slowly changing, and construction of high-end *Guadua* buildings has been growing in Ecuador during the last decade. Progressive architects and builders such as Velez and Villegas from Colombia have had an important influence on the use of bamboo for high-end construction. Notably, they designed and built the Colombian pavilion that passed stringent German building standards for the World Expo 2000 in Germany (von Vegesack and Kries 2000). In Ecuador, the high-end use of *Guadua* is mainly encountered in tourist eco-lodges such as in the Maquipucuna Reserve and others. Additionally, the growing demand for bamboo parquet flooring in the international market is further changing the perceived usefulness and importance of *Guadua* and large investors are seeing

Guadua through speculative eyes. The first steps in creating more awareness about *Guadua*, and training and fomenting revenue generating uses are already yielding results as a culture of sustainable management for Guadua is growing (El-Comercio 2002). The Ministry of Environment is now discussing measures to regulate the management of native and planted *Guadua* among other non-forest timber products of value for the country (Galindo 2007).

3.2.5 Resource assessment of Guadua angustifolia Kunth

The extent of *Guadua* in Ecuador is poorly documented. Parsons (1991) cites a USAID survey that reported 14,619 hectares of commercially accessible stands of *Guadua*, where more than half was in the provinces of Los Ríos and Guayas. Londoño in 2002 indicates that the entire extent of *Guadua* is 20,000 hectares, while another national statistic indicates that in 1997 the total area was 25,000 hectares and that it may have dropped by half by the year 2000. Yet other reports say that in 1985 there were 15,000 hectares and the area was down to 6000 – 9000 hectares by 1999 (Londoño 2002, Cleuren and Henkemans 2003, Klop et al. 2003). Finally, van der Lugt (2005) estimated the wild remaining area as 8,000 hectares plus 4,000 hectares in plantations. The extent of the distribution of *Guadua* has been better assessed in Colombia (Morales and Kleinn 2004, Kleinn and Morales-Hidalgo 2006). In Colombia, which is a country several times larger than Ecuador and where policies to protect *Guadua* are much more advanced than in Ecuador, *Guadua* covers about 51,500 hectares, of which an estimated 46,000 hectares are natural stands and 5300 hectares are plantations (Camargo 2006).

The information about demand for *Guadua* in Ecuador is also scarce and even erratic for more recent years. Parsons in 1991, after exhaustive research in Ecuador and Colombia estimated that there was an annual demand for 2 million canes in Ecuador. After that, different reports have inconsistent information, but the demand for *Guadua* is expected to have increased, as population has increased and rural people in coastal towns still build with *Guadua*. Additionally, the demand for *Guadua* is increasing for poles for the banana plantations at a fast rate, although the quantitative demand is unclear. Banana plantations only use the top part of the guadua, called "*cuje.*" The flourishing cut flower industry also use cut *Guadua* as wind breaks. The demand export market of bamboo for construction in Peru continues to grow, with an annual official export value of about 1 million dollars – estimated from 1 million canes, but the informal trade is thought to surpass the official numbers (INBAR 2001). Thus, the projected demand only for banana plantations is for 75 million *cujes (Cleuren and Henkemans 2003)* which would be equivalent to almost 58000 hectares of *Guadua* in full production, and area at least 5 times larger than the area of *Guadua* estimated to remain in natural condition.

We can only roughly estimate the impact of the exploitation of *Guadua* from the scarce information about the demand for *Guadua* in Ecuador. *Guadua* used in rural housing without any wood preservation deteriorates in four or so years, putting heavy pressure on the resource, owing to increased demands for frequent replacements (FAO 2004). This adversely affects the supplies of *Guadua*, even in *Guadua*-rich regions. Parsons' (1991) estimated demand of 2 million culms per year would require 1538 hectares at a sustainable harvest rate of 1300 culms per hectare per year (Londoño 1998). Alternatively, 615 hectares of Guadua could have disappeared yearly if the harvest method used was clear cutting; while only 3000 to 4000 hectares are known to have been planted in the last 5 years, of which 1000 hectares entered in production in 2005 (Klop et al. 2003, van der Lugt 2005).

3.2.6 Production and Carbon stocks in Guadua

The growth and productivity of Guadua has been studied and various relationships between stand site variables and culm density, growth, and quality have been determined (Camargo 2006). In Colombia, plant growth and biomass distribution of Guadua in relation to ageing has also been evaluated (Riaño et al. 2002).

Guadua has a harvesting cycle of four to five years (Parsons 1991, Cleuren and Henkemans 2003). Approximately 1300 culms per hectare per year would be the yield from well managed Guadua, because higher intensity of harvest per hectare can hamper culm diameter as well as culm density (Londoño 1998). A popular belief is that no more than 25% of the mature culms should be cut yearly. A study to find optimal cutting intensity found that between 20 and 40% mature culms harvested annually per stand yielded best results, depending on site conditions (Llivicota and Villamarin 2002). In Colombia, up to 50% of mature culms have been harvested annually, but continued harvest at such high intensity reduced stand productivity and culm diameter significantly (Londoño 1998, Morales and Kleinn 2004). If clear cut, *Guadua* stands die. Harvesting intensity of *Guadua* is also poorly documented in Ecuador. Coupled with increasing demand, poor harvest practices seem to be resulting in degradation (Cardenas and Marlin 2003, Cleuren and Henkemans 2003, Klop et al. 2003).

Above and belowground carbon stocks have been assessed for *Guadua* by destructive sampling, and C and N analysis of *Guadua* culms and the respective branches, leaves, rhizome system, and soils have been investigated in the Maquipucuna area. Significant variation was found in the proportion of carbon in dry mass in the different parts of the plant, where rhizome>culm>branch>leaf>fine roots. Total carbon sequestered was greatest in the culm (70% of total carbon sequestered). An equation has been developed that predicts the carbon sequestered in the culm and the carbon sequestered in the total above ground biomass using circumference at breast height (CBH) of *Guadua* (Gornall 2001). Productivity studies initiated at the Maquipucuna Reserve area show that *Guadua's* average daily growth rate is 6.5 cm, depending on its stage of growth and rainfall, and daily growth recorded ranges between 1 and 17cm. Further studies underway are aimed at relating growth patterns to carbon sequestration and development stage.

3.2.7 Soil C stocks under Guadua and pastures

Pasture maintains high soil carbon levels (Guo and Gifford 2002); however we have found that *Guadua* may be a better option in contributing to global C sequestration through increased soil carbon storage. A study was conducted in the Maquipucuna area, in natural *Guadua* stands with densities that ranged from 0.15 to 0.3 canes per meter square, in order to test a hypothesis that *Guadua* has greater soil carbon levels than pasture ecosystems. The entire comparative analysis is described in a separate publication (Tian et al. 2007). The soil C stock in "equivalent 0 - 30" cm depth was greater under bamboo (60.8 - 123 Mg ha^{-1}) than under pasture (33.4 - 75.3 Mg ha^{-1}). The carbon stock of standing Guadua biomass (51.8-95.6 Mg ha^{-1}) was much higher than the standing biomass of pasture (3.53-8.14 Mg ha^{-1}). Higher soil N stock and lower C/N ratios were observed under bamboo than pasture. From these results, it is likely that significantly more C would be stored in terrestrial ecosystems by reforesting pastures with *Guadua*.

3.2.8 Modeling habitat suitability of Guadua

A maximum entropy modeling software, Maxent (Phillips et al. 2006), is used here for modeling *Guadua* distribution (versions 2.3 and beta 3.0), and thus finding the optimal areas for carbon sequestration projects with *Guadua*. This approach may have other applications within the Corridor, for example in finding the optimal site conditions for augmenting wild orchid populations, or in identifying areas of distribution of endangered species. The conceptual underpinning of Maxent is the second law of thermodynamics, which says that in the absence of outside influences, processes tend to maximum entropy. It calculates a probability distribution of maximum entropy (i.e., that is most spread out, or closest to uniform) across the study area. The distribution is constrained by matching the values of the environmental variables or a function of them, also called features to their empirical average—the average value, or a function thereof, of the variables at the pixels with known species occurrence records or sample points (Phillips et al. 2006). The environmental variables used to predict *Guadua* occurrence can be climatic variables, elevation, soil category, vegetation type or other environmental variables (Phillips et al. 2006). Maxent is one of the various methods of element distribution modeling (EDM), which originates from the classic ecological principle that biotic and abiotic factors restrict the distribution of every species in space and time, influencing their biogeographic and evolutionary histories (Dunning et al. 1992). EDM is also known as predictive distribution modeling, predictive range mapping, species distribution mapping, habitat distribution mapping, ecological niche modeling, and various other similar names (Beauvais et al. 2006). All the biophysical conditions that a species requires for its long-term survival constitute its fundamental niche, while its realized niche is that subset of the fundamental niche that it actually occupies (Hutchinson 1957). Thus, because EDM models are based on environmental attributes of records collected where the species was actually found, and because we do not know what the entire distribution of the species is, EDM is said to approximate the realized, rather than fundamental, niche of a target species (Phillips et al. 2006). Although EDM models species occurrence in ecological space, in practice what is evaluated is a projection of the species' requirements into geographic space.

3.3 MATERIALS AND METHODS

3.3.1 The study area: The Chocó Andean Corridor

The study area for the proposed project is the Chocó Andean Corridor, which is located in Northwest Ecuador, extending over parts of the Provinces of Pichincha, Imbabura, and Esmeraldas is shown in figure 3.5. The Chocó Andean Corridor spans an altitudinal gradient from sea level to Paramo at ca. 4950 meters. Natural forests are still the most common vegetation cover of the region, but agricultural uses, predominantly pastures, oil palm, heart of palm, and banana plantations, are common. The establishment of shade grown coffee and rustic cacao, which are common companion crops of *Guadua,* is emerging as an effort to create surrogate forests over degraded pastures to aid in the reconnection of the fragmented landscape (Justicia 2006). Mean annual precipitation ranges from 460 to 5038 mm. There is a rainy season from September to May, and December is normally a dry month. The mean annual temperature ranges from 1°C in the highlands to 26 °C in areas by the coast.

3.3.2 The focal area: The Maquipucuna Reserve

A plant diversity assessment, evaluation of carbon stocks of *Guadua*, evaluation of *Guadua* diameter classes, and the comparative study of soil and plant carbon levels in natural *Guadua* stands and pastures were conducted at the Maquipucuna Reserve, which is located in the Parroquia Nanegal, at the southeastern extreme of the Chocó Andean Corridor (78° 37'W, 00° 05'N). The Maquipucuna Reserve is owned and managed by the Maquipucuna Foundation and consists of 5456 hectares, ranging in elevation between 962 and 2873 meters, of which over 90% is old growth forest, whereas the rest is a mixture of secondary forest, pasture, sugar cane, and shade-grown coffee. Vegetation types in the Reserve include Western Andes montane cloud forests and Western Andes lower montane evergreen forests (Sierra 1999). Biodiversity is very high at the Maquipucuna Reserve where close to 2000 plant species, 45 species of mammals, over 220 butterfly species, and 367 species of birds have been recorded (Maquipucuna 1995, Raguso and Gloster 1995, Webster and Rhode 2001, Leon 2006). Soils in the region are mainly Andosols (listed as Inceptisols-Andepts before Andosols became a soil order) and Entisols (USDA Taxonomy) derived from volcanic ash (MAG-IICA-CLIRSEN 2002). The surface soil and upper sub-soil were derived from Holocene volcanic eruption over buried palaeosols, and the last ash deposits from which modern soils have developed are generally homogenous (Rhoades 1997). Our study sites were located between 1000 and 1500 meters of elevation within the region where Guadua grows well, receiving approximately 2000 mm of rain per year.

3.3.3 Plant Diversity in natural Guadua stands and diameter classes

A rapid assessment of plant diversity in natural *Guadua* stands was produced by establishing 5 (50 m x 1 m) transects at the Maquipucuna Reserve between 1200 meters and 1500 meters and recording every plant with diameter at breast height 2.5cm and larger. Because of the patchy nature of *Guadua,* transects were set up in different stands but the result is presented as an average for one 250 m x 1 m transect to ease comparison with the plant diversity estimates for the forests in the area.

Camargo (2006) obtained a Weibull distribution for diameter classes in *Guadua* plantations in Colombia. For this study, the diameter at breast height (at about 1.3 m above the ground) was measured for 513 mature Guaduas culms in 7 different stands in the localities of Orongo, Palmitopamba, Chacapata, and the Maquipucuna Reserve proper in the northern end of the Maquipucuna Reserve. The size of the stands varies and thus the number of mature Guaduas per stand. I use the Maquipucuna diameter distributions for the carbon calculations of managing natural *Guadua* stands, and a Weibull distribution for average density for calculating carbon benefits of *Guadua* plantations.

3.3.4 Actual extent of Guadua in the Chocó Andean Corridor

The estimation of the total area of *Guadua* is a challenge because *Guadua* is interspersed within the forest and it is often in small patches, and a great part of the study area is either steep terrain or has cloud cover most of the year. We used several geographic information system (GIS) based approaches to assess the current coverage of *Guadua*; habitat suitability or potential distribution of *Guadua* along the Chocó Andean Corridor; and the areas under pastures that have a range of suitable ecological conditions for *Guadua*.

First, we developed a land use map for the Chocó Andean Corridor at the scale 1:50,000 for the year 2002, using the software IDRISI, of a mosaic of LANDSAT 7 satellite images (p10r59 February 2000, p11r59 January 2000, p11r60 April 2002 and p10r60 November 2001). Supervised classifications were aided by ground-truthing.

Inadequate identification of *Guadua* from landsat images and limited time ground truth of all the other land uses, confirmed the limitation of using middle resolution Landsat images (Morales and Kleinn 2004). Thus, in 2006 we made additional field visits targeted at obtaining a large number of georeferenced polygons representing *Guadua* stands to determine the spectral footprint of *Guadua*. For the 2006 field season, governmental and non-governmental institutions that work in conservation projects and that have interest and knowledge about *Guadua* were contacted, informed about the project, and provided key collaboration for surveying the area. The organizations supplied information concerning *Guadua* management, contact with local guides, accommodations, and even logistic support within their areas of influence. *Guadua* was mapped in the San Lorenzo and Muisne areas in the province of Esmeraldas with the support of *Altropico*, *Sirua* and *APROCANE,* Fundación *Cabo San Francisco,* and *Jatun Sacha*. In the Pichincha and Imbabura provinces, *Guadua* was mapped with the support of: *FURARE, Ecuabambú, Consejo Provincial de Pichincha, Fundación de Turismo Ecológico Comunitario"Juventud Sembrando Vida," Corporación Utopía*, and the staff of *Reserva Maquipucuna*. Two methods of Geographic Positioning System (GPS) data collection and observation were utilized in the field: 1) direct GPS data collection at each stand and 2) taking reference GPS points from the primary roads and estimating the size of the stand. Using these techniques, over 1700 stands were georeferenced in 50 days of field work (Hagamen and Unda 2006). In the near future a new grant will allow us to use high resolution images of <1m (Justicia 2006)

Direct GPS points: Representative and accessible stands were mapped on foot, with GPS points taken around the border of each stand to determine the geographic position and area of the stand.

GPS reference points from roads: The roads in each sector that met the following conditions were identified: within the area of the Chocó-Andean Corridor, between the altitudes of 0-1600 meters above sea level and parallel or near to rivers or streams. The roads were traveled by vehicle, and reference GPS points were taken from the road in a direct line with the existing *Guadua* stands. Distance between the stand and the GPS point were approximated, as was the area.

3.3.5 Maxent modeling for habitat suitability of Guadua in the Chocó Andean Corridor

Environmental variables

All the environmental variables examined, potentially represent physiological and physical limits for Guadua. Stand occurrence points were associated with the local environmental values in ArcGIS 9.2 and transformed into Excel CSV files while variables were exported in ASCII format to the statistical software Maxent to run the models. Thirty-six environmental variables of climate, topography, soil characteristics, and distance to streams were initially explored (Table 3.1). All variables were recorded at a pixel size of 30m, yielding a 9106 x 7547 grid. The nineteen climatic variables listed were obtained from the WorldClim data base (Hijmans et al. 2005a) at 1km resolution and were re-sampled to 30m. Even though resolution does not increase by re-sampling to smaller cell size, it is more appropriate for the analysis to take advantage of the higher resolution of the elevation model. Elevation, slope, and aspect were used as topographic variables derived from a 30m digital elevation model (DEM) compiled and constructed by IRD/MS with Savane GIS (Souris 2007). Thirteen soil variables generated by the national project "Generación de Información Georeferenciada para el Desarrollo Sustentable del Sector Agropecuario" in Ecuador were also used (MAG-IICA-CLIRSEN 2002). Some soil layers had been generated at 1:50,000, while the rest was at 1:250,000. Distance to streams was derived from a 1:250,000 layer generated by Centro de Levatamiento Integrado de Recursos Naturales por Sensores Remotos (CLIRSEN) for Ecuador and available in the year 2000.

General Maxent parameters

There are several parameters that can be adjusted when modeling with Maxent. Thus, a summary description of how maximum entropy algorithms are applied to species distribution, taken from Phillips (2006), will help in understanding the influence of the different parameters on the final probability distributions, and the choices made in our modeling.

A suitable set of features or environmental variables represent our incomplete knowledge and our ecological assumptions about the limits and constraints to the geographic distribution of the species. Thus, Maxent aims at estimating a probability distribution $\pi(x)$ of maximum entropy (the most spread out spatial distribution of a species) subject to constraints such as the values of the variables at the points of known observations of the species (Phillips et al. 2006). The values of $\pi(x)$ range from 0 to 1 and sum to 1. In modeling species probability distributions, our study area is the space X, and the occurrence points would be sample points $x_1, \ldots, x_m$, where each x has a non-negative probability $\pi(x)$. Maxent does not work directly with the values of the environmental variables, but the variables are transformed into feature vectors, and so the features may take the value of the mean of variables, their square, product with other variables, thresholds, or binarizations of categorical variables. The "features" are assumed to have real value functions $f_1, \ldots, fn$ for each x in X. The probability of the feature f_j under π is defined and denoted by $\pi(f_j) = \sum_{x \in X} \pi(x) f_j(x)$. By the maximum entropy principle, the probability distribution of $\hat{\pi}(f_j)$ can be approximated by the average probability distribution (observed empirically from our data points) of the values of the features (or their functions) at each occurrence point (x) and denoted as $\tilde{\pi}$ (f_j). Assuming an ideal randomized selection of sample points x with associated f_j values, $\tilde{\pi}$ (f_j) would be the empirical average of fj or $\frac{1}{m}\sum_{i=1}^{m} f_j(x_i)$. Thus, $\hat{\pi}(f_j)$ would be equal to $\tilde{\pi}$ (f_j) for each f_j. However, because sampling is non-uniform, the true probability $\hat{\pi}(f_j)$ does not always equal the sample probability function $\tilde{\pi}$ (f_j). So Phillips et.al. (2006) present an alternate characterization for the empirical average as a Gibbs distribution $q_\lambda(x) = \frac{e^{\lambda . f(x)}}{Z_\lambda}$ or $P(x) = \exp(\lambda_1 * f_1(x) + \lambda_2 * f_2(x) + \lambda_3 * f_3(x) \ldots) / Z$ where $\boldsymbol{f}$ are the feature vectors and $\boldsymbol{\lambda}$ are the feature weights, and Z_λ is a normalizing constant that ensures that q_λ sums to 1. In each modeling run, the program starts with a uniform distribution or probability of zero, and iteration after iteration increases the probability of the sample locations for the species. The probability is displayed in terms of "gain," which is the log of the number of grid cells minus the log loss (average of the negative log probabilities of the sample locations). The gain increases until the gain from iteration to the next falls below the *convergence threshold*, or until *maximum iterations* have been executed. Because $\hat{\pi}(f_j)$ almost never equals $\tilde{\pi}$ (f_j), Maxent facilitates the relaxation of the constraints through enabling the modification of a regularization parameter, β_j and the convergence threshold (Dudík et al. 2004). Thus, a probability distribution model maximizes the entropy of the species (Guadua) distribution subject to relaxed constraints so that feature averages over sample locations are expected to be close to the actual values rather than exactly equal to them, and the values in the probability distributions are interpreted as a relative index of environmental suitability, where higher values represent a prediction of better site conditions for the species. In summary, the larger the number of variables and sample points, the larger the number of constraints (or features) that will get generated by the combination of variables on points, thus the distribution will be more localized within the area of sampling, i.e. over fitting. Ecologically, this would be interpreted as an overly conservative estimate of the highest quality sites for Guadua.

Because the probabilities over the entire area add to one, the individual values of the probabilities of f_j are very small. To get around that, I present model predictions as cumulative probabilities, where the value of a given grid cell is the sum of that cell and all other cells with equal or lower probability, multiplied by 100 to give a percentage (Phillips et al., 2006).

There are other parameters set by default or with suggested values defined empirically by the Maxent authors (Phillips et al. 2006) such as the value of weights that are defined intrinsically by the software. This study explored the different feature types, as well as the auto feature function that employs default rules dependent on the number of presence records determined empirically as in Phillips et al (2006). As sample size increases, the program tightens the constraints. The maximum number of iterations used was 1000.

Model building

Each *Guadua* stand point was associated with the respective environmental variables (creating sample with data files, SWD), so that the program would not have to search for background values in the entire 30m raster grids. This was necessary because a computational limit was encountered when using all the variables. Maxent is programmed with Java, and Windows XP only makes 1.3 GB of RAM memory available to Java, so the large grids with 30m pixels demanded more memory than was available.

A set of 435 random points was selected from the1741 GPS points in order to minimize the possibility of spatial autocorrelation. First, a file of 5000 random background points was generated and then all points that were within 750m of any background point were selected.

The models were parameterized as follows: 40% of points set aside for testing, regularization multiplier was 1, maximum number of iterations of 1000, convergence threshold of 10^{-5}, and feature type was set to auto-feature, which for the large sample size means the program by default uses linear, quadratic, product, threshold and hinge features (Phillips et al. 2006).

Two types of tests were used to evaluate if the distributions modeled perform significantly better than random, but also to aid in the selection of the best models. The first was a binomial test that requires a threshold (a cut off point that delimits suitable from unsuitable areas for the species) in order to evaluate omission (false negatives) and commission errors (false positives.) The true positive rate, also known as *sensitivity*, represents absence of omission error. While *specificity,* the fraction of all negatives that are correctly classified negative, is the absence of commission error. High sensitivity is a necessary condition for a good model, (but according to Phillips in Maxent it is important to correctly predict a large proportional area to model the species' potential distribution adequately, therefore a measure of fractional area is used instead of the value of commission error (Phillips et al. 2006). Omission rates, fractional values predicted, and the corresponding p-values were tabulated and compared for all models at three cumulative threshold levels. There is no standard way to determine thresholds for Maxent models; however, there are some guidelines to choose appropriate thresholds, and they depend on factors such as:

the predicted values assigned to the training localities, the number of training localities and the context in which the prediction is to be used (Phillips et al. 2006).

A second approach to evaluation is threshold independent. It compares model performance using receiver operating characteristic (ROC) curves, which are graphical plots of the sensitivity vs. (1 - specificity). In Maxent, ROC curves evaluate performance at all possible thresholds by a single number, the area under the curve (AUC) (Phillips et al. 2006). ROC analysis aids in the selection of optimal models and is used to discard suboptimal ones. The best possible predictive model would yield a point in the upper left corner or coordinate (0,1) of the ROC space, representing 100% sensitivity (all true positives or hits are found) and 100% specificity (no false positives or false alarm are found). A (0,1) point would yield an AUC of 1 and would equate to perfect classification, on other hand a completely random guess would give points along a diagonal line from the left bottom to the top right corners or an AUC of 0.5. Figures 3.7 through 3.12 include the ROC (Sensitivity vs. Specificity for the different models of *Guadua*). AUCs for model 1 are the closest to one, yet the distribution does not cover areas empirically known to be good for *Guadua*.

3.3.6 Optimal areas for reforestation

Various factors, abiotic and biotic (intrinsic and extrinsic), influence the productivity of *Guadua.* Maxent statistical models help us identify the areas with the most suitable abiotic conditions. One of the characteristics of Maxent is that by using a large number of environmental variables and a large number of sample points, Maxent tends to constrain the distribution to the area where the sample points were collected, and has less applicability to areas not sampled. In addition to modifying the features or modifying parameters as explained above, there are various other ways to relax the constraints set by Maxent such as reducing the number of variables, reducing the number of sample points, or increasing the spread of the sample points. Several of these options were evaluated as described below.

After running 30 or so models with a combination of environmental variables and parameters as described in the methodology, the resulting distributions were variably constrained to the areas sampled. Thus, some areas empirically known to be suitable for *Guadua* were shown as not suitable. One main reason why this happens is because *Guadua* points were only collected where natural stands remain and not in areas where Guadua is known to occur but that have been transformed into other land uses. In order to solve the problem of sub-representation of *Guadua* points in areas where the forest has been cleared, and because *Guadua* land historically has been equated with "good banana land" (Young and Judd 1992), I extracted the banana areas from the land use map, transformed them into points, attributed each point with the environmental variables, and used the additional points as proxies for additional *Guadua* data points. In addition, because there is consensus in the literature as to what are the most favored environmental conditions by Guadua, I tried relaxing the constraints by reducing the number of environmental variables to only the ones indicated as relevant in the literature. A third type of model was run with the literature variables plus the variables with the most predictive power as indicated by the run with all the variables. Of the various models explored, as expected, the model that used all 36 variables and 435 random points was the model that constrained the distribution just to the sampling regions. The models produced with all the variables and the banana points, as well as the models produced with the smaller set of environmental variables, spread the distribution of suitable areas to regions not sampled but which empirically are known to be good *Guadua* areas. Of the latter models, I chose model 3 (all the variables, Guadua and banana points) for the next step of calculating potential carbon production (Figure 3.9). It is a conservative choice, because the model spread the distribution slightly to areas not sampled but known to have *Guadua*, but is constrained by a large set of variables that have the same effect on both the Guadua point data set as well as on the Guadua-banana point data set (Figure 3.13).

The map produced in model 3 was classified into three different cumulative probability levels (suitability or threshold values): not suitable (3), suitable (2), and most suitable (1). I use the minimum training presence or minimum predicted value assigned to any of the training localities as the minimum suitable value, i.e. smaller values than the minimum predicted value belong to class 3. Class 2 is for values between the minimum predicted value and the point at which there is omission of 10 percentile training presence. The most optimal areas were those that fall between the 10 percentile training presence and a 100 cumulative threshold. Class 2 and 1 are suitable for *Guadua*, but as we increase the threshold, we are supposed to find environmental conditions that most tightly reflect the features at the sample points. Therefore, the predicted area decreases sharply in the upper class.

The suitability map of *Guadua* was intersected with the 2000 land use map of the region using ARCGIS 9.2, in order to match the different land uses with their suitability classes for *Guadua*. Finally, a county map (Fundacion-Maquipucuna 2002) is overlaid on the resulting map of optimal areas for reforestation in order to identify the communities and institutions that would potentially partner in a Guadua carbon credits project and thereby aid in the connectivity of the Chocó Andean Corridor with "Guadua forest." Figure 3.6 shows a model of how the optimal areas were obtained.

3.3.7 The potentional for additional carbon stored through Guadua reforestation and conservation of Guadua stands through management in CO_2 equivalent (CO2e) over 30 years

The calculation of the carbon "additionality" estimates the CO_2 sequestration potential of a Guadua reforestation project versus a pasture baseline scenario, and the increased CO_2 sequestration potential of managed natural Guadua stands versus the baseline scenario of clear cutting. Carbon dioxide equivalent or, CO_2e, is a metric measure obtained by multiplying the metric tons of a greenhouse gas by its associated global warming potential (GWP). It is a measure used to compare the impact of emissions from the various greenhouse gases. CO_2 is the reference gas, therefore its GWP is 1, and therefore 1 metric ton of CO_2 is also 1 metric ton of CO_2e (IPCC 2005). In traditional methodologies for reforestation currently approved in the Clean Development Mechanism (CDM) there are still uncertainties that prevent a precise estimate of the carbon stocks of baselines (Brown et al. 2002, Brown 2003). Therefore, carbon benefits of reforestation projects, even with approved methodologies by the CDM Board are only best estimates. To reduce uncertainty, these projects tend to be very conservative, for example, by ignoring the soil carbon changes resulting from reforestation projects or limiting the species mix to species that have known specific density and growth rates or the planting of nitrogen-fixing species (UNFCCC 2007b).

We have made significant progress in the knowledge of carbon stocks in *Guadua* systems that enable us to significantly improve the estimates of the carbon additionality of reforesting pastures with

Guadua in the Chocó Andean Corridor (Gornall 2001, Tian et al. 2007). Reforestation of pasture with *Guadua* and management of natural *Guadua* are the GHG sinks evaluated here in terms of tCO2e. Because there are also gaps in the knowledge of precisely how much and how often we can harvest Guadua in order to maximize culm harvest in terms of carbon, I make highly conservative estimates, as described in the next paragraphs, when I estimate actual net Green House Gas (GHG) removal by *Guadua*.

In order not to overestimate the carbon benefits of Guadua, I only use the volumetric estimates and regressions for mature culms with diameter at breast height of 8 cm and above obtained from the Maquipucuna area. That is, only the C of approximately 52% of the culms is accounted for in order to estimate carbon additionality. The proportion of C found in *Guadua* is as follows: culm (72%), upper branches (10%), lower branches (3%), leaves (7%), and rhizomes (8%). Following are the equations that relate the circumference at breast height (CBH) of the culm (stem) and the amount of C sequestered in the above ground biomass (Gornall 2001).

a) Culm C (kg) = -25.2 + 1.32 CBH

b) Aboveground C (kg) = - 32.2 +1.68 CBH

c) Rhizome C (kg) = - 2.8 + 0.15 CBH

The intrinsic factors of *Guadua* which influence its carbon productivity are density, age distribution, harvest intensity, and diameter distribution (Camargo 2006). Table 3.2 lists the frequencies of diameter classes used for natural and for planted stands. The available published information of long term studies of *Guadua* plantations in the coffee region of Colombia provide information about the impact of harvest intensities and other stand variables on *Guadua* productivity (Londoño 1998, Riaño et al. 2002, Camargo 2006). From that information, very conservatively, I chose to use the lowest recommended ratio of culms harvested per year per hectare to standing culms per hectare (1000/5300) to drive a simplified carbon harvesting and accumulation model for *Guadua* in plantations over a 30-year period. The recommendations for harvesting 25% of the mature culms and maintaining a permanent standing biomass of 60% (Londoño 1998) are used to calculate the carbon accrued when managing natural stands because the recommended planted densities would not apply to the natural stands without cutting down the standing trees.

Finally, the rapid growth of *Guadua* has an energy cost (carbon loss through respiration) which we still do not know. We also do not have information about death rates, litter production, or the carbon content of shoots of very young *Guadua*. It is a conservative assumption to say that that this is also compensated by only counting the carbon of the mature canes of 8cm DBH or larger. Traditional reforestation methodologies do not take into account the respiration cost of growing forest plantations, and only discounts litter and deadwood (UNFCCC 2007a).

Estimating baseline net greenhouse gas (GHG) removals by sinks

The project involves replacing pasture with Guadua and managing natural Guadua stands. Baseline net GHG removals by sinks will be determined by the equation:

$$B_{(t)} = \sum_{i}^{I} (B_{A(t)_i} + B_{B(t)_i} + B_{S(t)_i}) * A_i$$

where:

I = 2, number of strata to consider

i = 1 pastures

i = 2 natural *Guadua* stands

$B_{(t)}$ = carbon stocks in the living biomass pools and soil within the project boundary at time t in the absence of the project activity (tC)

$B_{A(t)\,1}$ = carbon stocks in above-ground biomass of pastures (tC/ha)

$B_{A(t)\,2}$ = carbon stocks in above-ground biomass of natural *Guadua* stands (tC/ha).

$B_{B(t)1}$ = carbon stocks in below-ground biomass of pastures (t C/ha)

$B_{B(t)2}$ = carbon stocks in below-ground biomass of natural *Guadua* stands (t C/ha)

$B_{S(t)\,1}$ = carbon stocks in soil down to 30cm in pastures (tC/ha)

$B_{S(t)\,2}$ = carbon stocks in soil down to 30cm in natural *Guadua* stands (tC/ha)

A_1 = area of pastures to transform to *Guadua* 29854 (ha), which corresponds to pastures with suitability index 1.

A_2 = Area of accessible verified natural *Guadua* stands 4398 (ha)

Actual net greenhouse gas removals by sinks

Actual net GHG removals by sinks are the net changes in carbon pools for the project scenario, which is reforesting pastures with *Guadua*, and conserving natural *Guadua* stands by management. The stocks of carbon for the project scenario at the starting date of the project activity (t=0) shall be the same as the baseline stocks of carbon at the starting date of the project (t=0). Therefore:

$$N_{(t=0)} = B_{(t=0)}$$

For all other years, the carbon stocks within the project boundary at time t ($N_{(t)}$) have been calculated as follows:

$$N_{(t)} = \sum_{i}^{I} (N_{A(t)_i} + N_{B(t)_i} + N_{S(t)_i}) * A_i$$

where:

$N_{(t)}$ = total carbon stocks in biomass at time t under the project scenario (t C/ha)

$N_{A(t)\,i}$ = carbon stocks in above-ground biomass at time t of stratum i under the project scenario (t C/ha)

$N_{B(t)\,i}$ = carbon stocks in below-ground biomass at time t of stratum i under the project scenario (t C/ha)

A_i = project activity area of stratum i (ha)

i = stratum i (I = total number of strata)

Applied to the Guadua project scenarios, the calculations done are as follows:

$$N_{(t)} = \sum_{i}^{I} (N_{A(t)_i} + N_{B(t)_i} + N_{H(t)_i} + N_{S(t)_i}) * A_i$$

where:

$N_{(t)}$ = total carbon stocks in biomass, harvested Guadua, and soil at time t under the project scenario (tC/ha)

$N_{A(t)\,i}$= carbon stocks in above-ground biomass at year t (t C/ha)

$N_{B(t)\,i}$ = carbon stocks in below-ground biomass at year t (t C/ha)

$N_{H(t)\,i}$ = carbon harvested during 24 years in planted Guadua, and 28 years in natural Guadua (t C/ha)

$N_{S(t)\,i}$ = carbon stocks in soil in year t (t C/ha)

A_1 = project activity area for reforestation with Guadua 29854 (ha);

A_2 = project activity area for conservation of Guadua through management 4398 (ha)

The calculations shown below were performed for each stratum:

$N_{A(t)1}$, the carbon stocks in above-ground biomass in planted Guadua (tC/ha) is:

$$\sum_{DBH\geq 8}^{19} 0.6 * TC * (-32.2 + 1.68 * DBH * \pi) * freq_{DBH} / 1000$$

The calculations of $N_{A(t)2}$, $N_{B(t)\,2}$ and $N_{S(t)\,2}$, are detailed in Tian et al. 2007.

$N_{S(t)\,1}$ (soil C under a planted stand) is assumed to have the same value as $N_{S(t)\,2}$ (soil C under a natural stand).

$N_{B(t)\,i}$, the carbon stocks in below-ground biomass in planted Guadua (t C/ha) is:

$$\sum_{DBH\geq 8}^{19} 0.6 * TC * (-2.8 + 0.15 * DBH * \pi) * freq_{DBH} / 1000$$

Where:

- In order to have very conservative estimates only large diameter Guaduas are accounted for in the analysis, thus 19 ≥DBH≥ 8 and is an integer.
- TC is the total number of culms per hectare. TC is 5300 for the planted stands and 2137 for the natural stands.
- 0.6 is the fraction of culms estimated to be mature at all times
- π is the constant 3.1415
- $freq_{DBH}$ is the proportion of Guadua of each diameter class (Table 3.2)

$N_{H(t)\,1}$,the carbon harvested at each time interval (t C/ha) is:

$$\sum_{t=i}^{t=n} \sum_{DBH \geq 8}^{19} 0.2 * TC * (-25.2 + 1.32 * DBH * \pi) * freq_{DBH} / 1000$$

Where:

- *t* is the year at which the carbon is accounted for and n is number of years of project activity. For planted stands harvesting starts in year 5, and then proceeds yearly; in natural managed stands harvesting is assumed to start in year 2.
- In order to have very conservative estimates only large diameter Guadua is accounted for in the analysis, thus 19 ≥DBH≥ 8 and is an integer
- *TC* is the total number of culms per hectare. *TC* is 5300 for the planted stands and 2137 for the natural stands.
- 0.2 is the fraction of culms harvested yearly
- π is the constant 3.1415
- $freq_{DBH}$ is the proportion of Guadua of each diameter class (Table 3.2)

Leakage

Estimation of leakage should not be required for this project because it does not result in the displacement of activities or people; it is not expected to trigger activities outside the project boundary that generate additional GHG emissions that would be attributable to the project (UNFCCC 2006b, a). Thus the value of leakage due to the project would be 0.

$L_{(t)} = 0$

where:

$L_{(t)}$ = leakage (tC) attributable to the project activity within the project boundary at time t.

Ex ante estimation of net anthropogenic greenhouse gas removals by sinks

Net anthropogenic greenhouse gas removals by sinks is the actual net GHG removals by sinks minus the baseline net GHG removals by sinks minus leakage.

The resulting temporary certified emission reductions (tCERs) at the year of verification tv are calculated as follows:

$tCER_{(tv)} = 44/12 * (N_{(tv)} – B_{(tv)} – L_{(tv)})$

if changes in carbon stock are considered to be equal to zero, then $B_{(tv)} = B_{(t=0)}$ and

$L_{(tv)} = 0$

where:

$tCER_{(tv)}$ = tCERs emitted at year of verification tv (t CO_2)

$N_{(tv)}$ = carbon stocks in the living biomass pools and soils within the project boundary at year of verification tv under project scenario (t C)

$B_{(tv)}$ = carbon stock in the living biomass pools and soils within the project boundary at year of verification tv that would have occurred in the absence of the project activity (t C)

$L_{(tv)}$ = leakage attributable to the project activity within the project boundary at year of verification tv (t C)

tv = year of verification

44/12 = conversion factor from t C to t CO_2 equivalent (t CO_2/t C)

3.4 RESULTS

3.4.1 Plant Diversity in natural Guadua stands and diameter classes

It is useful to compare the plant diversity assessment for the 250m2 of natural Guadua stands with the results of the botanical study for the Maquipucuna Reserve and the region wide RAP (RAP Botanical Report - Western Ecuador) produced in 1991 by Alwyin Gentry. The report was not published, but is reproduced in the Socio Environmental Assesment of the Guayllabamba Upper Watershed Protective Forest (Fundacion-Maquipucuna 1995). In various transects adding to 0.1 ha at the Maquipucuna Reserve, Gentry found 123 woody plant species of diameter at breast height (DBH) larger than 2.5 cm; the number of species found in natural Guadua stands is presented in that context as well as the list of families encountered (Tables 3.3 and 3.4). It is concluded that plant diversity within a natural *Guadua* stand is high with 19 families and 25 species with DBH larger than 2.5 cm found in a total of 5 transects each of 50 x 1m. It is worth noting that only a small area was sampled because working in natural stands without causing major disturbance is a major challenge as the thorny lateral branches interweave forming a thick matrix that needs to be cleared to enable walking. *Guadua* is frequently found associated with *Bactris setulosa* ('Chonta'), which is a palm threatened by habitat transformation and overexploitation and is listed as LR/NT in the IUCN Red list of Threatened Species (Henderson 1998). As opposed to *Guadua*, 'Chonta' takes decades to mature, therefore reforestation projects with *Guadua* should consider including 'Chonta'in the reforestation program. It is worth noting that 'Chonta' wood is valued and that the lipid-rich fruits are an important animal food.

Even though the diameter of mature *Guadua* remains constant throughout the life of the culm, the diameter classes in both natural and planted *Guadua* stands are distributed following a quasi normal distribution (Figure 3.16). This result is consistent with the Weibull distribution reported by Camargo (2006) for *Guadua* plantations.

3.4.2 Actual extent of Guadua in the Chocó Andean Corridor

Here I report the area of Guadua, ca. 9,573.53 ha obtained from the interpretation of Landsat 7 images (P10R60, P10R59, P11R59 y P11R60) for reference only, as more reliable results are expected from the use of high resolution photographs in an ensuing project.

The area of Guadua assessed from the field work in 2006 is 4398 hectares. Although it is probably a conservative estimate, it will be used to calculate carbon additionality through conservation and management. These *Guadua* remnants are easily accessible and threatened with destruction as we could witness during our field visits.

A map showing the location of Guadua stands according to each method is shown in Figure 3.5. The location only coincides in two places, and the differences could be explained by several factors, the main one being that Landsat interpretation did not offer as reliable results because of the difficulty of distinguishing small *Guadua* patches from primary and secondary forest and shrubs. Other possible explanations is that Guadua could have been transformed to pastures or other uses in lapse of 6 years between the preparation of the land use map and the new set of field visits, and that new areas could have grown especially because Fundación Maquipucuna has promoted reforestation with Guadua in the area starting in the year 2000.

3.4.3 Maxent modeling for habitat suitability of Guadua

Regardless of the modeling method chosen, evaluation of the model's predictions is challenging because the actual distribution of species is not known and I only have presence records (Beauvais et al. 2006). Therefore, model predictions need to be interpreted with caution. In Maxent, evaluation focuses on finding if performance is better than random. Prediction values are not probabilities of occurrence, but a sort of index of suitability from 0 to 100, therefore the selection of a model threshold value that separates suitable from unsuitable environments is highly dependent of the context in which the results will be used.

The threshold-based and ROC evaluations, as well as the maps of the best six models are reported in figures 3.7 to figure 3.12. Model 1, which used all variables and only the random *Guadua* points, obtained the highest area under the curve (AUC) value of 0.992 for training data and 0.982 for testing data. Model 3, which used the *Guadua* and 150 banana points and a set of variables highlighted in table 3.1.corresponding to conditions preferred by *Guadua* (Young and Judd 1992, Londoño 1998, Camargo 2006), had the second highest AUC values of 0.976 for training data and AUC of 0.953 for testing data. Model 2, 4, and 6 that used literature variables obtained the lowest AUC values. However, all AUC values obtained are close to 1, representing that all most true positives or hits are found in both training and testing data, and that almost no false positives are included in the model.

Several jackknife tests of variable importance were produced, for the training data, for the testing data and for the AUC. The results of the analysis of importance of variables as well the response curves for model 1 are reported in figures 3.13 through 3.15. Overall, in accordance with the literature, elevation is either the most predictive variable or one of the variables with the most predictive value, which is also related to temperature changes characteristic of elevation change near the equator. In addition, in both models where all 36 variables were used, rainfall seasonality emerged as a variable with high explanatory value, even more than annual rainfall. This is in line with the importance that the literature gives to rainfall as a limiting factor for Guadua, but reinforces the importance of the seasonality of rainfall for Guadua growth (Camargo 2006).

3.4.4 Optimal areas for reforestation with Guadua

Participation and interest of local communities and institutions are two key ingredients for the success of any reforestation project. Therefore, the extensive help provided for the fieldwork and ample participation of different organizations and people in the *Guadua* inventory are a great expression of the interest that people and institutions from the Chocó Andean Corridor have to work with *Guadua*.

The following discussion refers to the results of model 3, which was produced from GPS points of *Guadua* and 150 banana points for those areas not collected and where there is empirical evidence that Guadua would grow well and 36 environmental variables. Approximately 303,327 hectares or 10% of the total area of the Chocó Andean Corridor presents excellent conditions for *Guadua,* i.e. areas in red and deep red in the map representing a cumulative threshold above 36.892. At the same time there are good conditions for *Guadua* in additional 38% of the area, i.e. the areas classified above the minimum presence threshold of 3.546 (Table 3.5).

The largest potential habitat for *Guadua* lies in the areas of high-graded and managed forest (553,369 hectares) and on pastures (241,230 hectares), which together represent 56% of the area suitable for *Guadua*. About 20% (268,861 hectares) of the area suitable are within natural forests, a large portion of which lies within the Cotacachi-Cayapas Ecological Reserve (CCER). This may explain why in the land use classification of the year 2000 (CLIRSEN 2000), a large area that corresponds to my modeled areas suitable for *Guadua* has been classified as natural grass or shrubby vegetation but which, in reality may be *Guadua*. It seems reasonable to think that large areas of *Guadua* exist in the interior unexplored areas of the CCER. Table 3.5 also details the suitability classification by the most relevant land uses.

The area chosen for carbon offset calculations through reforestation amounts to 29854 hectares of pasture with suitability index of 1. This choice does not suggest that the area chosen is the only good candidate for reforestation, but it was chosen to illustrate the potential of *Guadua*. Certainly, if a reforestation project were to take place, suitability indices could be classified in more than 2 levels, and the level of suitability could be one of the parameters used to prioritize reforestation areas.

3.4.5 Projecting carbon stocks and additionality from Guadua projects

Two scenarios or strata are considered. Reforestation of pastures into *Guadua* is assumed to take place in 29854 hectares located in the areas of highest suitability for *Guadua*. The other component is the conservation through management of 4398 hectares of natural *Guadua* identified through GPS location. The estimation of the net carbon benefits or additionality of reforesting pastures with Guadua follow in as much as possible the protocol and terminology approved by the CDM Executive Board (UNFCCC 2006a). This is a calculation of above and belowground carbon pools with and without the project. Currently approved CDM methodologies only allow carbon pools of "living" biomass above and belowground, and not soil carbon. The main reason for this is that there is not enough data from all the different land uses and geographic zones about the land use history as well as soil organic matter dynamics to determine the baseline accurately. I present carbon offset calculations with and without soil carbon. We have demonstrated that *Guadua* has higher soil carbon levels than pastures (Tian et al. 2007), thus I can put this result in the context of the carbon project. The other difference with traditional reforestation projects is that the carbon harvested is accounted for as an anthropogenic gain. The baseline or without project scenario assumes that areas under pasture would continue as pasture for 30 years. In any case this is a conservative estimate, as it is likely that large areas of pastures could be transformed into sugar cane, given the latest policies of the government promoting ethanol, in which case the baseline would even be less carbon per hectare (UNFCCC 2007a). The area under natural *Guadua* for the calculations conservatively assumes that *Guadua* will continue as *Guadua*. However, in reality, clear cutting of the natural *Guadua* stands is the more likely scenario as extrapolating from the decreasing trend of *Guadua* areas. Table 3.6 presents the parameters used in the carbon calculations as well as the assumptions and data sources. Table 3.7 presents the calculations on a yearly basis and Table 3.8 present a summary of the results of the following estimates of greenhouse gas (GHG) removals.

Estimated baseline net greenhouse gas (GHG) removals by sinks

With soil carbon

The baseline carbon content is 66 tC/ha for pastures and 169 tC/ha for the natural *Guadua*. With 29,854 ha of pastures transformed into *Guadua* the baseline is 1,974,245 tC. The baseline for 4398 hectares of managed *Guadua* is 742,714 tC. Pasture is assumed to remain as pasture therefore there is no net greenhouse gas (GHG) removal. The baseline for natural *Guadua* is assumed, very conservatively to remain as *Guadua*, rather than being cleared, and that the stand would go the natural process of growth and death, and decomposition in the stand, thus the net GHG removal by these sinks would be zero. The estimated baseline, plus baseline net GHG removals by sinks by year 30 are 2,717,139 tC.

Actual net greenhouse gas removals by sinks

Net GHG removals by *Guadua* reforestation is 760 tC/ha for pastures and 382 tC/ha for the management of natural *Guadua*. With 29854 hectares of pastures transformed into *Guadua* the net GHG removals is 22,689,040 tC. The net GHG removal for 4398 hectares of managed *Guadua* is 1,680,036 tC. All pasture is assumed to be cleared on year one so there is a loss of carbon, and soil carbon increases at steady yearly increments during the 30 years to match the soil carbon content under Guadua. Soil carbon remains constant in managed Guadua. Harvest of Guadua takes place yearly, after year 5 on the reforestation scenario and after year 1 on the managed Guadua scenario; and in both cases harvest is counted only until year 29. The estimated net GHG removals by sinks by year 30 are 24,369,076 tC.

Ex ante estimation of net anthropogenic greenhouse gas removals by sinks

The net anthropogenic GHG removals of the reforestation component is 694tC/ha, and 213tC/ha for the management of *Guadua*. The net anthropogenic project benefit is 20,714,795 tC or 75,954,248 tCO_2 equivalent for reforestation and 937,322 tC or 3,436,849 tCO_2 equivalent for management. The total project net GHG anthropogenic removal is 79.391 million tCO_2 e.

Without soil carbon

The assumptions are the same as in the calculations above, except that the soil carbon pool is ignored completely. The net anthropogenic project benefit is 19,669,905 tC or 72,122,985 tCO_2

equivalent for reforestation and 941,720 tC or 3,452,975 tCO_2 equivalent for management. The total project net GHG anthropogenic removal is 75.58-million tCO_2 e.

3.5 CONCLUSIONS

The many uses of native bamboo (*Guadua angustifolia*) can form the foundation for an effective integrative biodiversity conservation and climate-change mitigation strategy within the Chocó Andean Corridor in Northwest Ecuador.

Guadua stands harbor important levels of biodiversity. There are indications that Guadua is important habitat for various species of birds (Cortes-Herrera et al. 2004, www.sciencemag.org 2007, BirdLife-International 2007). Additionally, with more than 25 tree species in 19 families found in only 250m^2 area of *Guadua* transects, including the IUCN red listed "chonta" palm, it is evident that *Guadua* forests could help support important plant biodiversity if an appropriate density and management regime is applied. It is critical to protect the decreasing areas of natural stands of *Guadua*, and I have demonstrated that their protection through management can generate income from carbon offsets and the annual harvests used for construction. *Guadua* is a native plant that grows in clumps and is part of the high biodiversity natural forests of the Corridor. Its characteristic fast growth, versatility as a timber substitute, and increasing demand, can be used to create economic incentives to reforest biodiversity-barren pastures or to conserve and manage, rather than destroy, secondary forests. The density of 5300 culms per hectare used to estimate the carbon-offset calculations of reforestation with *Guadua* is conservative with respect to the management recommendations from long-term studies in Colombia; however, it is twice as many canes as found in unmanaged natural stands. When cultivated with increased densities it is expected that the biodiversity of *Guadua* plantations will be less than in natural stands, however, it supports more biodiversity than sterile land uses such as exotic and degraded pastures (de Koning et al. 2003). Further research should help refine our knowledge about the optimal density to allow the establishment of an ecosystem that benefits biodiversity. Monitoring studies, such as the bird monitoring work initiated by Fundación Maquipucuna in conjunction with the Warnell Forestry School of Natural Resources from the University of Georgia to assess the impact of land uses on bird community assemblages, will help evaluate the biodiversity impact of different planting densities of *Guadua* (Mordecai et al. 2007).

In this study, I have also shown that a surprising 20% of the Corridor is under high-graded and secondary forest uses that present optimal site conditions for *Guadua*. This offers the opportunity of incorporating this bamboo as part of a forest management regime. The typical land use change sequence in the lowland Corridor is that high-graded and secondary forests are being cleared to make way for more profitable uses such African oil palm or heart of palm, rather than reforesting and waiting 15 – 30 years until timber is ready for harvest. If *Guadua* were part of forest management, there would be an economic return after 5 years, thus creating a competitive economic incentive to manage, rather than clear high-graded and secondary forests. If in addition to the benefits of harvesting *Guadua*, one were to add payments for carbon offsets resulting from a CDM carbon initiative, the *Guadua* project would become increasingly attractive. Furthermore, substituting degraded pastures with *Guadua* and managing natural stands Guadua stands can generate important climatic mitigation benefits. The carbon accrual for a 30 year project can be up to eight times higher per hectare than the amount of CO2e removed by a traditional reforestation project for carbon credits such as the ChoCO2 (UNFCCC 2007b) for the same area. While a 30-year project of conservation and management of natural *Guadua* stands could generate twice the tCO2e per hectare than traditional reforestation. For example the ChoCO_2 project is a traditional reforestation project being implemented at the Maquipucuna Reserve and adjacent lands that expects to generate 165,997 tCO_2e from the reforestation of 523 hectares under the auspices of Conservation International, and financing from RICOH corporation with approved methodology by the Executive Board of the CDM number AR-AM0007 (UNFCCC 2007b). The payments for carbon credits of ChoCO_2 barely cover the costs of planting and guarding the trees over the 30-year project life. If *Guadua* were used in the reforestation project totally or at least in part, the carbon credits generated would range from 1.96 to 7.61 times larger. The increased tCER payments, plus the annual yield from harvesting *Guadua* could help fund conservation projects in the Maquipucuna Reserve beyond the 30 years, thus helping biodiversity conservation not only by restoring biodiversity to pastures, but generating revenues to effectively guard the rest of the protected area. Reforesting a conservative number of 100 ha of pasture for *Guadua*, starting after year 5 would generate annually about $106,000 from the harvest in addition to any carbon payments.

Reforesting with *Guadua* offers authentic win-win opportunities for conservation and sustainable development, but there is a need for strong support from policies and institutions to formally adopt and promote *Guadua* as a timber substitute. On one hand it must be recognized that land tenure security is a pre-condition to any reforestation/afforestation CDM project (UNFCCC 2006c); therefore, government policies and authorities must create an environment of respect for private property. On the same line, government policies and authorities must recognize and secure the ancestral land tenure rights of indigenous people, including Afro-Ecuadorian citizens living in the area for over 500 years. The personal experience of the author is that policies like the Agrarian Reform and Colonization Law abolished in the early 1990's, and again in the agenda of government authorities, created chaos by instigating squatting on private properties and ancestral territories of indigenous communities. The size of project areas is important; to be viable, CDM projects must offset transaction costs often of several hundred dollars per tCO_2e, thus at current market prices they should generate more than 50,000 tCO_2 e or more than 1000 tCO_2 a year (Michaelowa et al. 2003). This implies that small farmers by themselves will never have a chance to participate in this type of project. From the evaluation of the extent and location of suitable areas for reforestation with *Guadua*, it seems that the best scale to organize projects is at the Municipality or county level, which is also the right scale to apply monitoring projects. Counties or municipalities have the capacity to establish municipal laws or ordinances, which can help, enforce the commitments of a CDM reforestation project. CDM projects are technically complex, thus other institutions such as competent NGO's should support counties in their efforts, thus creating a process of institution building and decentralization at the county level. In a sense, this is also a way to adapt the local institutions to the market demands of climate change. In order to manage funds of CDM reforestation/afforestation projects with small land owners, it has been suggested to use trust funds (de Koning et al. 2005) and would certainly be reasonable for *Guadua* CDM projects. In addition to acceptance of *Guadua* as a CDM project, and strengthening the land tenure regime, the government needs to establish policies that create economic incentives and strengthen the market for *Guadua*. The demand currently exceeds the supply of *Guadua* produced on pasturelands, and the exploitation of wild *Guadua* needs control. In addition to accepting *Guadua* CDM projects, the government could establish credit programs for small growers, but also economic incentives, such as decreased taxes, for large timber companies to make the transition from tropical hardwood harvests from natural forests to *Guadua*, and some disincentive for timber extraction if benefits are granted for using managed *Guadua*. Additionally, research projects at local universities and in association with international research centers should be promoted to investigate economic uses of *Guadua*. Finally, *Guadua* offers the opportunity to implement large-scale projects that can also generate local employment. The project can result in the creation of local jobs through planting, tending, harvesting and in post-harvest economic uses such as plybamboo factories or in furniture manufacturing.

This study treats harvested *Guadua* as a positive contribution in the pool of net anthropogenic GHG removals by sinks because the Guadua harvested is expected to replace timber extracted from natural forests and because the long-term fate of the carbon in *Guadua* is potentially traceable. It will be necessary to establish a system to trace the *Guadua* harvested from the stands, which can be done through life cycle analysis of the product (e.g., furniture, buildings) and implemented through a system of certification such as Smartwood certification from the Forestry Stewardship Council (Forest-Stewardship-Council 2007). The high calorific content of *Guadua* biomass also opens up the possibility of using harvest and manufacturing residues in alternative energy projects, although that topic needs further elaboration.

The identification of areas suitable for *Guadua* is fundamental in the preparation of CDM reforestation/afforestaiton projects. The use of GIS technology is standard in the definition of land use classes and land use change. This study in addition proposes the use of Maxent statistical modeling to identify areas suitable for Guadua. Regarding the choice of species used for reforestation, some CDM projects are planting few species of commercial value or higher species mixes of native trees. In both cases, the choice is based on important empirical experience from locals, but for the case of native species there is a lack of knowledge about growth and the interaction with other species chosen. As is the case with *Guadua*, the use of Maxent modeling could help verify the assumptions made and improve the decision process of where to plant the different species.

Several steps can help improve the Maxent model of *Guadua* in the future. First, knowing that *Guadua* has a large geographic range, it may be of great utility to model site suitability with locations of *Guadua* in other areas and countries with as many variables as possible. Because many variables contain unknown amounts of redundant information, it may be useful to apply principal component analysis to weight the variables. In any case, the precision of Maxent will increase with additional empirical data points for *Guadua* occurrence. Specially, areas that were modeled using banana occurrence should be surveyed for *Guadua* remnants to get additional points and to verify the distribution. Within the area of prediction we can raise or lower the threshold to increase or decrease the area eligible, keeping in mind it is not recommended to lower the threshold below the minimum presence threshold, this can help us in the prioritization of areas for reforestation.

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Table 3.1 Environmental variables used in modeling distributions: rows shaded denote the variables most influential in the distribution of Guadua according to literature, and the variables with most explanatory value from models 1 and 3 were used in models 2 and 4. All the other variables were used to model the distribution in models 1 and 3.

Name	Description	Type
c1_tannual	BIO1 = Annual Mean Temperature	Continuous
c2_tdrange	BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))	Continuous
c3_tisoth	BIO3 = Isothermality (mean diurnal range/temperature annual range)(*100)	Continuous
c4_tseas	BIO4 = Temperature Seasonality (standard deviation *100)	Continuous
c5_tmxwarm	BIO5 = Max Temperature of Warmest Month	Continuous
c6_tmncolm	BIO6 = Min Temperature of Coldest Month	Continuous
c7_tarange	BIO7 = Temperature Annual Range (P5-P6)	Continuous
c8_twetq	BIO8 = Mean Temperature of Wettest Quarter	Continuous
c9_tdryq	BIO9 = Mean Temperature of Driest Quarter	Continuous
c10_twarmq	BIO10 = Mean Temperature of Warmest Quarter	Continuous
c11_tcoldq	BIO11 = Mean Temperature of Coldest Quarter	Continuous
c12_pannual	BIO12 = Annual Precipitation	Continuous
c13_pwetm	BIO13 = Precipitation of Wettest Month	Continuous
c14_pdrym	BIO14 = Precipitation of Driest Month	Continuous
c15_pseas	BIO15 = Precipitation Seasonality (Coefficient of Variation)	Continuous
c16_pwetq	BIO16 = Precipitation of Wettest Quarter	Continuous
c17_pdryq	BIO17 = Precipitation of Driest Quarter	Continuous
c18_pwarmq	BIO18 = Precipitation of Warmest Quarter	Continuous
c19_pcoldq	BIO19 = Precipitation of Coldest Quarter	Continuous
c20_elev	Elevation	Continuous
c21_slope	Slope	Continuous
c22_aspect	Aspect	Continuous
c23_spH	Soil ph	Categorical
c24_stext	Soil texture	Categorical
c25_sdepth	Soil depth	Categorical
c26_stons	Soil stoniness	Categorical
c27_sorgmat	Organic matter	Categorical
c28_sphreatic	Phreatic layer	Categorical
c29_sflood	Flooding	Categorical
c30_ssalin	Salinity	Categorical
c31_sfert	Fertility	Categorical
c32_sdrain	Soil drainage	Categorical
c33_stoxic	Soil toxicity	Categorical
c34_serosn	Erodability	Categorical
c35_stype	Soil type	Categorical
c36_dstream	Distance to stream	Continuous

Table 3.1 continued….Description of the soil variables

Soil pH (23_spH)		
Code	**Class**	**pH range**
1	very acidic	< 4.5
2	acidic	4.5 – 5.5
3	moderately acidic	5.6 – 6.5
4	neutral	6.6 – 7.4
5	moderately alkaline	7.5 – 8.5
6	alkaline	> 8.5
The degree of acidity or alkalinity of a soil, hydrogen ion concentration expressed as a pH value		
Soil Texture (24_stext)		
Code	**Class**	**Particle content**
1	coarse	fine sand, medium sand, coarse sand, loamy sand
2	medium coarse	fine to coarse sandy loam, silty loam
3	medium	loam, silt, clay loam (<35% clay), sandy clay loam, silty clay loam
4	fine	clay loam(> a 35%), clay, sandy clay, silty clay
5	very fine	clay (> 60%)
Soil texture is reflects the proportionate distribution of the different sizes of mineral particles in a soil.		
Effective depth for plant growth (25_sdepth)		
Code	**Class**	**Effective depth (cm)**
1	shallow	0 – 20 cm
2	medium	20 – 50 cm
3	slightly deep	50 – 100 cm
4	deep	>100 cm
Effective depth for plant growth is the vertical distance into the soil from the surface to a layer that essentially stops the downward growth of plant roots		
Soil stone content (26_stones)		
Code	**Class**	**Stone content**
1	without any	<10 %
2	few	(10 – 25) %
3	frequent	(25 - 50) %
4	abundant	(50 – 75) %
5	rocky	> 75 %
Stone content of the soil that can interfere with root growth		
Organic matter content of the soil (27_sorgmat)		
Code	**Class**	**Organic matter content (%)**
1	very low	< 1
2	low	1 – 2
3	medium	2 – 4
4	high	> 4
Organic matter consists of plant and animal material that is in the process of decomposing.		
Phreatic level of water (28_sphreatic)		
Code	**Class**	**Depth (cm)**
1	shallow	0 – 20
2	slightly deep	20 – 50
3	medium deep	50 – 100
4	deep	> 100
Depth at which ground water can be found		

Table 3.1 continued….Description of the soil variables

Floodability of soils (29_sflood)	
Code	**Class**
1	none
2	under water < 3 months
3	under water between 3 to 6 months
4	permanent: flooded through the year
Lenght of time soils remain saturated, flooded, or ponded during the growing season to develop anaerobic conditions in the upper part.	

Soil salinity (30_ssalin)		
Code	**Class**	**Electrical conductivity range (mmhos/cm)**
1	none	0 – 2
2	low	2 – 4
3	medium	4 – 8
4	high	> 8
Soil salinity refers to the total concentration of salts in the soil		

Soil fertility (31_sfert)	
Code	**Class**
1	very low
2	low
3	medium
4	high
Soil fertility refers to the soil content of nutrient elements for plants, and is calculated using pH, organic matter, bases saturation, exchange cation capacity.	

Drainage class (32_sdrain)		
Code	**Class**	**Description**
1	Excessively drained	Water is removed from the soil very rapidly.
2	Well drained	Water is removed from the soil readily, but not rapidly. It is available to plants throughout most of the growing season, and wetness does not inhibit growth of roots for significant periods during most growing seasons
3	Moderately drained	Water is removed from the soil somewhat slowly during some periods. Moderately well drained soils are wet for only a short time during the growing season, but periodically they are wet long enough that most mesophytic crops are affected
4	Very poorly drained	Water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season (imperfect).
Drainage class: Refers to the frequency and duration of periods of natural water saturation or partial saturation.		

Soil toxicity (33_stoxic)	
Code	**Class**
1	none
2	low
3	medium
4	high
Toxicity refers to the content of elements such Al that are toxic to plant growth	

Erodability (34_serosn)	
Code	**Class**
1	none
2	slight
3	moderate
4	high
5	severe (eroded)
Soil erodability refers to the imminent danger or risk of erosion	

Table 3.2 Relative frequencies of diameter classes used for the carbon calculations of natural and planted Guadua stands.

Diam (cm)	Natural stands	Planted stands
1	-	-
2	0.002	-
3	0.010	0.001
4	0.006	0.008
5	0.025	0.020
6	0.045	0.040
7	0.066	0.060
8	0.078	0.090
9	0.105	0.120
10	0.189	0.144
11	0.154	0.150
12	0.185	0.135
13	0.082	0.100
14	0.039	0.060
15	0.010	0.040
16	0.004	0.020
17	-	0.010
18	-	0.001
19	-	0.001

Table 3.3 Plant diversity in natural Guadua in relation to primary forests in Western Ecuador

Sampling data from 0.1 ha of plants > 2.5 cm dbh in Western Ecuador (Gentry 1991 in Fundacion Maquipucuna 1995)		
Name	**#Species**	**# Families**
Wet forest		
Río Palenque (1)	119	51
Río Palenque (2)	119	43
Centinela (600 m elev.)	140	55
Bilsa	120	46
Moist forest		
Jauneche	96	38
Esmeraldas Univ.	96	42
San Sebastián	97	49
Neotropical Moist & Wet average	152	46
Dry forest		
Capeira	60	27
Perro Muerto	52	32(+1)
Manta Blanca (300m2)	(34+)	(21+)
Cerros de Amotape - Peru (800 m elev.)	58	28
Neotropical Dry forest average	60	25
Maquipucuna(1600 m elev.)	ca 123	49
***Guadua angustifolia* Kunth** (250 m2) 5(50mx1m) transects across *Guadua* stands	25	19

Table 3.4 Plant families found in 50 x 1m transects of Guadua ($250m^2$) at the Maquipucuna Reserve

Families in natural Guadua
ARECACEAE(PALMACEAE)
BEGONIACEAE
CYATHEACEAE
EUPHORBIACEAE
FLACUORTIACEAE
LAURACEAE
MELASTOMATACEAE
MIMOSACEAE
MIRTACEAE
MORACEAE
MYRISTICACEAE
MYRTACEAE
PAPILIONACEAE
PIPERACEAE
POACEAE
RUBIACEAE
SAPINDACEAE
SOLANACEAE
URTICACEAE

Table 3.5 Guadua suitability classification by land use. CT = cumulative threshold; SI = Suitability Index; G&MF = graded & managed forests; P = pasture; OP = oil palm; SC = sugar cane; SCC & C = short cycle crops & corn; SV = Shrubby vegetation; NF = natural forest; OU = other uses. Values with SI = 1 are most suitable; 2 are suitable and 3 were below the minimum threshold chosen which was minimum training presence, and are considered not suitable.

CT	SI	G&MF (ha)	P (ha)	OP (ha)	SC (ha)	SCC & C (ha)	SV (ha)	NF (ha)	OU (ha)	Total area with *Guadua* potential (ha)	Fraction
36.892 - 100	1	115,540	29,854	41,782	1,683	22,327	22,129	69,943	1,429	303,257	10%
3.546 - 36.892	2	437,829	211,376	141,819	1,553	79,445	38,516	198,918	7,401	1,109,455	38%
SUB-TOTAL		**553,369**	**241,230**	**183,601**	**3,235**	**101,772**	**60,644**	**268,861**	**8,830**	**1,412,712**	
% of the suitable area		38.93%	16.97%	12.92%	0.23%	7.16%	4.27%	18.91%	0.62%		
% of the total area		18.95%	8.26%	6.29%	0.11%	3.49%	2.08%	9.21%	0.30%	48.69%	
0 - 3.546	3	445,111	264,398	39,718	14,914	269,765	87,680	376,667	211,413	1,498,253	51%
TOTAL		**998,480**	**505,628**	**223,319**	**18,149**	**371,537**	**148,324**	**645,527**	**220,243**	**2,910,965**	**100%**

Table 3.6 Areas of suitability for Guadua in pastures and high-graded forests in communities (highlighted) that participated in the Guadua inventory and expressed interest in working with Guadua. SL is the area disputed by the Provinces of Pichincha and Esmeraldas. Suit.1 is highest suitability; Suit. 2 is suitable.

Municipality	Use Class	Suit. 1 (ha)	Suit. 2 (ha)	Total (ha)
Quininde	Pasture	5,348	72,960	78,308
Muisne	Pasture	2,928	43,863	46,791
SL	Pasture	4,885	17,813	22,698
Atacames	Pasture	118	19,662	19,780
Esmeraldas	Pasture	2,471	17,180	19,651
Santo Domingo	Pasture	2,504	10,699	13,203
Pedro Vicente Maldonado	Pasture	4,200	5,100	9,300
Rio Verde	Pasture	1,480	7,072	8,551
Eloy Alfaro	Pasture	286	7,488	7,774
Quito	Pasture	3,754	2,550	6,304
Puerto Quito	Pasture	1,029	3,000	4,029
San Miguel de los Bancos	Pasture	164	1,799	1,962
San Lorenzo	Pasture	575	722	1,297
Ibarra	Pasture	39	479	518
Tulcan	Pasture	-	299	299
Espejo	Pasture	54	230	284
Mira	Pasture	12	265	278
Cotacachi	Pasture	7	108	115
Pimampiro	Pasture	-	76	76
Urcuqui	Pasture	1	10	11
Bolivar	Pasture	-	2	2
Quininde	High-graded Forest	28,712	73,214	101,926
Eloy Alfaro	High-graded Forest	2,057	80,551	82,608
Rio Verde	High-graded Forest	4,188	76,613	80,801
Santo Domingo	High-graded Forest	5,118	71,822	76,939
San Lorenzo	High-graded Forest	18,505	35,898	54,403
Cotacachi	High-graded Forest	31,237	7,852	39,090
SL	High-graded Forest	4,463	28,011	32,474
San Miguel de los Bancos	High-graded Forest	10,315	19,300	29,615
Puerto Quito	High-graded Forest	528	20,138	20,666
Quito	High-graded Forest	8,696	1,110	9,806
Esmeraldas	High-graded Forest	729	8,627	9,356
Ibarra	High-graded Forest	47	6,480	6,527
Mira	High-graded Forest	96	4,050	4,147
Pedro Vicente Maldonado	High-graded Forest	836	1,569	2,405
Tulcan	High-graded Forest	-	2,145	2,145
Espejo	High-graded Forest	14	435	449
Urcuqui	High-graded Forest	-	13	13

Table 3.7 Parameters for calculation of carbon additionality

	Planted *Guadua*	**Source**	**Natural stand**	**Source**
# culms per hectare	5300	(Londoño 1998, Riaño et al. 2002)	2137	This study
# culms harvested/yr/ha	1000		345	
% mature culms	60% = 3180		68% = 1453	
% young culms	30% = 1590		22% = 470	
% shoots	10% = 530		10% = 214	
# trees/ha with dbh>5 cm, average 10 cm	Information not available		265	
Harvest cycle	Every year after year 5		Every year after year 1	
Guadua MgC/ha soil	92	(Tian et al. 2007)	92	
Pasture MgC/ha soil	55	(Tian et al. 2007)		
Diameter class distribution	Table 3.2, Weibull distribution for medium density.	Camargo 2006	Table 3.2	This study
Aboveground tC/ha pasture	4	This study		
Belowground tC/ha pasture	7	This study		

Table 3.8 Actual net greenhouse gas removals by sinks. $N_{(t)r}$ and $N_{(t)m}$ are total carbon stocks at time t under reforestation and management respectively; $N_{A(t)r}$ and $N_{A(t)m}$ are carbon stocks in above-ground biomass at time t; $N_{B(t)\,r}$ and $N_{B(t)\,m}$ are carbon stocks in below-ground biomass at time t; $N_{H(t)\,r}$ and $N_{H(t)\,m}$ carbon harvested during 24 years in reforestation, and 28 years in management (t C/ha); and $N_{S(t)\,r}$ and $N_{S(t)\,m}$ are carbon stocks in soil in year t. All carbon stocks are expressed in tC/ha.

	$N_{A(t)r}$	$N_{B(t)\,r}$	$N_{H(t)\,r}$	$N_{S(t)\,r}$	$N_{(t)r}$	$N_{A(t)m}$	$N_{B(t)\,m}$	$N_{H(t)\,m}$	$N_{S(t)\,m}$	$N_{(t)m}$
t=0	**4**	**7**	**0**	**55**	**66**	**66**	**11**	**-**	**92**	**169**
t=1	-4	-7	0	55	44	60	10	-	92	169
t=2	19	2	0	56	77	56	11	10	92	169
t=3	52	3	0	58	113	56	11	20	92	177
t=4	64	4	0	59	127	56	11	30	92	184
t=5	75	5	0	60	140	56	11	40	92	191
t=6	51	13	24	61	149	56	11	51	92	199
t=7	51	13	48	63	174	56	11	61	92	206
t=8	51	13	73	64	200	56	11	71	92	213
t=9	51	13	97	65	225	56	11	81	92	221
t=10	51	13	121	66	251	56	11	91	92	228
t=11	51	13	145	68	276	56	11	101	92	235
t=12	51	13	170	69	302	56	11	111	92	243
t=13	51	13	194	70	327	56	11	121	92	250
t=14	51	13	218	72	353	56	11	132	92	257
t=15	51	13	242	73	378	56	11	142	92	265
t=16	51	13	266	74	404	56	11	152	92	272
t=17	51	13	291	75	429	56	11	162	92	279
t=18	51	13	315	77	455	56	11	172	92	287
t=19	51	13	339	78	480	56	11	182	92	294
t=20	51	13	363	79	506	56	11	192	92	301
t=21	51	13	388	81	531	56	11	202	92	309
t=22	51	13	412	82	557	56	11	213	92	316
t=23	51	13	436	83	582	56	11	223	92	324
t=24	51	13	460	84	608	56	11	233	92	331
t=25	51	13	484	86	633	56	11	243	92	338
t=26	51	13	509	87	659	56	11	253	92	346
t=27	51	13	533	88	684	56	11	263	92	353
t=28	51	13	557	89	710	56	11	273	92	360
t=29	51	13	581	91	735	56	11	283	92	368
t=30	**75**	**13**	**581**	**91**	**760**	**66**	**11**	**283**	**92**	**375**

Table 3.9 Carbon sequestration potential of Guadua projects in the Chocó Andean Corridor of Northwest Ecuador

ESTIMATES WITH SOIL CARBON

Estimated baseline net greenhouse gas (GHG) removals by sinks

	$B_{A(t)}$ (tC/ha)	$B_{B(t)}$ (tC/ha)	$B_{S(t)}$ (tC/ha)		B(t) tC/ha	Area(ha)	B(t) tC
Pasture	4	7	55		66	29,854	1,974,245
Wild Guadua stand	66	11	92		169	4,398	742,714

Actual net greenhouse gas removals by sinks

	$N_{A(t)\,i}$ (tC/ha)	$N_{B(t)\,i}$ (tC/ha)	$N_{H(t)\,i}$ (tC/ha)	$N_{S(t)\,i}$ (tC/ha)	N(t) tC/ha	Area (ha)	N(t) tC
Reforestation	75	14	581	91	760	29,854	22,689,040
Conserv. Guadua	66	11	206	92	382	4,398	1,680,036

Ex ante estimation of net anthropogenic greenhouse gas removals by sinks

	N(t) tC/ha	B(t) tC/ha	ΔtC/ha	Area (ha)	ΔtC project tC	tCER(30) tCO2 e
Reforestation	760	66	694	29,854	20,714,795	75,954,248
Conserv. Guadua	382	169	213	4,398	937,322	3,436,849

ESTIMATES WITHOUT SOIL CARBON

Estimated baseline net greenhouse gas (GHG) removals by sinks

	$B_{A(t)}$ (tC/ha)	$B_{B(t)}$ (tC/ha)		B(t) tC/ha	Area(ha)	B(t) tC
Pasture	4	7		11	29,854	332,275
Wild Guadua stand	66	11		77	4,398	338,098

Actual net greenhouse gas removals by sinks

	$N_{A(t)\,i}$ (tC/ha)	$N_{B(t)\,i}$ (tC/ha)	$N_{H(t)\,i}$ (tC/ha)	N(t) tC/ha	Area (ha)	N(t) tC
Reforestation	75	14	581	670	29,854	20,002,180
Conserv. Guadua	66	11	206	291	4,398	1,279,818

Ex ante estimation of net anthropogenic greenhouse gas removals by sinks

	N(t) tC/ha	B(t) tC/ha	ΔtC/ha	Area (ha)	ΔtC project tC	tCER(30) tCO2 e	
Reforestation	760	66	694	29,854	19,669,905	72,122,985	
Conserv. Guadua	382	169	213	4,398	941,720	3,452,975	

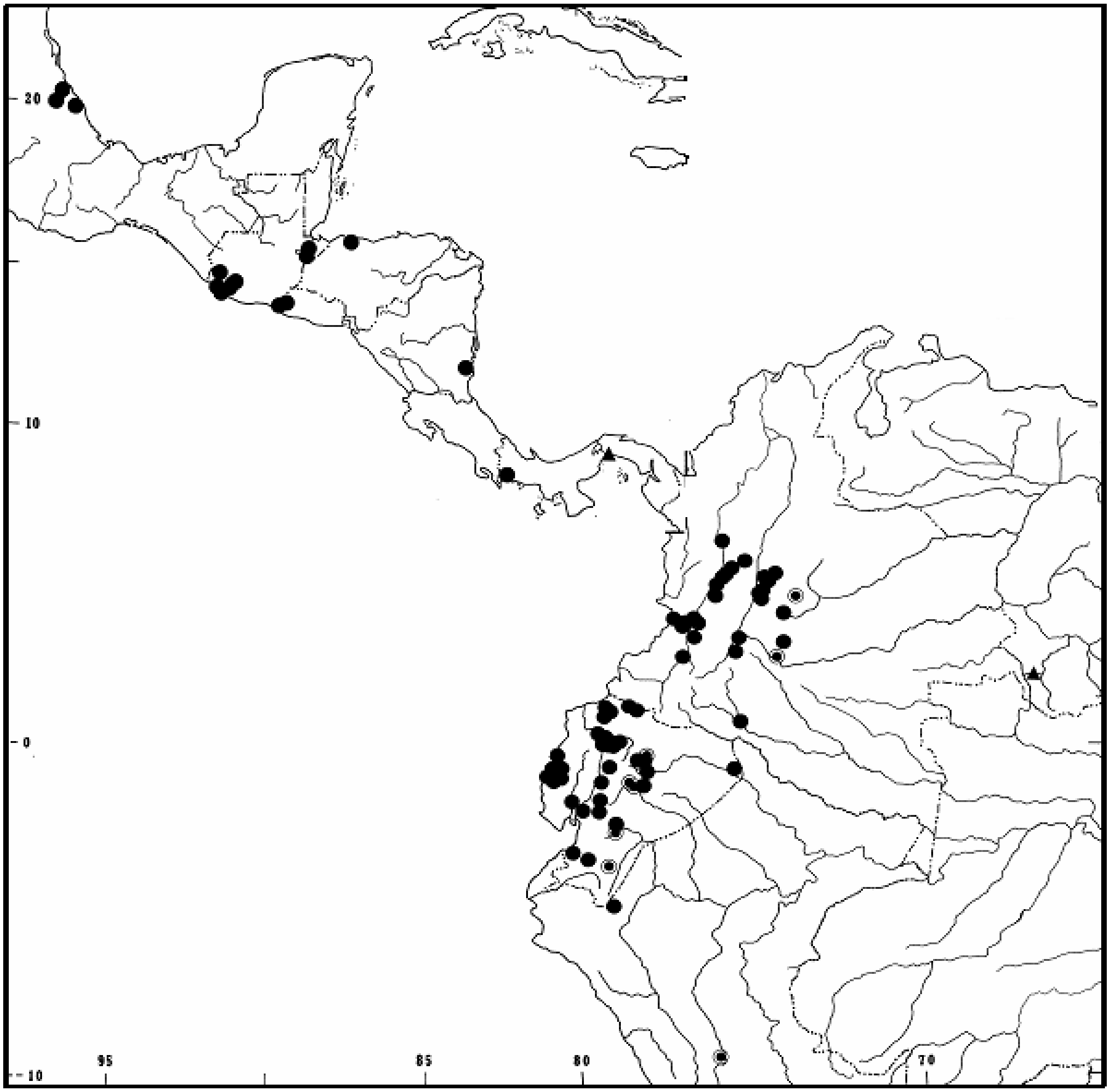


Figure 3.1 Distribution of Guadua angustifolia subs. angustifolia in America. Solid dots = native; dots with circle = Amazon populations; triangles = cultivated (adapted from Young & Judd 1992).

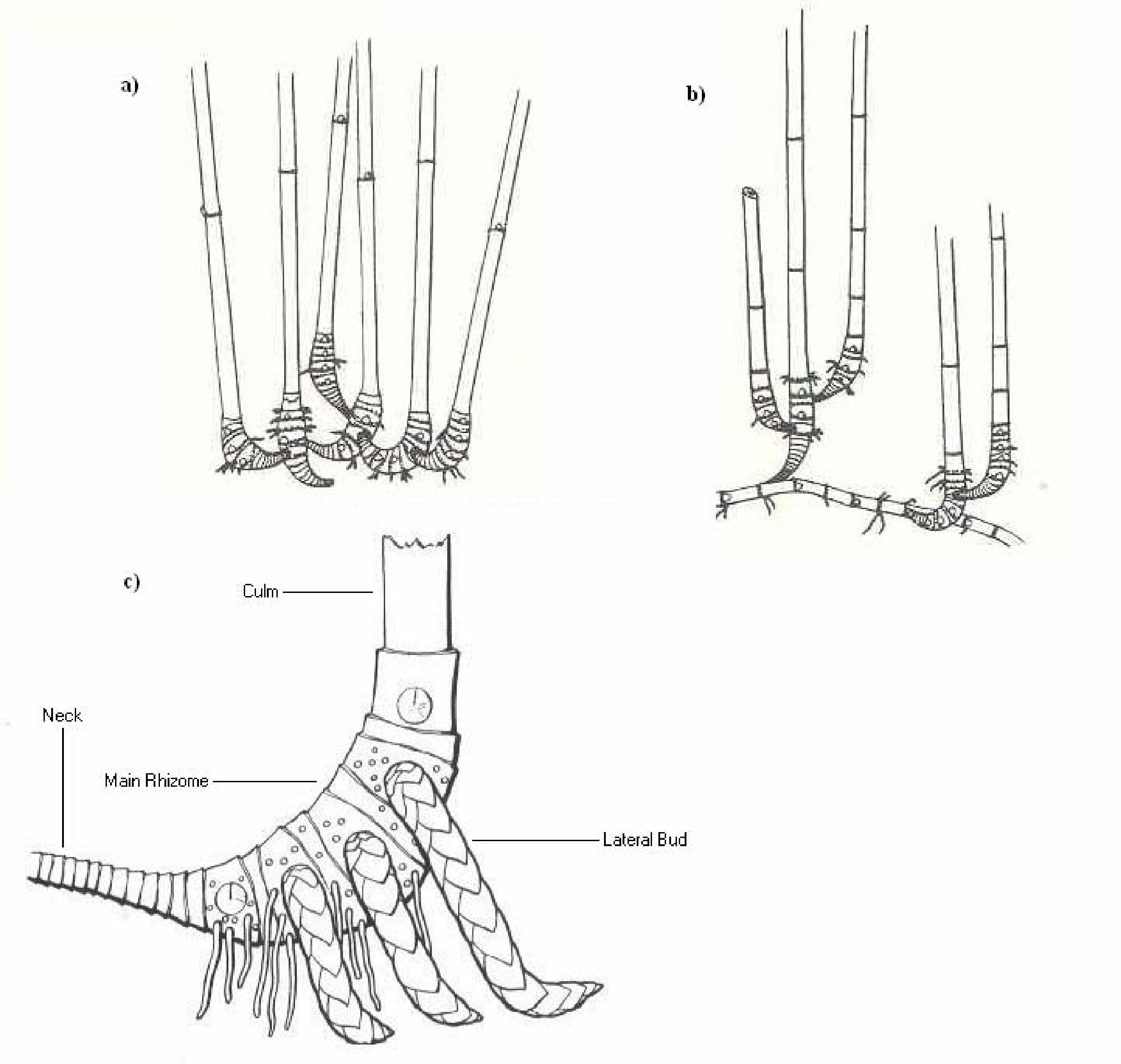


Figure 3.2 Two rhizome systems found among bamboo species: a) pachymorph rhizome systems result in a clumping pattern of distribution, and b) leptomorph rhizomes have a monopodial branching pattern that result in a running type of distribution of bamboos. c) Guadua has pachymorph rhizomes with a sympodial branching pattern that has a main rhizome, fine roots, and lateral buds (adapted from Stapleton 1997, McClure, 1966).

Figure 3.3 Physiognomy of a *Guadua angustifolia* stand and the different stages of culm development. a) A natural *Guadua* stand on average spans from 0.5 to 1 ha; b) Shoots practically emerge overnight, and this is a stage of very rapid growth which lasts about 6 months. Culms are protected by pubescent, thick and large leaves. This stage of development lasts 6 months; c) Young culms have loose the culm leaves and start to develop branches, leaves, and thorns in the thorny variety. This is also a stage of growth and lasts from 11 to 15 months; d) Mature culms are grayish and of more opaque green as lichen, mosses and fungi cover the surface. This is the optimal stage for harvest and lasts about 17 to 20 months; d) Over-mature and dry culms last in that stage from 60 to 100 months. In the early months the culms can be harvested for use, and in the later months, the culms have to be removed to avoid damage by falling (Camargo 2006 and Londoño 1998)

Figure 3.4 Traditional and modern uses of Guadua and Bamboo. a) Traditional Guadua house in the lowlands of the Chocó Andean Corridor; b) Fishing trap for river shrimp “michilla”; c) Training center of the Chocó Andean Corridor; d) Bamboo house (courtesy of Ipirti, Bangalore, India); e) 200,000m2 cover and decorate Madrid’s airport.

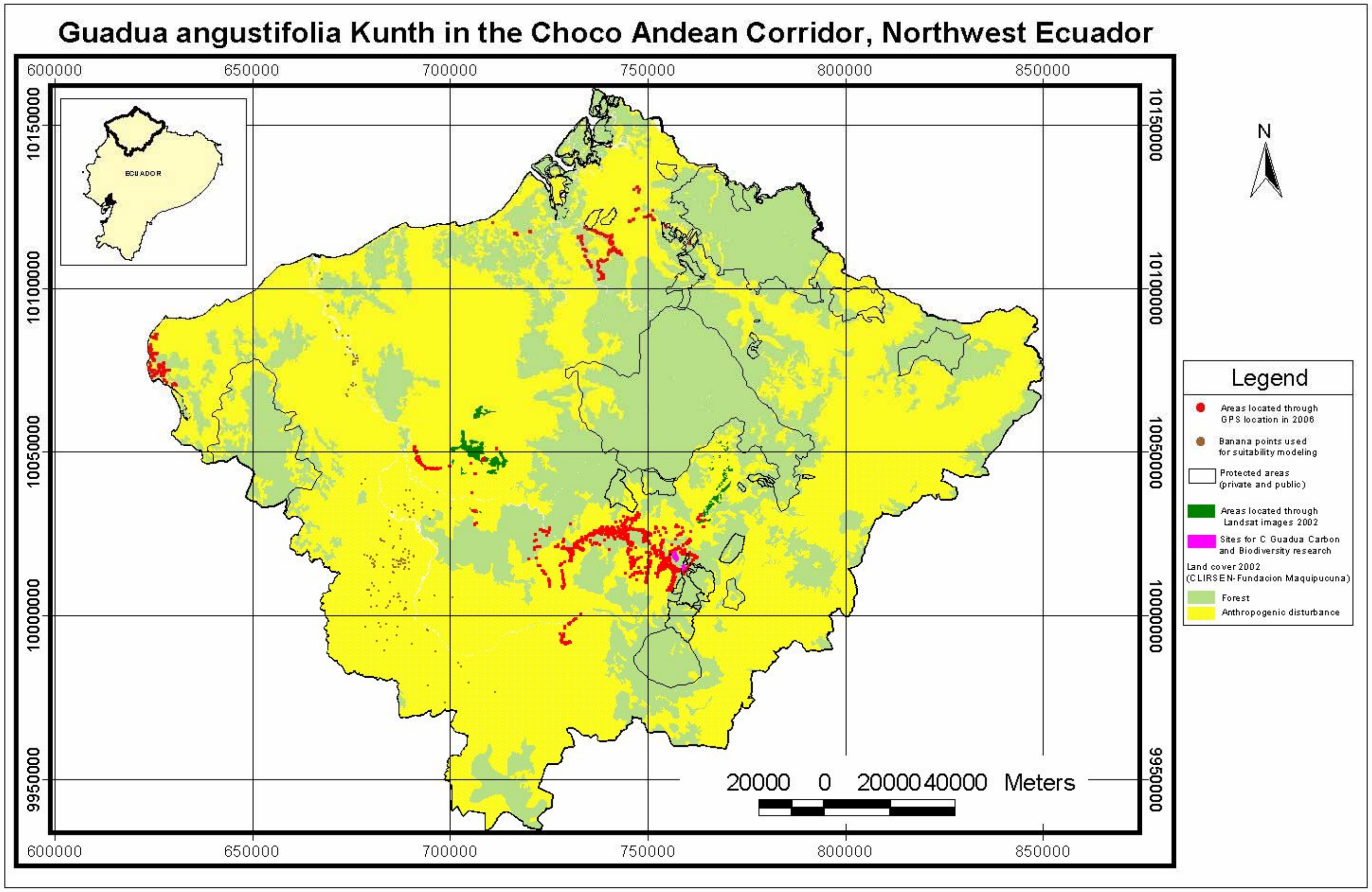


Figure 3.5 Study area and extent of Guadua in the Corridor: Polygons obtained from GPS points in red provide one partial measure of the current extent of *Guadua*; those points were also used for habitat suitability modeling. Banana points from the areas were banana is present according to the land use map of 2000 (CLIRSEN 2000) were also used for habitat suitability modeling. Location obtained from Landsat image interpretation in green. Carbon studies were done at the Maquipucuna Reserve (in areas marked in pink).

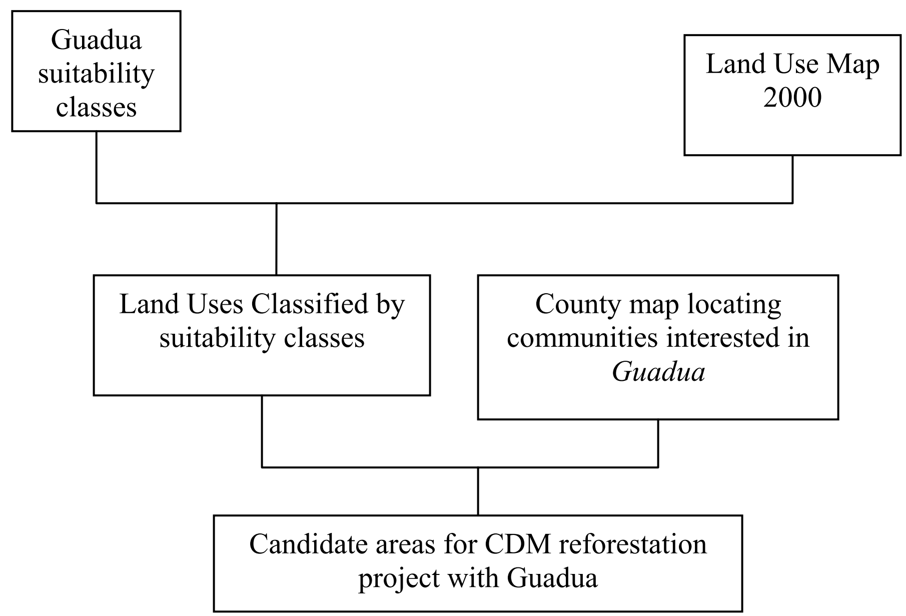
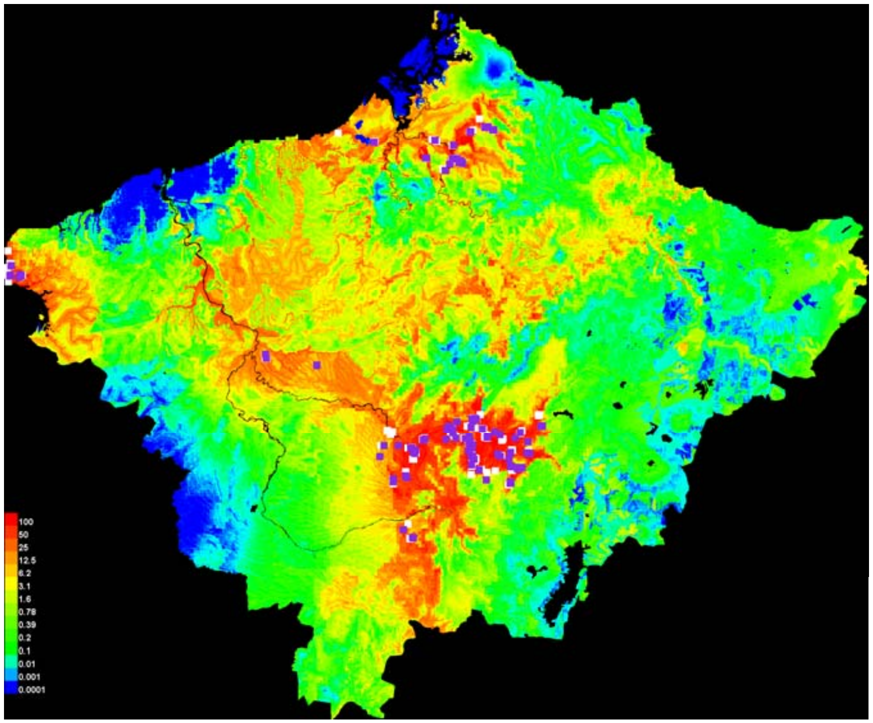


Figure 3.6 Model to locate candidate areas for CDM reforestation project with Guadua.

CT	Description	FPA	TROR	TEOR	P-value
6.333	Minimum training presence (light orange)	0.188	0	0.007	0.00E+00
51.411	10 percentile training presence	0.019	0.098	0.156	0.00E+00
4.467	Balance training omission, predicted area and threshold value	0.226	0	0.007	0.00E+00



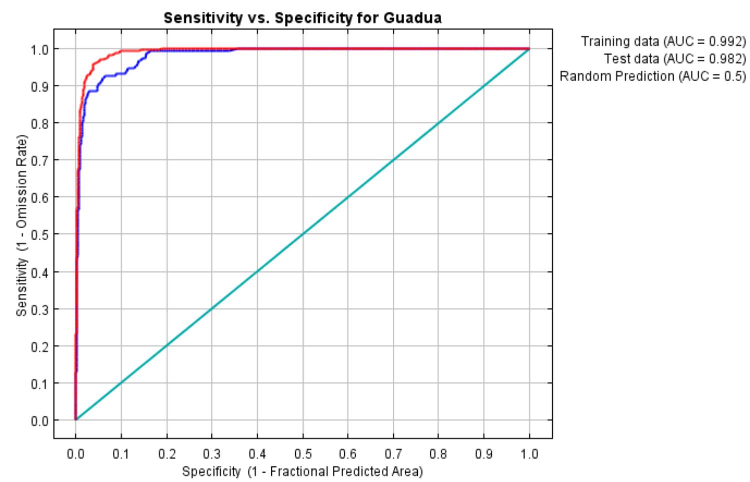
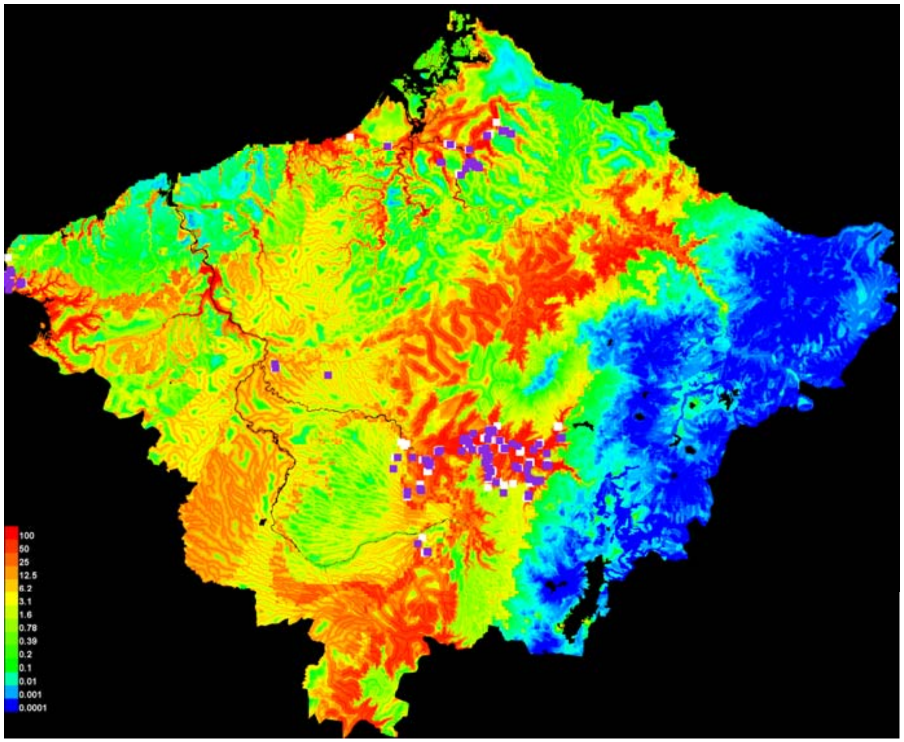


Figure 3.7 Model 1: Suitability map and the corresponding threshold values when using all random GPS points taken in the field and 36 environmental variables. To the right of the map is the ROC curve with the AUC value which is the highest of all models, meaning that there is the best correspondence of collected points to the model. However, this model misses areas where *Guadua* points were not collected and are empirically known to have *Guadua*. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. CT = cumulative threshold; FPA = fractional predicted area; TROR = training omission rate; TEOR; testing omission rate.

CT	Description	FPA	TROR	TEOR	P-value
1.572	Minimum training presence	0.482	0	0.006	2.04E-39
28.634	10 percentile training presence	0.1	0.098	0.147	0.00E+00
4.186	Balance training omission, predicted area and threshold value	0.352	0.008	0.025	8.93E-63



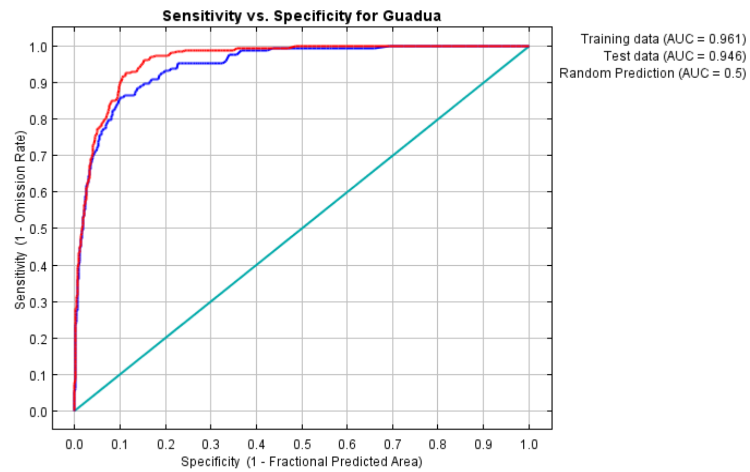


Figure 3.8 Model 2: Suitability map and the corresponding threshold values when using all random GPS points taken in the field and environmental variables from the literature (annual rainfall, elevation, soil pH, soil texture, distance to streams) spreads the suitability conservatively to areas where Guadua points were not collected and are empirically known to have Guadua. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. CT = cumulative threshold; FPA = fractional predicted area; TROR = training omission rate; TEOR; testing omission rate.

CT	Description	FPA	TROR	TEOR	P-value
3.546	Minimum training presence	0.361	0	0	0.00E+00
36.892	10 percentile training presence	0.068	0.099	0.154	0.00E+00
3.546	Balance training omission, predicted area and threshold value	0.361	0	0	0.00E+00

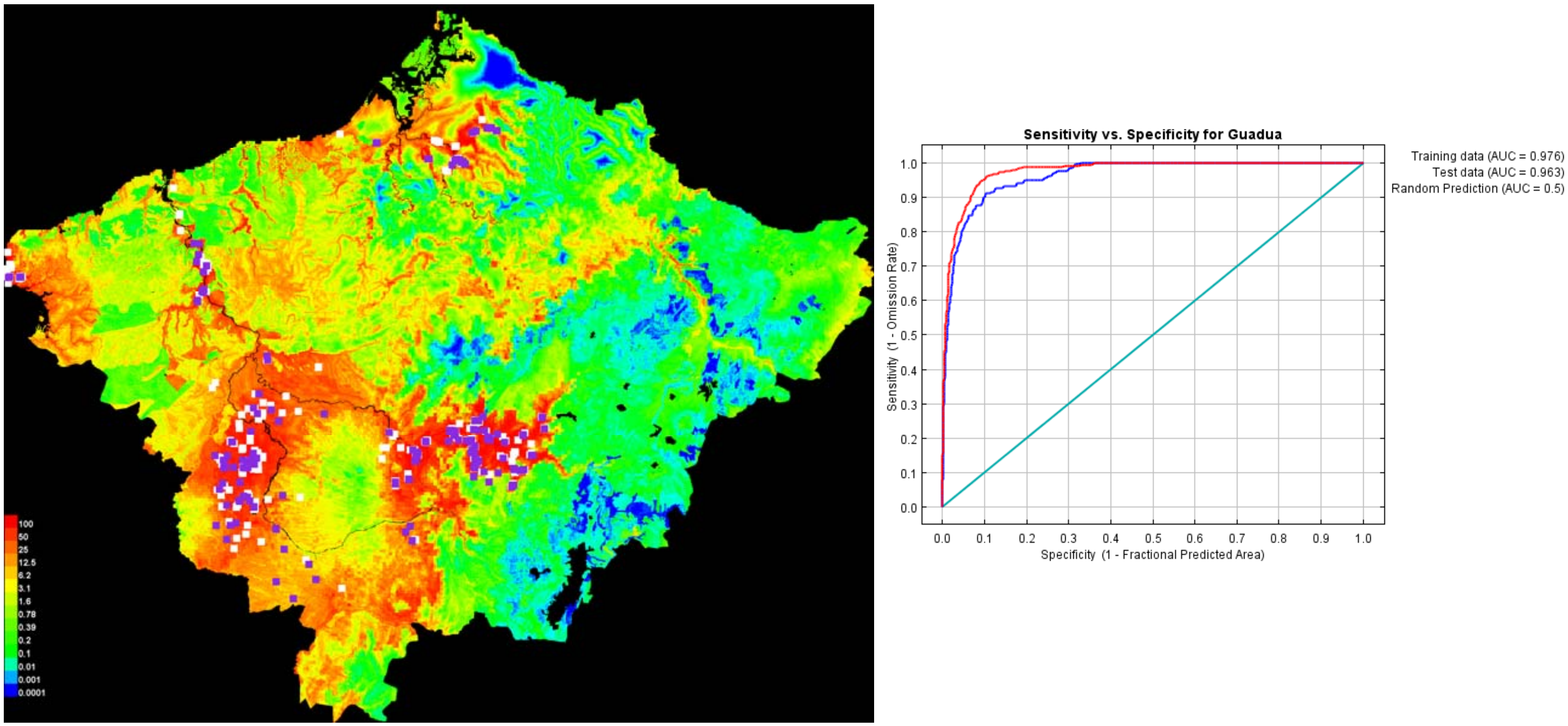
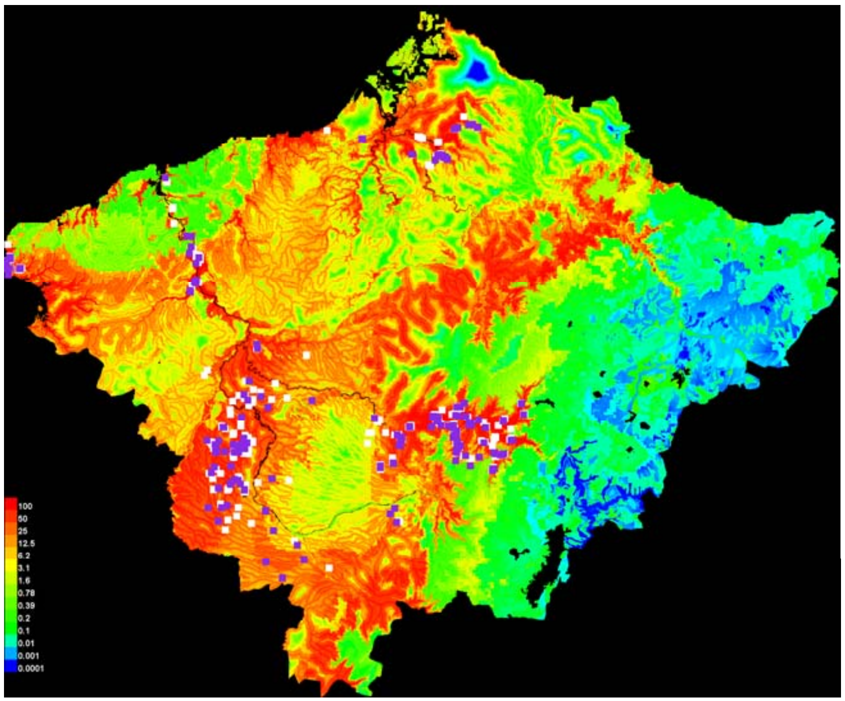


Figure 3.9 Model 3: Suitability map and the corresponding threshold values when using all random GPS points plus 150 banana points and 36 environmental variables. This model the second highest ROC value, meaning that there is the better correspondence of collected points to the model than using only collected Guadua points, and spread out the distribution of suitable areas to where *Guadua* points were not collected and are empirically known to have *Guadua*. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. CT = cumulative threshold; FPA = fractional predicted area; TROR = training omission rate; TEOR; testing omission rate.

CT	Description	FPA	TROR	TEOR	P-value
1.076	Minimum training presence	0.609	0	0	9.24E-33
24.909	10 percentile training presence	0.19	0.099	0.132	0.00E+00
2.013	Balance training omission, predicted area and threshold value	0.545	0.003	0	6.76E-42



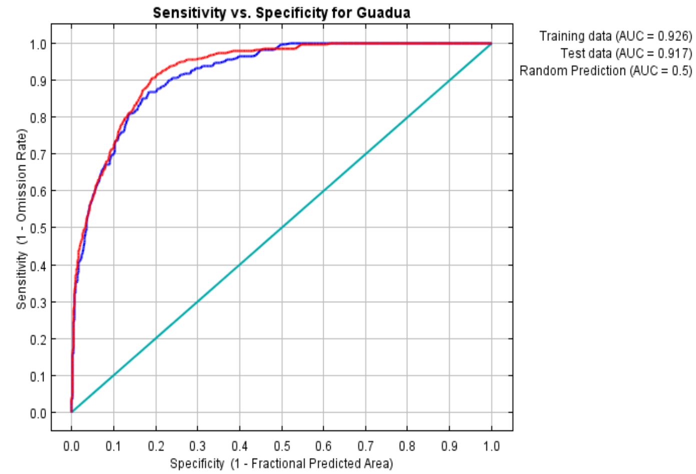
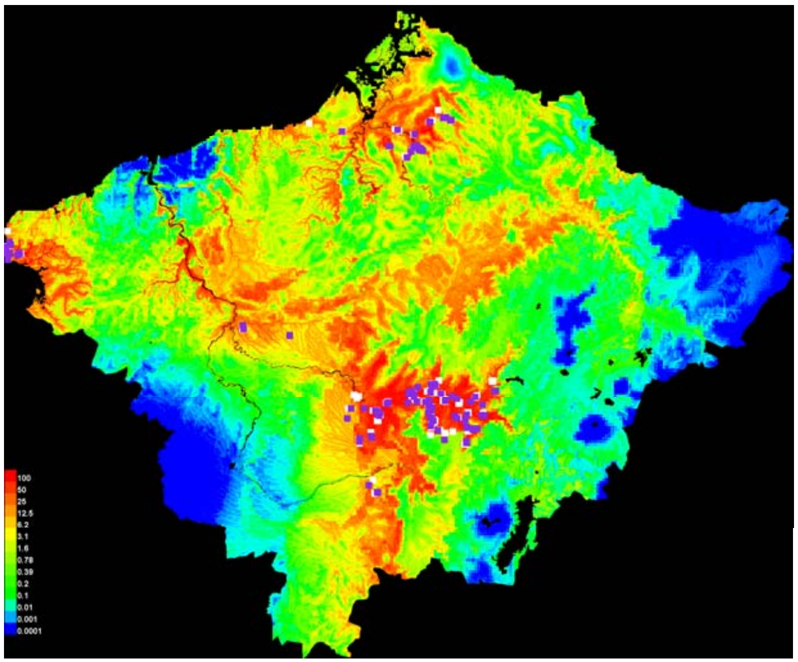


Figure 3.10 Model 4: Suitability map and the corresponding threshold values when using all random GPS points taken in the field and environmental variables from the literature (annual rainfall, elevation, soil pH, soil texture, distance to streams) has the lowest highest ROC value, but spreads out the most the suitability to areas where *Guadua* points were not collected and are empirically known to have *Guadua*. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. CT = cumulative threshold; FPA = fractional predicted area; TROR = training omission rate; TEOR; testing omission rate.

CT	Description	FPA	TROR	TEOR	P-value
5.445	Minimum training presence	0.223	0	0.012	0.00E+00
42.531	10 percentile training presence	0.031	0.098	0.16	0.00E+00
4.623	Balance training omission, predicted area and threshold value	0.242	0	0.012	0.00E+00



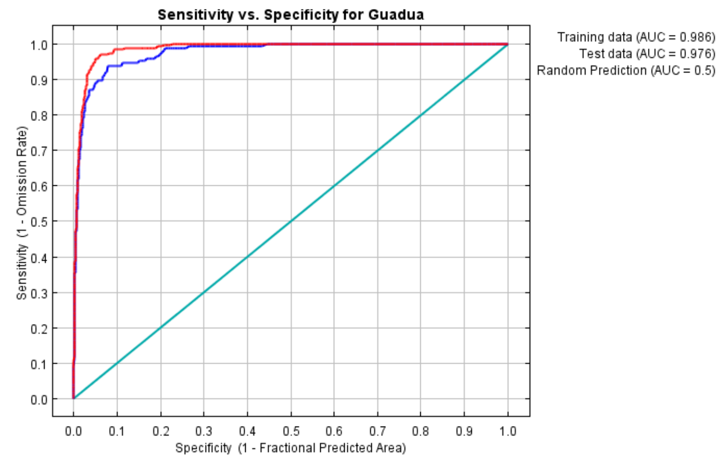
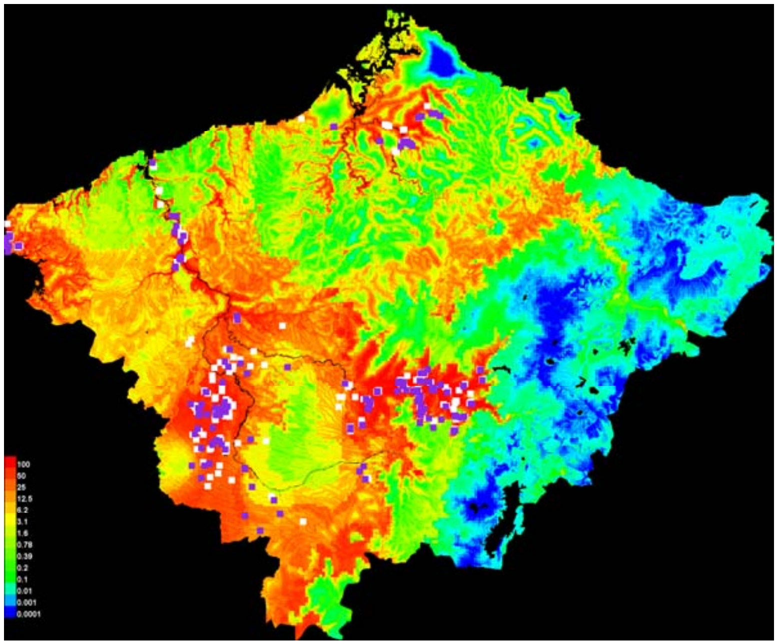


Figure 3.11 Model 5: Suitability map and the corresponding threshold values when using all random GPS points taken in the field, environmental variables from the literature (annual rainfall, elevation, soil pH, soil texture, distance to streams), and the most predictive variables from model 1. Had and AUC value of 0.986, it spreads slightly the suitability compared to model 1 but fails to select areas where *Guadua* points were not collected and are empirically known to have *Guadua*. Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. CT = cumulative threshold; FPA = fractional predicted area; TROR = training omission rate; TEOR; testing omission rate.

CT	Description	FPA	TROR	TEOR	P-value
1.494	Minimum training presence	0.529	0	0	1.15E-44
31.596	10 percentile training presence	0.113	0.099	0.128	0.00E+00
2.211	Balance training omission, predicted area and threshold value	0.487	0.003	0	1.92E-52



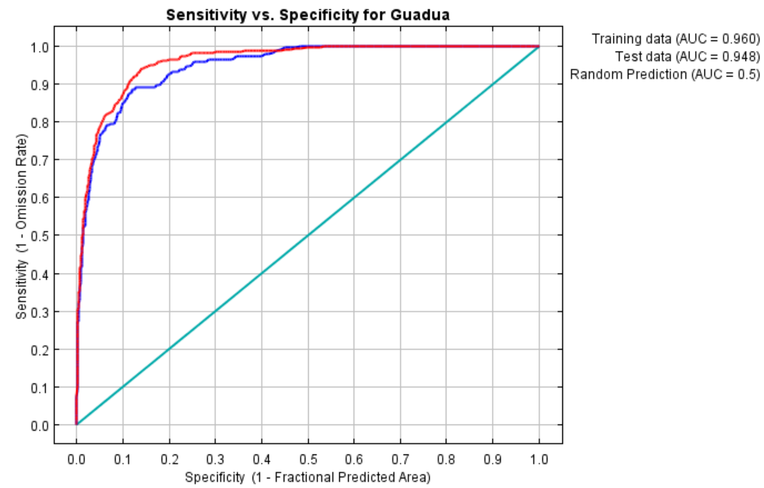
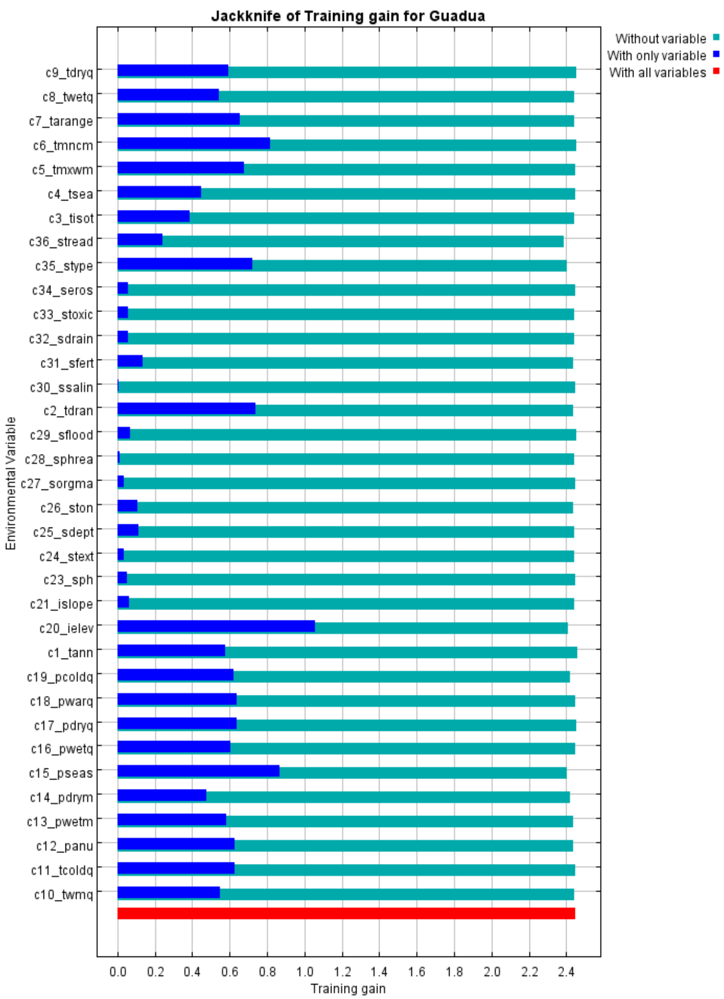
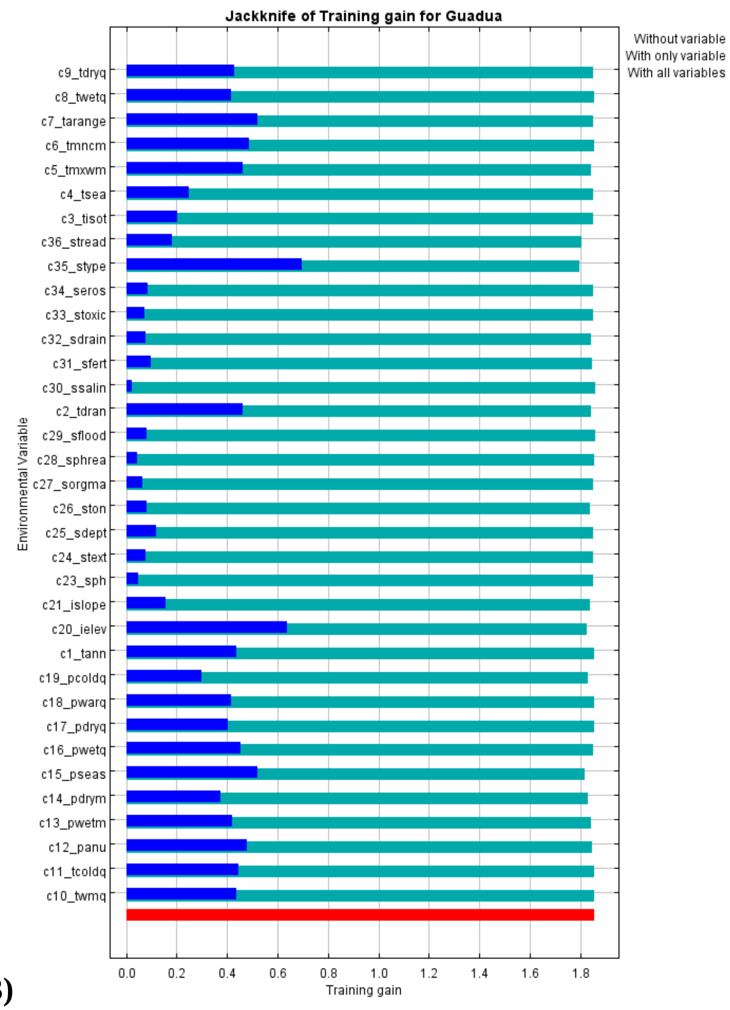


Figure 3.12 Model 6: Suitability map and the corresponding threshold values when using all random GPS points taken in the field, plus the banana points and using environmental variables from the literature (annual rainfall, elevation, soil pH, soil texture, distance to streams), and the most predictive variables from model 1. Had and AUC value of 0.96, it spreads the suitability similarly to model 3 but the AUC is lower than that of model 3.Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations. CT = cumulative threshold; FPA = fractional predicted area; TROR = training omission rate; TEOR; testing omission rate.



1)



3)

Figure 3.13 Analysis for variable importance for training gain: Model 1 (*guadua* points with all environmental variables) - The environmental variable with highest gain when used in isolation is c20_ielev, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is c36_stread, which therefore appears to have the most information that is not present in the other variables. Model 3 (*guadua* & banana points with all environmental variables) - The environmental variable with highest gain when used in isolation is c35_stype, and the environmental variable that decreases the gain the most when it is omitted is c35_stype.

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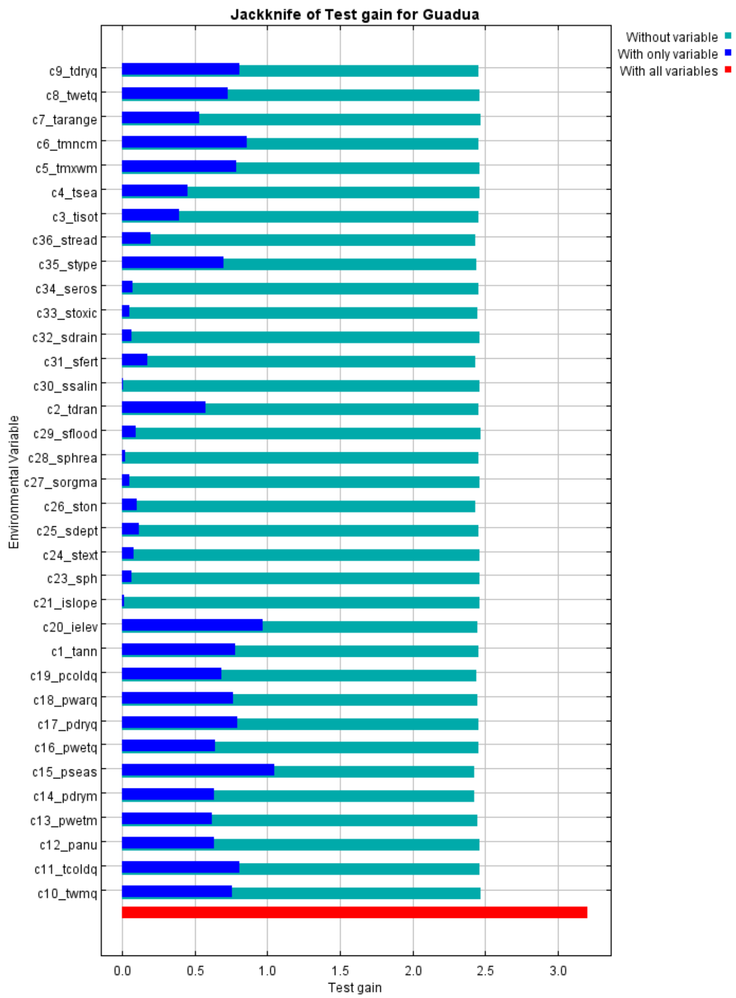

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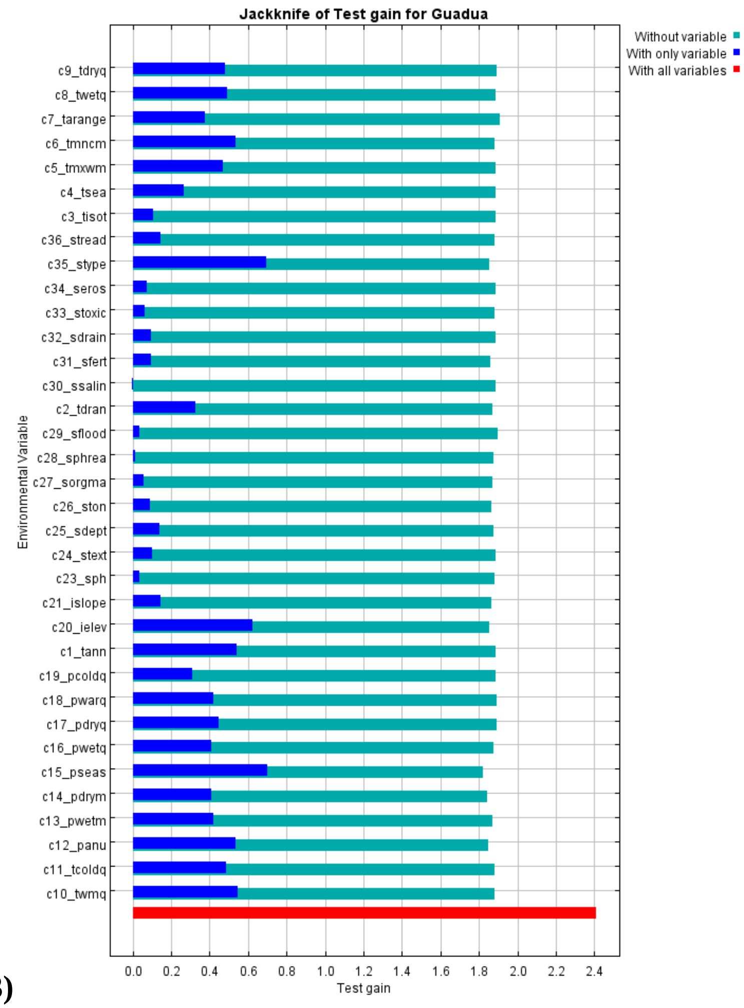


Figure 3.14 Analysis for variable importance for test gain: Model 1 (Guadua points with all environmental variables)- The environmental variable with highest gain when used in isolation is c15_pseas, which is also the environmental variable that decreases the gain the most when it is omitted. Model 3 (Guadua & banana points with all environmental variables) - Two environmental variables tie with the highest gain when used in isolation, c35_stype and c15_pseas, and the environmental variable that decreases the gain the most when it is omitted is c15_pseas.

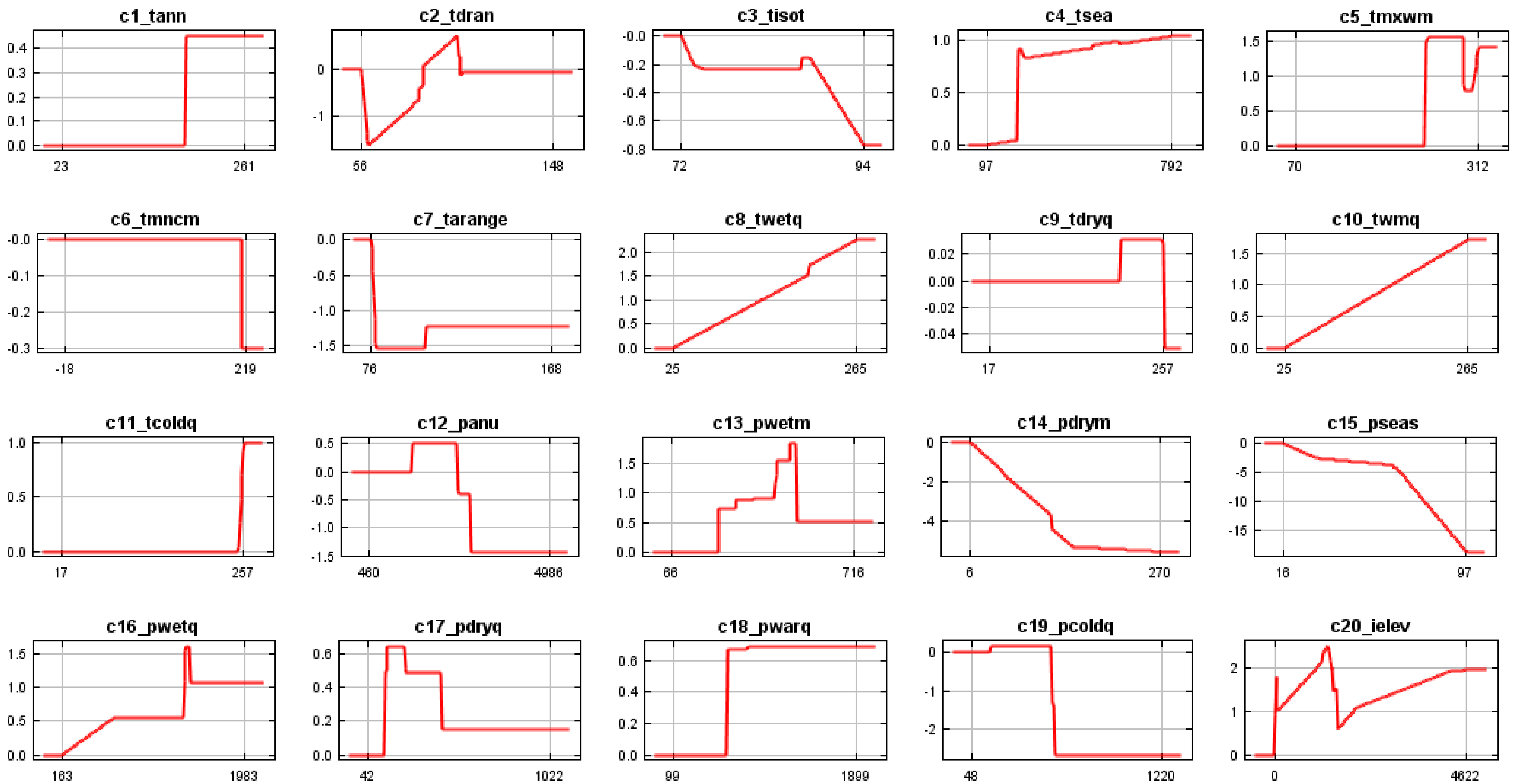
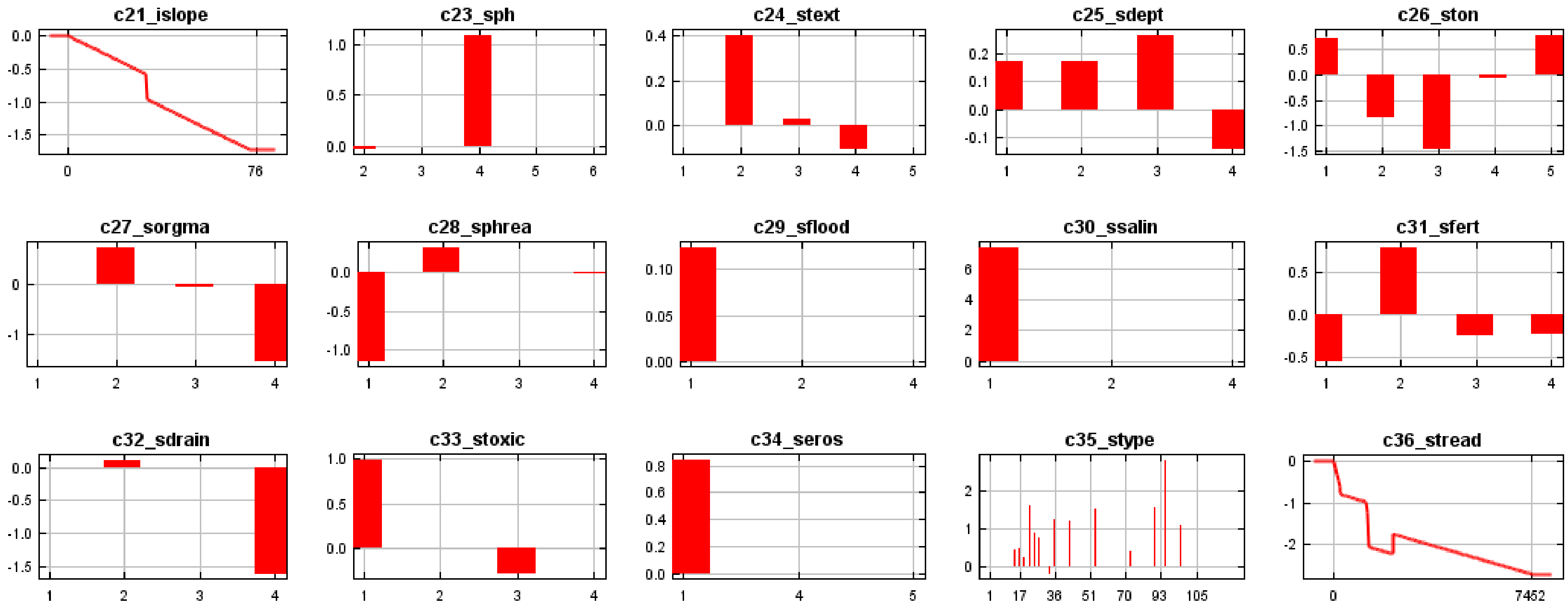


Figure 3.15 These curves show how each environmental variable affects the Maxent prediction for Model 1 (*Guadua* points and all environmental variables): The (raw) Maxent model has the form exp(...)/constant, and the curves show how the exponent changes as each environmental variable is varied, keeping all other environmental variables at their average sample value. Table 3.1 has the name and description for each variable. Temperature related variables are expressed in °C/10.



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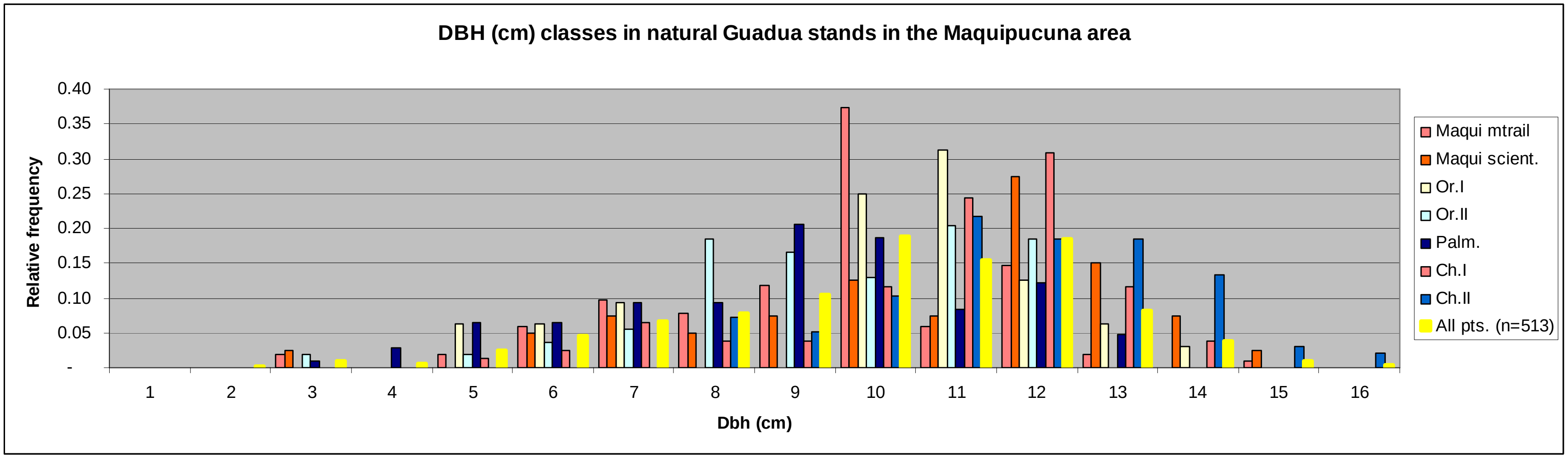
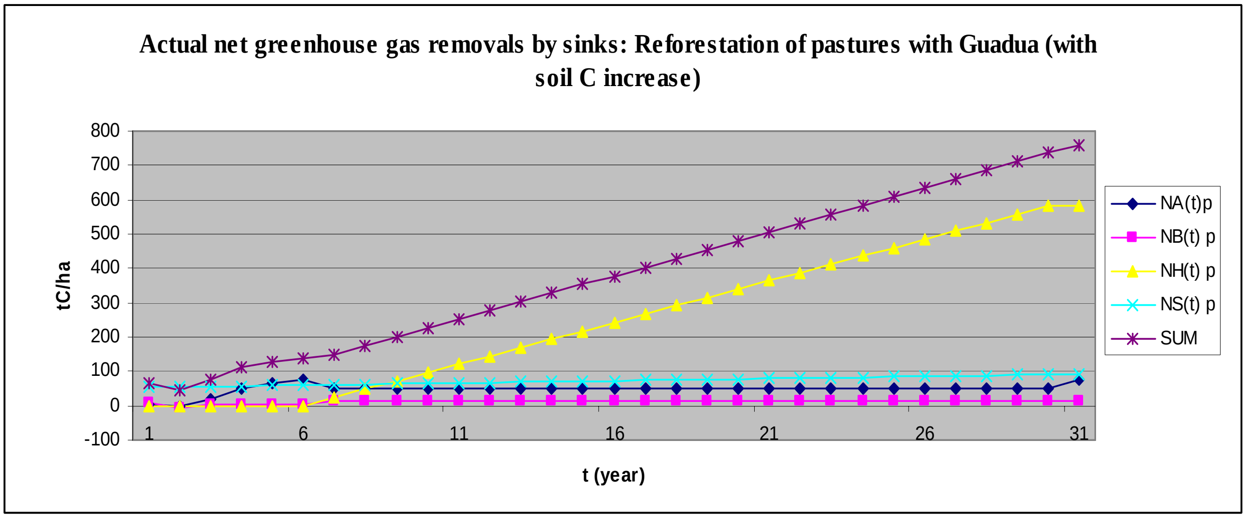


Figure 3.16 Distribution of diameter classes in 7 natural Guadua stands in the Maquipucuna Reserve area. Maqui mtrail and Maqui scient. are stands at the northern end of the Maquipucuna Reserve. Or. I and Or. II are stands at the Orongo locality. Palm. is a stand in Palmitopamba. Ch. I and Ch. II are stands in the Chacapata locality. All pts. is the result grouping the diameter at breast height (DBH) measurements of all localities.



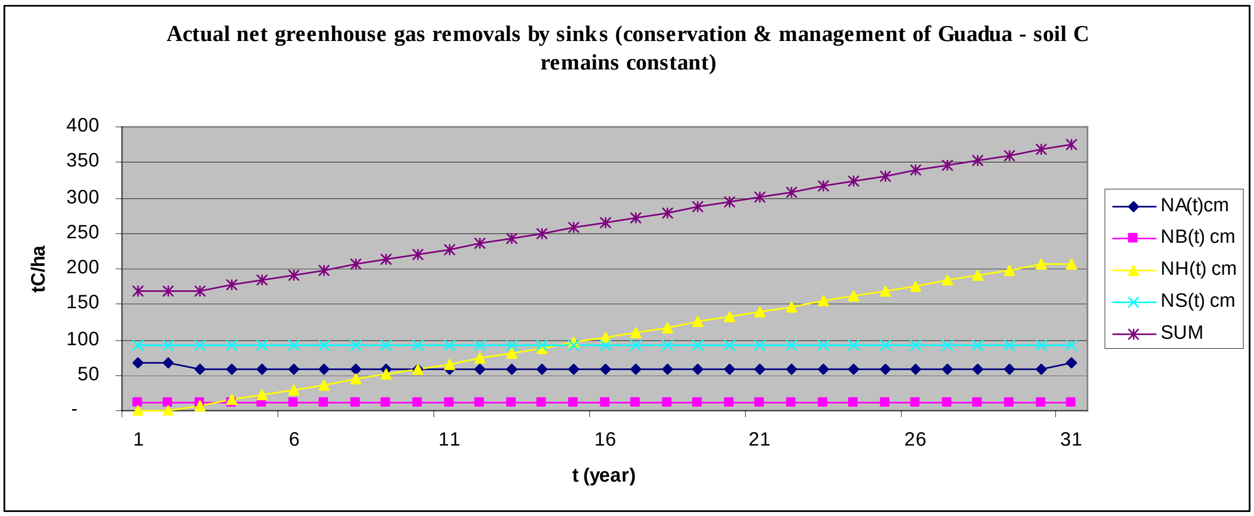


Figure 3.17 Carbon accumulation curves for Guadua projects. SUM = Net anthropogenic tC/ha removal by sinks; $NA_{(t)p}$ = Above ground tC/ha removal by sinks; $NB_{(t)p}$ = Net tC/ha baseline + baseline removal by sinks; $NH_{(t)p}$ = Net tC/ha harvested + stored as timber; $NS_{(t)p}$ = Net soil carbon tC/ha. *p* = reforestation of pasture with *Guadua*, *cm* = conservation and management of native *Guadua*.

CHAPTER 4

THE CHOCO ANDEAN CORRIDOR PROJECT: LESSONS LEARNED

4.1 BACKGROUND

4.1.1 The Maquipucuna Reserve

Located on the western slopes of the Andes and less than two hours away from Quito, the Maquipucuna Reserve is the gateway to the Chocó Andean Corridor in both space and time. The experiences gathered in the establishment and management of the Maquipucuna Reserve and during the building of its community support were the foundations for planning the Chocó Andean Corridor. The establishment of a conservation project in the Maquipucuna area epitomized the challenges of conservation in Ecuador. Conservation in Ecuador is hampered by: lack of government support and rampant corruption instigating land trafficking, marginalized rural communities making a meager living in the surroundings and fragmenting the area by cutting timber and making charcoal to establish pastures, communities that feared that establishing a conservation area would do away with their jobs as timber cutters and farm workers, lack of funding for long term protection of the Reserve, insufficient studies to inform of the specific importance of the area, and extreme views and policies of environmentalists (from the right and the left) against purchasing land for conservation—policies that still hinder private conservation (Jost 2006).

The Maquipucuna Reserve is located in the Parroquia Nanegal, at the southeastern extreme of the Chocó Andean Corridor (78°37'W, 00°05'N) (Figure 4.1), and nearby towns are Yunguilla, Nanegalito, Sta. Marianita, Nanegal, Palmitopamba, and Chacapata. The Reserve is owned and managed by the Maquipucuna Foundation and consists of 5456 hectares, ranging in elevations between 962 and 2873 m.a.s.l., of which over 90% are old growth forests, whereas the rest are secondary forests and shade-grown coffee. The remnant pasture and sugar cane areas are becoming reforested through a climate change mitigation project (ChoCO_2) within the Clean Development Mechanism of the Kyoto Protocol.

The vegetation types of Maquipucuna are Western Andes montane cloud forests and Western Andes lower montane evergreen forests (Sierra 1999). According to the classification of Harling (1979), this area could be called ‘cloud forest’, a term commonly used for areas across Tropical America, but is generally divided into two categories of ‘lower montane wet forest’ and ‘high montane cloud forest’. The first of these two covers the majority (80%) of the Reserve, from 962 – 2500 m.a.s.l. and is the vegetation type on the north side of the Reserve. Its soils are mainly Andisols (USDA Taxonomy) derived from volcanic ash, on steep slopes, which for the most part surpass 50% slope. The surface soil and upper sub-soil derive from Holocene volcanic eruption over buried palaeosols, and the last ash deposits from which modern soils have developed are generally homogenous (Rhoades 1997). Annual precipitation from data taken over more than 10 years indicate that, for the northern part of the Reserve near Nanegal, the annual average is 2179 mm, while near sourthern edge of the Reserve , near Nanegalito, is 2453 mm (Fundacion-Maquipucuna 1995). Annual average temperatures, obtained through GIS analysis extracting the values from high-resolution climate layers (Hijmans et al. 2005b), for the lower elevations of the reserve is 20.5°C, with an average daily range of 13.6°C, minimum temperature of the coldest month of 15.1°C, and the maximum temperature of the warmest month of 25.7°C. For the highest elevation, the annual average temperature is 13.5°C, with an average daily range of 9.3°C, minimum temperature of the coldest month is 6.4°C, and the maximum temperature of the warmest month is 20.7°C.

The purchase of the land was possible thanks to the vision of the Thomas and Clara Butler foundation, which—although it had already committed some funds for the land purchase of Maquipucuna through the TNC-Fundacion Natura-WWF’s debt-for-nature swap—gave a direct and extra grant to F. Maquipucuna to secure the land purchase at the end of 1988 and thereby established the Maquipucuna Reserve, since the debt-for-nature swap process of approval lingered through 1989. The first property of 2500 hectares purchased by F. Maquipucuna was then owned by Banco del Pacífico after the bank had received it as a payment for a defaulted loan of a timber company that went bankrupt by mismanagement of the loan money. The bank had initiated a process of fragmentation of the land by the sale of 80-hectare parcels, which was stopped by the purchase of the whole property. The management and protection of the reserve was funded during the first years by the interests[6] of a donation made by the Butler Foundation through the The Nature Conservancy and Fundación Natura to purchase debt-for-nature (Deacon and Murphy 1997). In 1989, Fundación Maquipucuna requested the Ministry Agriculture (then in charge of environmental and forests affairs) to declare the area and its buffer zone as a Protected Forest. The category of "*Bosque y Vegetación Protectora*"—the only private protection category in current forestry legislation—was granted to the Maquipucuna Reserve and the surrounding Upper Guayllabamba River Watershed (UGRW) in 1989. Subsequent years' protection of the Reserve have been funded by additional direct grants of the Butler Foundation and reinforced by training and additional community involvement by a one-time GEF-World Bank through the community environmental guards program of the Chocó Andean Corridor grant.

The Maquipucuna Reserve has extraordinary levels of biodiversity; a characteristic that led Dr. Grady Webster to define Maquipucuna as "one of the botanical crown jewels of the Andes" (Webster and Rhode 2001). After more than 15 years of inventory work the flora of the Maquipucuna Reserve and its immediate surroundings is known to include 157 families, 663 genera, and 1960 species of vascular plants (Webster and Rhode 2007). Maquipucuna also harbors 75 IUCN Red listed plant species (IUCN 2006) and 322 species of orchids, of which 56 are endemic (Reynolds 2004). The total plant species list of the Maquipucuna area represents 12.20% of the entire inventory of vascular plants for Ecuador (Jørgensen and León-Yánez 1999, Webster and Rhode 2007). In the year 2004, Birdlife International, Aves y Conservación and the Ministry of Environment recognized the Maquipucuna—Guayllabamba area as an Important Bird Area (IBA). At least 367 bird species, including 30 species of hummingbirds and 59 threatened species (Greenfield 1993, Fundacion-Maquipucuna 1995, Prieto 2003, Leon 2006) represent over 20% of the bird diversity of the country or 4% of the earth's bird diversity. The high biodiversity of the Maquipucuna Reserve has also been documented with other fauna groups: 220 species

[6] The Butler Foundation channeled through the debt-for-nature swap for the Maquipucuna Reserve two US$25,000 grants which at about US$0.10 of the face value purchased US$250,000 of debt to be disbursed in the local currency Sucres in a lapse of 5 years. Fundación Natura retained the capital of the first donation and capital and interests of the second donation.

of butterflies identified over only 350 collector hours (Raguso and Gloster 1995). Vertebrates include the endemic frog Colosthetus maquipucuna (Coloma and Ron 2004) among many frog species, and at least 45 species of mammals including the charismatic Spectacled Bear (Fundacion-Maquipucuna 1995). The Reserve has a scientific station, Thomas Davis Scientific Station, located on the north end of the Reserve, and is one of few research field stations found in the Tropical Andes region (Webster and Rhode 2001). Using this station as a base, scientists from Ecuador and elsewhere have carried out research projects on a broad range of topics and biodiversity assessments in both the Reserve and the Chocó Andean Corridor (Currie-Alder 1997, Rhoades 1997, Eckert 1998, Fernandez and Palacio 1999, Zahawi and Augspurger 1999, Bostwick 2000, Kapan 2001, Svenning 2001, Castellanos et al. 2003, de Koning et al. 2003, Lash 2003, Persson 2003, Suárez-Capello et al. 2003, Udvardy 2003, Droogenbroeck et al. 2004, Küper et al. 2004, Myster 2004, O'Dea et al. 2004, Reynolds 2004, Stephenson et al. 2004, Heinrichs 2005, Justicia and Carroll 2005, O'Dea et al. 2006a, O'Dea et al. 2006b, Widener 2006, Baez and Balslev 2007, Tian et al. 2007). The Scientific Station is located alongside the Eco-Lodge Umachaca and is part of the ecotourism infrastructure at the Reserve, which serves national and international tourists. This complex also serves as a base for environmental education, such as the *Niño Naturalista* program. There is also a model agroecologic self-sufficiency farm (PASA) with an organic garden, other crops, and livestock including chickens, fish and pigs. The Research complex consists of the Scientific Station, as well as the Training Center in Sta. Marianita, Orongo agricultural research station, and the Pucara of Palmitopamba, the latter for archeological research. The Training Center has a tissue culture laboratory where orchids and bromeliads are raised from seeds and sold through one of the Foundation's micro-enterprise projects. Eventually, endangered local orchids will be propagated here and returned to augment wild populations. The Orongo field site, located one hour from the Reserve, serves primarily for shade-grown coffee production and integrated pest management research. The Pucara of Palmitopamba is a site for archeological exploration and education that dates back to pre-Inca and Inca times. All of these sites are used for national and international volunteer tourism programs and internships as well.

The challenges faced in protecting the integrity of the properties of Maquipucuna typify some of the most pressing barriers to conservation in Ecuador, the corruption and lack of land tenure security that threaten both the private and government public property and the protection of ancestral protected territories of indigenous communities. Invasions and squatting by groups organized by land traffickers and speculators, habitually instigated by corrupt employees from government offices, have plagued the southern edge of the Reserve. Because of its proximity to the newest highway that connects Quito with the coast and a revaluation of forested land for ecotourism, the price of land in the area has increased, between 1988 and 2007, from $25 per hectare to over $1000 per hectare and with that, the interest of land traffickers has greatly increased. In 2004, the squatting on Reserve land became a problem that reached critical proportions and attracted extensive media attention and massive support from local communities surrounding the Reserve and from the Chocó Andean Corridor as far away as Otavalo for the protection of reserve lands from squatters (Fundacion-Maquipucuna 2004, LLacta.org 2004). At that critical point, the threatened legal protection of the Reserve motivated for the first time the General Accounting Office (GAO) to audit INDA (Instituto Nacional de Desarrollo Agropecuario) and other government entities for issuing of land titles to colonists (Davila 2005a). The GAO report found irregularities and ordered the Instituto Nacional de Desarrollo Agropecuario (former Agrarian Reform Office) to abstain from issuing land titles in a protected area. The GAO found that the squatters were using a land title of a property [7] of about 112 ha outside the Maquipucuna Reserve in the Upper Guayllabamba River Watershed Protected Forest to support their claim of over 1500 ha of land within the Maquipucuna property. For the same reason, the GAO demanded that the Ministry of Environment take better care of its Protected Forest (UGRW) and prepare its management plan. The GAO also ordered the municipal government of Quito to prepare a study of the area and define clearly the limits of the government protected area and to also

[7] The land title is for the *Montecristi-Chorrillos* property, which had been taken away from its original owner—an old sick man who could not cultivate on his property—through an Agrarian Reform and Colonization Law disposition. The Montecristi-Chorrilos property covers an area of forests on very steep terrain with slopes of 100% and higher and its extension is ten '*caballerias*" or about 112 ha. A '*caballeria*" is a unit of land area used in Spain, South America, Texas, and the Caribbean used between the 16th–20th centuries equivalent to 11.2896 hectares or 16 square '*cuadras*' (United-Nations 1966).

abstain from registering land titles without due diligence (Contraloria-General-de-la-República-del-Ecuador 2005, Davila 2005b). The GAO report was a great step towards progress in conservation because it created jurisdiction for a problem that afflicts the protection of many forested areas (Davila 2005b, a).

4.1.2 Government policies related to land tenure and biodiversity conservation

Ecuador has had some of the most progressive environmental legislation (Ministerio-del-Ambiente-del-Ecuador 2007). For instance, it is remarkable that the last political constitution of the Republic of Ecuador, which dates from 1998, identifies eight times either sustainable management of natural resources or economic sustainable development as both the right and duty of the people and the government. Its stress on sustainability surpasses all constitutions of the Americas (Center-for-Latin-American-Studies 2007). In 1996, Ecuador even created a Ministry of Environment, which is responsible for implementing the nation's environmental legislation and regulations. Unfortunately, the problem in Ecuador is its chronic lack of capacity to enforce laws and their regulations. It has been argued that the reason is the lack of funding for implementation and enforcement. In the experience of Fundación Maquipucuna, lack of funding is not the cause, but a lack of government's political will to assign enough resources to protect biodiversity—especially outside areas of the national park system. The other two barriers to implementation and enforcement are institutionalized corruption within various governments offices, but specially the land adjudication agency (INDA - Instituto Nacional de Desarrollo Agrario), and a lack of honest authorities who understand laws and their application.

4.2 THE ORIGIN OF THE CHOCO ANDEAN CORRIDOR PROJECT, THE POLITICS, AND FUNDING OF ITS ESTABLISHMENT

From the onset of the establishment of the Maquipucuna Reserve, it was clear that fragmentation and deforestation taking place in the surroundings was a challenge. Thus, Fundación Maquipucuna (FM), with the proposal for land purchase of the Maquipucuna Reserve area, presented a proposal to TNC in 1988 to establish a system of protected areas with community-based projects to expand the Maquipucuna area. As funding was available only to purchase the land of the Reserve, soon after the land was purchased, FM put a request to the National Forestry Directorate (DINAF) to declare the Reserve (then

2,500 hectares) and its surroundings as “Protected Forests and Vegetation” (Bosque y Vegetación Protectora). Between February and July of 1989, the DINAF declared the Maquipucuna (2,500 hectares) and the surroundings, Guayllabamba Upper Wathershed (13,880 hectares), as Protected Forests and Vegetation. That is a weak legal protective status, but the only available in Ecuadorian legislation for the conservation and management of private areas.

In the early days, fundraising for community work in the surroundings of the Maquipucuna Reserve was especially difficult. First, because there was little national and international awareness of its ecological importance with publications and attention centering on the extinction and forest loss in the lowlands of western Ecuador (Dodson and Gentry 1991) and, second, because international aid agencies did not consider the local communities surrounding the areas “the poorest of the poor (Coleman 1991).”

Thanks largely to the support of the Butler Foundation, to such research alliances as with the University of California at Davis and the University of Georgia, U.S. Peace Corps volunteers, and volunteers from various parts of the world, Fundación Maquipucuna initiated various community-based alternative-income-generating activities in and around the Maquipucuna Reserve during the 1990s (Polson 1996, Vogel 1997, Alcorn 2000, TNC 2000, Verdeny-Esteve 2006). These activities include an international renowned ecotourism program, a community guards program, and a scientific research program. In 1993 a proposal to manage the buffer zone area of the Maquipucuna Reserve was submitted to the World Conservation Union (IUCN), which subsequently funded an Environmental Socio Economic Assessment - ESAR (Fundacion-Maquipucuna 1995). Following this assessment, IUCN established the Program for Native Forests (PROBONA), which together with the United Nations Small Grants program provided FM with the funding to initiate a community-based forestry program with the community of Yunguilla. The ESAR helped identify problems and strategies that became the basis for further projects that FM drafted to obtain funding, such as from the Dutch IUCN committee, with which FM initiated a community run ecotourism program with the Cooperativa Santa Lucía. Both Yunguilla and Santa Lucia are considered national successes and are often featured in international manuals of ecotourism and the media (Drumm et al. 2005).

Between 1992 and 1993, the concept of a conservation corridor was developed between FM and the Institute of Ecology (now Odum School of Ecology) at the University of Georgia (UGA). After various trips to the Chocó Andean region, FM and UGA realized that FM's experience in the conservation of the Maquipucuna Reserve and its surroundings could be replicated to address the problems of deforestation and environmental deterioration in the rest of the area. Various types of such environmental degradation as pollution of the rivers from the oil palm factories and high levels of sedimentation were observed in the lowland rivers in the area of Maldonado, Borbon and Esmeraldas that partly resulted from the deforestation in the Chocó Andean region. The goal was ambitious, but realistic; there were a large number of protected areas[8], both public and private, and aerial photos indicated that opportunities still existed for saving the remaining forests. By reconnecting forest patches and protected areas through reforestation and by establishing surrogate shade-grown coffee forests, we were making a commitment to create a continuous wildlife corridor from the coast to the summits of the western Andes. Between 1993 and 1994, the United Kingdom-based charity, Rainforest Concern when it was just beginning visited Fundación Maquipucuna and offered support to continue the land purchases. After visiting the Maquipucuna Reserve and its projects and learning about the Chocó Andean Corridor, Rainforest Concern expressed its desire to partner in the establishment of the Chocó Andean Corridor project.

Between the years 1997 and 1999, Fundación Maquipucuna negotiated the project with the Global Environmental Facility-World Bank (GEF-WB) and was awarded a planning grant. This was the first time that a conservation corridor had ever been proposed in Ecuador and the Corridor idea received various types of reactions. The author, staff of the Fundación Maquipucuna, and consultants, organized a participatory process of planning that included several field visits to land owners, communities, and NGOs working in the area, and various meetings held in Quito. A stakeholder assessment, a report of

[8] Mindo-Nambillo Protective Forest, Cuenca Alta del Río Guayllabamba Protective Forest, Maquipucuna Protective Forest, Pululahua Geo-botanical Reserve, Los Cedros Protective Forest, El Chontal Protective Forest, Cotacachi-Cayapas Ecological Reserve, Awá Ethnological Reserve, Cayapas-Mataje Ecological Reserve, and Protective Forests La Florida, Siempre Verde, and Alto Chocó.

recommended conservation routes, a regional ecotourism planning report of the Chocó Andean Corridor, and the project proposal resulted from the planning grant (CDC 1999, Trousdale and Ross 1999, Justicia 2000). The interest, support and participation in the preparatory phase of the proposal were extensive, and the majority of the stakeholders, especially the rural communities, were very welcoming of the project. However, some of the large NGOs were not supportive for various reasons; one complained that "it" should be the one to manage such a large-scale project; another NGO complained that establishing conservation corridors was a way to privatize biodiversity (Arcos 1999, Bravo 2004). However, the support at the local community level was overwhelmingly large, and in the year 2000 Fundación Maquipucuna received new funding from the GEF-WB for a medium-sized project (GEF, 2000). At the end of 1999, FM requested that it be represented on the board of Rainforest Concern in the same way that in all the years of partnership Rainforest Concern was represented on FM's Board of Directors because that had been the original agreement between both organizations and Rainforest Concern was publicizing such representation . At that request, Rainforest Concern decided to leave Fundación Maquipucuna's Board and to continue raising funds for land purchases and community development projects with other NGOs using a Chocó Andean Corridor land-purchase campaign and by setting up its own office in Quito. This included collaborating with Flora and Fauna International in 2003 to purchase the first part of the Awachachi reserve to link the Cotacachi-Cayapas Ecological Reserve to the Awá Indigenous Reserve in the Esmeraldas province. In the year 2000, representatives of Fundación Maquipucuna visited Conservation International- Washington (CI) to lobby support for the Chocó Andean Corridor, CI representatives became enthusiastic about the project, and CI-Washington and Fundación Maquipucuna signed a cooperation agreement. However, once Conservation International established its own office in Ecuador, it also established its own Conservation Corridor Chocó Manabi strategy, and though its corridor proposal included Fundación Maquipucuna's project as a match, it excluded the Tropical Andes mid-elevations of western Ecuador, which are part of the altitudinal conservation strategy Chocó Andean Corridor (Conservation-International 2005, 2007).

On February 15, 2001, the Government of Ecuador signed the authorization for the company Oleoducto de Crudos Pesados S.A. (OCP) to construct a new pipeline for the country to transport heavy crude oil from the Amazon region (Lago Agrio) to Esmeraldas on the Pacific Coast. The OCP consortium held seven members: Occidental Petroleum, Alberta Energy Corp., Kerr McGee, AGIP-ENI, Perez Companc, Repsol-YPF and the construction company Techint. The construction of the OCP pipeline was to be financed by a consortium of international banks, led by Westdeutsche Landesbank of Dusseldorf (WestLB). As shown in figure 4.2, the OCP would take the northern route, crossing one of the last intact remnants of forest within the Chocó-Andean Conservation Corridor, the Protected Forests Cuenca Alta del Río Guayllabamba and Mindo-Nambillo. Two years before the authorization, at the time of bidding, the oil company Williams proposed an alternative route for the construction of the pipeline. Williams Corp. of Tulsa, OK, USA, built the existing Trans-Ecuadorian Oil Pipeline System (SOTE) pipeline 30 years ago, so it had much experience with Tran Andean pipelines. Both the OCP and the Williams route would follow the existing SOTE for most of the way, with the only difference that OCP diverts north of Quito, while Williams suggested taking the existing route south of the capital. In the year 2000, Fundación Maquipucuna, CECIA (now Aves & Conservación) and local conservation groups co-founded and actively participated in the Committee for the Route of Least Impact (*Comité Pro-Ruta Menor Impacto*) because they believed the Williams route would be a better choice. The overall ecological and social impact of the Williams route would be much smaller because it followed a route where damage had already been done, it would not cross any protected area, and it would need less new access roads. Landowners of the areas affected in the Chocó Andean Corridor, such as Mindo and the Guayllabamba Watershed, were active in the Committee; however; the rest of the national and international NGOs were completely apathetic until it was too late. Despite the efforts of the *Comite Pro Menor Impacto*, the Government of Ecuador approved the construction through the Northern Route. The construction contract specified that OCP must comply with the World Bank's social and environmental safeguard policies, although the World Bank (WB) in no way was involved with the financing of OCP. Paradoxically, the only connection the WB had to OCP was through the financing of the Chocó Andean

Corridor. Multiple North American and European activists groups, as well as political organizations and institutions, became involved in the opposition against OCP after the contract was awarded. These groups primarily tried to exert influence on OCP through over-simplified messages pressuring U.S., German and Italian members of either the OCP or the financing consortium (Widener 2006). The opposition to OCP was formidable, especially as not only activist groups were involved, but also such more mainstream organizations as the Green Party of Germany and German Trade Unions. These groups tried to pressure the Westdeutsche Landesbank, along with other financing institutions, to force OCP, through the project's financial arrangements, to apply World Bank standards. The World Bank became nervous about all the international pressure from activist groups and warned FM that it might have to stop funding the GEF-Chocó Andean Corridor. Fundación Maquipucuna had to switch its efforts to building institutional support to guarantee enforcement of World Bank Social and Environmental Standards (WBES) for Best Environmental Practices from OCP. It prepared a report about OCP's compliance with WBES, which was distributed at a public hearing of the Parliament of North Rhine Westfalia, and FM representatives visited the Westdeutsche Landesbank in Germany. Birdlife International also played a prominent role, as it was the only international NGO that was involved in the process from the beginning, and its local associate CECIA was invited to make a presentation at the public hearing in North Rhine Westfalia. The outcome was that the WB wrote a letter to OCP expressing its concern for its GEF project and requested that OCP cease claiming to adhere to World Bank standards, unless those claims were proven through independent verification. After that letter, the risk of withdrawing funding from the Chocó Andean Corridor diminished, but staff of the project with World Bank representatives periodically continued inspecting the construction sites to verify that the OCP would be adhering to WBES. FM also intensified training and the community guards program and participated in the Comisión de Veeduría (a local watch group).

According to the Environmental Impact Assessment (EIA) of the OCP of January 2001, the section of the pipeline, that crosses the Corridor (250 km – 280 km) falls in a 3E category. That means that catastrophes which could have dramatic consequences, such as earthquakes and volcanic eruptions, are probable (occurring 1 time every 10 to 100 years). The areas under more threat of spills or failure of the pressure reducing station of Chiquilpe would be the area surrounding the Chiquilpe Station and the two rivers that pass close by the Maquipucuna Reserve (Rio Pichan or Nono) and the Upper Guayllabamba River Watershed (Rio Alambi). The financing of a compensatory fund is one of the World Bank's safeguard environmental standards, which OCP originally was willing to fund but not in an amount large enough to create compensation for the whole OCP, but only for a small project solicited by Fundación Natura for the Mindo area. Fundación Maquipucuna was a critical player in increasing the amount of the fund and influencing the negotiations of the Eco-Fondo (a trust fund with contributions from the oil companies that formed OCP) among Bird Life International, CECIA, Fundación Maquipucuna, Fundación Natura. The trust funds would be used to benefit other vulnerable areas along the route of the OCP. After more than three years of negotiations, OCP established a trust fund of US $16,930,000 to be spent until 2022, of which 60% is earmarked for environmental sensitive areas along the OCP, 30% for protected areas of the national park system located in areas of oil production, and 10% for such strategic environmentally fragile areas as the dry forests of Southwestern Ecuador. By then various other NGOs had joined in the negotiation of the Ecofund including The Nature Conservancy. The fund was to be managed by the newly created Fondo Ambiental Nacional, which started allocating funds in 2005. To date, the Chocó Andean Corridor region has only received three grants from this fund, two grants through Aves & Conservación (Birdlife International's local associate) and one grant to Fundación Agua for analyzing the options for the definition and declaration of a highly biodiverse marine protected area in the Esmeraldas region.

Recently, Fundación Maquipucuna has been awarded two major grants to continue the establishment of the Chocó Andean Corridor. *Our Shared Forests*, from the United States Fish and Wildlife Service and *Securing altitudinal connectivity in the Chocó Andean Corridor: conservation tools for the conservation of the Guayllabamba-Maquipucuna reserve and beginning the creation of the Santiago-Cayapas reserve* from the MacArthur Foundation. *Our Shared Forests* is a bi-national migratory bird conservation partnership between the Ecuadorian NGO Fundación Maquipucuna, the

University of Georgia's State Botanical Garden, and the Chocó Andes Alliance and APROCANE (Association of cocoa producers of the north of Esmeraldas) in Northwest Ecuador. It will enhance the conservation of neotropical migratory bird species in both Northwest Ecuador and Georgia. In Ecuador, the project targets the Chocó Andean Corridor, which is recognized as one of the earth's top biodiversity hotspots and foci of bird endemism. In Georgia, it targets 10 bird species that migrate between Georgia and Northwest Ecuador.

Both new grants use a multidisciplinary approach that blends scientific information, conservation priority setting, restoration, and education, and both will help increase significantly the area under private protection in Northwest Ecuador by setting up at least 14,000 hectares of newly protected private forests. Additionally, they will enable a management plan for the extant Protective Forests Guayllabamba and Maquipucuna, which comprise the IBA Maquipucuna-Guayllabamba and part of the IBA Mindo. In the lowlands, the research will define the guidelines for a 20,000-hectare prospective protective forest, "The Río Santiago-Cayapas," and will make other strategic investments needed for long-term conservation. It will strengthen the capacity of communities related to the protected forests to adhere to conservation, by promoting third party certification of over 800 hectares of shade-grown coffee and cacao in order to qualify for the Smithsonian's "Bird-friendly" label.

4.3 CONCEPTUAL UNDERPINNINGS OF THE CHOCO ANDEAN CORRIDOR

The need of establishing a protection corridor, rather than just establishing additional isolated reserves, is justified by the fact that these Chocó, Andean, and unique floristic elements share special common characteristics. Their flora share high levels of local and regional endemism, 90% of the species are seed dispersed by animals, and there is a marked presence of Andean taxons in the lowlands and vice versa (Gentry 1986, Gentry 1988, Raguso and Gloster 1995, Borchsenius 1997, Jørgensen and León-Yánez 1999, Webster and Rhode 2001). These characteristics point to high levels of altitudinal migration and a need for habitat continuity. Such movements might range from annual migrations of seed dispersers between dry and wet season feeding areas, to daily movements of birds between feeding and roosting sites. The corridor could also support permanent immigration and emigration of individuals (both animals and plants) among habitat patches. These particular characteristics indicate that connectivity should be a critical parameter in reserve design in Northwest Ecuador.

The ecological goal of the Chocó Andean Corridor is the conservation of the threatened biodiversity of the Chocó Andean ecosystems of Northwest Ecuador—the Chocó and the Andean Cloud forests—through securing their functional connectivity (Justicia 1995, 2000). The Corridor is envisioned as a matrix of protected and sustainable land uses, instead of isolated integrated conservation and development projects (ICDP), along an altitudinal gradient and as an alternative to the threats posed by unsustainable cattle farming, timber extraction, charcoal production, and monocultures and mining, which are resulting in severe habitat fragmentation (Justicia 2000). The Corridor aims to secure the protection of remaining forests between existing protected areas privately and with local communities' participation because the phytogeographic regions of Northwest Ecuador are not well represented in the National Park System (Sierra et al. 2002, Justicia and Nibbelink 2007).

The operational objectives of the Chocó Andean Corridor are:

1. To identify conservation priorities and guidelines for the Chocó Andean bioregion taking into account threat, representation and spatial patterns of distribution of biodiversity.
2. To establish pilot corridors by increasing the extent of the area under conservation and sustainable management between protected areas.
3. To increase the quality, quantity, and democratization of environmental information, facilitating decision-making related to conservation and sustainable management of biodiversity in the Chocó Andean bioregion.
4. To design and establish a system of economic incentives for conservation and sustainable management in the Chocó Andean bioregion.

The conservation and management of the remaining forests does not happen in isolation, but as part of complex ecological and socio-economic systems, such as climate change and globalization, which demand creative adaptive management responses (Holling 2001). Figures 4.3 and 4.4 illustrate the different elements of the Chocó Andean strategy and their relation. When we establish a new project, we evaluate what level of development each element has in the project area and that helps us prioritize our actions. The implementation of the Corridor has been posed at various scales, respectful of the processes and dynamics taking place at each scale (Gunderson and Holling 2001). To reach its goals, the project uses a dual scale approach that blends scientific information, stakeholder involvement, innovative financing options, and coalition building. Long-term planning, monitoring and database creation and enhanced coordination are sought at the regional scale, matched with intensive field-based work in strategic pilot priority areas, such as the surroundings of the Maquipucuna Reserve and the Comuna Rio Santiago Cayapas. The pilot projects, rather than being designed as isolated integrated conservation and development projects (ICDP), are intended to build the institutional infrastructure and grassroots support for local and regional conservation, as well as the experimentation with economic sustainable alternatives to deforestation. Furthermore, besides functional ecological connectivity, the Chocó Andean Corridor strategy emphasizes connecting cultures and reaching economies of scale to optimize production and market seeking.

4.4 NOTABLE PROGRESS

The Corridor Project has made significant progress over the 12 years since it began in 1992.

4.4.1 Ecotourism.

A successful model for eco-tourism was developed (Polson 1996, Verdeny-Esteve 2006). FM won two prestigious international awards for its contribution of eco-tourism to conservation and community development (Ecotourism Showcase 2000 and the Skal 2003). An organic farm has been established that produces vegetables, fruit, eggs, poultry, pork, and fish for the Maquipucuna eco-tourism lodge in the corridor. The farm is also used as a demonstration site for local farmers. Composted manure is used to grow aquatic plants that support fish aquaculture and also to fertilize seedlings of native trees that will be added into coffee plantations. Maquipucuna's ecotourism program is community based, so in addition to the Maquipucuna Lodge, Maquipucuna has supported two other communities in embarking on their own Ecotourism-related projects, Yunguilla and Sta. Lucía. The Maquipucuna Lodge is owned by the foundation and managed by people from neighboring Sta. Marianita. The Maquipucuna Lodge also serves scientists and volunteers who work at Maquipucuna or its surroundings. The other operations promoted by Maquipucuna are owned and managed by community organizations. Maquipucuna, Yunguilla, and Sta. Lucía participated in the national pilot program for eco-certifications of tourism operations in Ecuador. They were successfully certified by the Ministry of Tourism and the Ecuadorian Association of Ecotourism—only 13 operations nationally participated. Over 120 families benefit from the ecotourism programs initiated. Ecotourism has become an alternative to timber cutting, charcoal production, hunting, cattle ranching, and generally, it has helped people recognize that intact forests have economic value now and for their children's children. Furthermore, now community leaders, men and women, are predominantly associated with the ecotourism activity in contrast to the lowest political representation they held approximately 15 years ago. A 2001 study found that the people who are today involved in ecotourism and are predominantly leaders of their communities were formerly owners of remote mountain forest farms or "montañeros," and landless peasants who worked as share croppers and day workers cutting timber or helping in farms communities. At that time they had the least power, and the more influential people were cattle ranchers and sugar cane growers and processors; now the influence is more balanced (Flora et al. 2001).

4.4.2 Environmental Education

A children's environmental education program, '*Programa del Niño Naturalista'* (PNN) was designed and introduced at the Maquipucuna Reserve as a model program for the Choco Andean corridor. A major project goal was to guide teachers and children (as well as parents) into understanding and valuing the wonderful world of plants, birds, insects, and the complex relationships within the rainforest, while presenting basic concepts such as plant and animal life cycles, pollination mechanisms, macroinvertebrates as indicators of stream integrity, and the value of soil. The PNN introduces the organisms at the Reserve while highlighting issues affecting these organisms and the ecosystems they are a part of. The program formed the foundation for weeklong environmental camps and field trips for students from local and Quito schools from second to eighth grade. A related Maquipucuna *Naturalist Program* for adults provides training for local guides/ program leaders.

Several schools have adopted the PNN, and it is already paying for itself. Private schools from Quito participate in the program, paying a small surcharge allowing the participation of poor local schools; yearly over 1000 children continue participating in these activities. The PNN was developed by partnership between Maquipucuna and The State Botanical Garden of Georgia, the Museum of Natural History and the Institute of Ecology, all at the University of Georgia, Athens. Building on this partnership, a new international initiative is underway: "Our Shared Forests: Georgia and Ecuador's bird connection," which promotes migratory bird conservation and provides practical tools for teachers and children from schools in Georgia and Ecuador and for coffee and cocoa farmers of the Chocó Andean region.

As the number of children and people involved in education grew, so did ideas. Throughout the project, the conception of environmental education evolved into a new paradigm for total education where children first learn basic environmental concepts and thinking skills while adults learn practical skills to produce sustainably and to create sustainable communities. As originally planned, the project carried out training through workshops and outreach programs. Soon it realized that there exists a large demand for technical assistance; neither short-term projects nor a weak public education system can fulfill it. The themes taught were relevant—leadership, organic agriculture, crafts making, business administration, ecotourism, bamboo management, etc., but to have sustainable and widespread impact, training must be formalized.

A feasibility study for the Chocó Andean Institute for Sustainable Systems (CAISS) has been conceived as the mechanism for institutionalizing training. Numerous communities from the corridor and other focus groups interested in rural education in the conceptualization of CAISS participated. Unanimously, the participants envisioned CAISS as the vehicle to enhance the quality of rural education in ecologically significant areas—that is, a key to the long-term reconciliation of environmental conservation, social equity, and economic growth. Thus, they envisioned graduates as having the skills not just to survive, but also to succeed in the modern world in a way that maintains the unique ecological and cultural environments that they are part of.

To make it feasible in the short term, CAISS infrastructure will build on what already exists. Physical infrastructure includes a training center, coffee and cocoa processing stations and the Orongo Agro-ecological station. In terms of human resources, a volunteer program attracts qualified people from different parts of the world to cooperate with the project. Funding will be sought to develop and adapt curricula and for seed operational investments until CAISS has a system to overcome the intrinsic cultural gap and temporal nature of volunteering because the school has been envisioned as a living sustainable system with financial sustainability as a goal from the onset.

4.4.3 Reducing deforestation in the upper corridor

Neighboring private cooperatives and communities that control over 12,300 hectares have reduced their rates of deforestation greatly. The Santa Lucia cooperative no longer clears any new forest. The fifty-three families living in the Yunguilla community used to clear an average of about one hectare per year of new forest; now only five families continue to clear forest and these clear only about 0.25 ha/family/year. Over 500,000 native trees and bamboo have been planted on 2,000 hectares of farmland. There are several reasons for the decline in deforestation. First, the success of the eco-tourism program demonstrated that tropical forests had inherent economic value. FM has helped both communities develop their ecotourism programs. Second, profitable alternatives to timber cutting were developed. Large diameter native bamboo grows well in pastureland, and FM promotes it as an alternative to timber for building construction and furniture. FM established a community-run center in the nearby town of Nanegal to train local people in the production and uses of bamboo. Third, the importance of natural forest as watershed protection and the significance of biodiversity as natural heritage are part of a regional environmental education initiative.

4.4.4 Training

Women's groups have received training through several workshops on drawing, craft making, jam making, organic gardening, and accounting, among others. The rest of the training events have involved both men and women and focused on management of native bamboo stands (*Guadua angustifolia*), building and carpentry techniques with Guadua, business management, dairy products, invitro plant propagation, ecotourism (first-aid, environmental interpretation, ecotourism norms, accounting, Global Positioning Systems (GPS), and English as a second language) and agro-ecological farming. A multi-purpose training center includes a tissue culture lab for propagating orchids and bromeliads. The training center has been designed with areas to "learn by doing & producing."

4.4.5 Sustainable livelihoods

In addition to the employment and revenue generated by eco-tourism and related cottage industries of jams, cheese, crafts, other significant economic development initiatives involve native bamboo, shade-grown organic coffee and cacao and production of orchids and bromeliads. Approximately 160 families have formed the Chocó Andes Coffee Alliance and produce shade-grown coffee without the use of pesticides or synthetic fertilizer. By developing good production practices, high quality coffee grades, and direct market linkages, the farmers receive premium prices, nearly four times what they had been getting before the Alliance was formed. FM purchases coffee from the Alliance and markets it directly under a master market brand Chocó Andes, used for all Corridor products. Studies are underway to identify additional species of native trees that, when added to shade-grown coffee, will make the system more "bird friendly."

FM has also partnered with the small-farm Association of Cocoa growers of North Esmeraldas in the lower part of the corridor. Native *Theobroma cacao* is grown on these farms along with "improved" varieties of cacao. Cacao from the native trees produces an exceptionally high quality aromatic bean. FM has initiated a bird monitoring program geared to identify minimum shade requirements as well as other ecological criteria to create a “Bird-friendly Cacao” label that will help farmers receive higher compensation for their product.

4.4.6 Research to inform adaptive management

A farm was purchased and developed into a research and training center for shade-grown organic coffee production. Experiments are underway with coffee polyculture with plantain and citrus, alder and other native trees as shade cover and with soil amendments for nematode and erosion control. Also, simulated drought research is underway to investigate how climate stress will affect pests that attack coffee when it is planted alone, in combination with citrus and plantain, and under native tree shade. Preliminary results are highly promising. Alder enriches soil nitrogen and provides shade to young coffee plants within two years. The addition of stalk residue from local sugarcane processing reduces root-knot nematodes and increases beneficial predatory nematodes in the soil beneath coffee plants, even under simulated drought conditions. Native forest trees are added to the polyculture. A similar research and training farm is envisioned for the cacao project.

Two protocols for monitoring water quality were created and tested. One protocol, “Stream visual assessment” was designed explicitly with community participation in mind and can be carried out by community members with minimal training. The other protocol, “Water quality assessment,” requires more technical training but provides results that are more rigorous. Both can be used to monitor the possible impact of the OCP pipeline in key sites within the pilot project area, especially the protected forests of the Cuenca Alta Río Guayllabamba and Mindo (Udvardy 2003).

Blood samples have been drawn from local poultry flocks and tested for evidence of exposure to avian diseases. Results indicate that local chickens have been exposed to many important avian diseases such as Newcastle and Cox virus. A similar study is underway with wild bird populations to reveal their exposure history to avian diseases. This is part of a larger study to assess the risk of avian disease transmission between poultry and wild birds in the shade-grown coffee ecosystem. Work is also underway on vector ecology. Bamboo water traps have been placed in forest habitats to assess the native and introduced mosquito fauna in container habitats. This is part of a baseline study on the vectors of dengue fever. Chagas disease occurs sporadically, and there is concern that land use changes are influencing the distribution and composition of the reduviid bug vectors of Chagas. Investigations are focused on forest-dwelling reduviid vectors and how land use changes are affecting their distribution.

A carbon ecology research program that compares primary, secondary, and native bamboo forests with other dominant land uses in the area is underway. We have published studies on the carbon stocks of forests, pastures, secondary forests and bamboo and are developing carbon models for reforested areas and native bamboo (*Guadua angustifolia*) (Rhoades 1997, Eckert 1998, Rhoades et al. 2000, Gornall 2001, Tian et al. 2007).

We have developed one of the most comprehensive GIS (geographic information database) environmental databases publicly available for the entire Chocó Andean region, including basic digital cartographic information as well as a sophisticated model of land use change (Fundacion-Maquipucuna 2002). The GIS theme maps for the pilot corridor were prepared at a 1:25,000 scale predominantly, and at 1:50,000 for the macro area, whenever possible. Different organizations and communities of the area are actively using all this information[9]. Monitoring land use change is in process and a grant from the MacArthur Foundation will enable us to enrich the results with high-resolution images down to < 50cm.

A bird monitoring program has been initiated throughout the Chocó Andean region building on studies of the impact of land use types on bird community assemblages (O'Dea et al. 2006b, Mordecai et al. 2007), with software developed by the project to analyze a long-term data base that will be created with local participation and for which training has already started.

4.4.7 Chocó Andes brand, a protected designation of origin and process

A high quality standard for Chocó Andes products is central to FM's market strategy. The Chocó Andes brand has been trade marked. Chocó Andes is a warranty of origin, quality, just price paid to the producer, and environmentally friendly (organic, bird friendly and responsible disposal of residues). Protected designation of origin (PDO) is a label of geographic identity that was initially defined in European Union Law in 1992. The purpose to create PDOs is to protect the names of regional foods to ensure that only products genuinely originating in one particular region (such as wine, cheese, sausages, etc) are allowed in commerce as such. This also aims to eliminate the unfair competition and misleading of consumers by non-genuine products, which may be of inferior quality or of different flavor. Increasingly, this type of labeling is spreading to other countries, as it seems to protect local farming.

[9] Some of the users of the Information System include Ministry of Environment, Provincial Council of Pichincha, Chachi Federation, Comuna Rio Santiago Cayapas, Yunguilla, Sta. Lucia Cloud forest reserve, Catholic University, Central University, San Francisco University, University of Texas at Austin, Oxford University, University of Georgia, PROBONA-Intercooperation, Conservation International, Fundación Sirua, Rainforest Concern, Aves & Conservación, among others.

While appealing to buyers' social conscience will support only a limited market for Chocó Andes products, a high quality product will continue to gain consumers, but that market needs protection from unfair competition by a designation of origin, which is in the process of being created. The Chocó Andes brand intends to cover all products from sustainable products and services from the conservation of the Corridor from coffee to carbon emission reductions to ecotourism.

FM is training farmers how to produce high quality coffee and, by locally grading the beans for quality, how to secure a premium price. Because FM buys and ships the beans and controls local roaster outlets, a high quality product is ensured. Research is also being carried out to determine guidelines to establish bird-friendly shade criteria for cacao. Organic certification processes are underway with both coffee and cacao farmer associations.

The Corridor is a major center of orchid and bromeliad diversity. In the 5,456 hectares of Maquipucuna Reserve alone, 329 orchid species have been described or 10% of the orchid species of the entire country of Ecuador (Reynolds 2004). Through collaboration with the Atlanta Botanical Garden, orchid and bromeliad production, sales, and wild reintroduction have been developed. A tissue culture laboratory for orchids and bromeliads has been established in the town of Marianitas and several species of orchids and bromeliads are being grown. Orchids in tissue culture are currently sold locally to tourists and in the U.S. at the Atlanta Botanical Garden and the University of Georgia. A digital compact disk featuring high quality photographs of local orchids has been produced.

4.4.8 Gender equity

A women's cooperative was established in the nearby town of Marianitas to produce jewelry and crafts from tagua nuts (vegetable ivory) and *chonta* palm. A similar cooperative exists in Yunguilla to produce jams from native fruits and craft paper from native plant fibers. Local women are active leaders in the coffee and cacao alliances. In *Marianitas*, a daycare facility was constructed to help women cooperate in daycare and thereby free up more time for economic activities. In this way, social capital among women has increased. Through their involvement in the conservation projects, women's roles have evolved from passive to active actors of development. Women now hold many of the elected public offices in the region.

4.4.9 Carbon valuation of conservation strategies

The amount of carbon from atmospheric greenhouse gases that is either sequestered or emitted from tropical landscapes is a significant contributor to the global atmospheric carbon budget. In the Maquipucuna Reserve, carbon stocks have been measured in the standing biomass and soil for native bamboo, pastureland, and young and old growth forest. In addition, soil and root carbon emissions have been measured for pasture and for young and old growth forest. FM is investigating ways to avoid carbon losses through forest protection and to develop new ways to sequester carbon while providing economic gains for communities.

By protecting 22,400 hectares of forest from projected deforestation, FM has avoided the emissions of approximately 3.36 million tones of carbon. Planting of 500,000 native trees and bamboo has been completed on 2000 hectares of small coffee and cacao farms and reforestation of an additional 2000 hectares is planned. Every hectare reforested is estimated to sequester between 150 - 300 tC over a 30-year period. In FM's "Grow your home" initiative where families are encouraged to grow native bamboo for home construction, the carbon sequestered could be significant at a landscape scale. Our studies have shown carbon stocks above and below ground for bamboo range from 80 to 240 tons of carbon per hectare at normal stand densities, much higher than pasture (Tian et al. 2007).

The amount of carbon emissions that are reduced through reforestation projects will be quantified through a formal process defined by the Kyoto Protocol. These emission reductions, as "certified emission reductions – CERs," will then be sold. The first reforestation project with a methodology approved by the Cleand Development Mechanism Executive Board of the Kyoto Protocol has initiated under the auspices of Conservation International and financing from the RICOH corporation from Japan (UNFCCC 2007b).

4.5 LESSONS LEARNED

4.5.1 About planning and monitoring

Be conservative when setting objectives for eco-regional conservation.

Local farmers through day-to-day decisions shape land use change. They must make decisions quickly, and, though they individually impact small areas, their cumulative impact is a major driver of land use change. Therefore, projects should focus on working with farmers if the objective is to achieve short-term visible results, but keeping in mind the limitations of that approach. The investments required to provide sufficient support to each community, and a variety of other project-specific factors, render the eco-regionalization of the community experience cumbersome and costly.

Indirectly, regional, national and foreign policies influence farmers' decisions over large areas, but the influence of these policies may be slowly and heterogeneously expressed at the farm level. Therefore, success at one scale is not necessarily perceived as success at all scales. For instance, the Corridor project met numerous communities that were frustrated about their experience with previous large aid projects even though the funding agencies considered them successful. The agency's criteria for success—studies, planning, meetings, budget expenditure—were quite different from the farmers' criteria—improved production, better markers, information to solve problems, etc.

We learned that it is possible, indeed necessary, to intervene at both scales—the farm/community and the nation—but leading local stakeholders to regional consensus is a complex process not realistically achieved in the short term. While this project was more successful at identifying local and community level conservation opportunities and achieving their commitment, the time period of the GEF grant was not sufficient to institutionalize the Chocó Andean Corridor at the government or national levels. In other words, it was hard to maximize both objectives—community impact and ecoregional impact—at the same time.

Engaging communities successfully requires that conservation projects provide them with strong incentives to participate, and a strong market-based approach with sound financial advice is one the most efficient ways.

Where the objective is to implement economic alternatives to deforestation, strong lasting markets are important. In other words, it's not worth pursuing economic activities—sometimes even those chosen by the community—if there aren't markets or cost-effective marketing and commercialization mechanisms for the products of conservation.

For example, the Corridor project was initially allocating a lot of human and financial resources to product development and marketing of crafts, such as paper made from natural fibers. The limited demand, the expensive cost of production, and expensive effort of marketing those small volumes rendered the process unsustainable. The project had to change its focus to products that that would involve a larger number of people in the production because those products have wider demand, such as shade grown organic coffee, shade grown organic cocoa, and native bamboo.

Innovative methods of conservation and development are best left to those people who will carry them out and who will ultimately gain or lose from the outcome. Therefore, successful projects will focus resources on stakeholders who directly influence land use change.

Projects need to face a crucial question: Conservation for whom and conservation by whom? Getting agreement of all stakeholders is not always possible, nor necessary. In the region, we found many conservation NGOs with agendas that did not address concerns of the communities responsible of land use decisions.

Although investing in research, planning and studies is necessary, if the goal is achieving conservation in the short term, there should be significant investments that directly benefit conservation:

- purchasing land to protect biodiversity,
- clarifying land tenure,
- paying for conservation easements,

- financing infrastructure for sustainable production,
- creating long term funding mechanisms to finance the costs of protection and maintenance,
- strengthening institutions to sustain conservation projects locally.

Listen to what the community has to say if you want them to listen to you

Representatives from communities along the Chocó Andean Corridor from sea level to almost 3000 m.a.s.l. gathered in a workshop in July of 2002 to identify community-based indicators for conservation success. Basic community needs—such as jobs, schools, and health care—were identified as preconditions to conservation and sustainable development. Ecoregional conservation projects have to address economic development issues by promoting eco-enterprises and by forging alliances with the government to facilitate the fulfillment of basic needs of health and education. Given limited funds available for research, in as much as possible, conservation ecology and anthropological research agendas in tropical areas should focus on creating knowledge about how to best meet the needs of local communities.

Measuring progress—Logical framework programming (LFP) is a great project management tool to measure performance but not impact and, if there is not flexibility, LFP can cripple adaptability to new situations.

Logical framework programming (LFP), Objectives Oriented Project Planning (OOPP) or the Logical Framework Approach (LFA) to programming is a great management tool, a legacy of development projects, which is now widely used to design, monitor and evaluate conservation projects. When funding is provided by bilateral and multilateral aid agencies, a log frame is always a required element of the project proposals, and increasingly international conservation organizations are also requiring it. A log frame is one of the products of the LFA and consists of a four-by-four matrix. Arranged in rows is a hierarchy of cause-effect related hypothesis: the *Goal (Main objective)*, *Purpose (results), Outputs (products)*, and *Activities.* The columns provide complementary information about each row. The first column is the narrative description, the second column lists the Verifiable Indicators (VI), the third lists the Means of Verification of the VIs and the fourth lists the Assumptions for success, which are either internal or external factors, beyond the control of the project, that can impact success. The logic of the table runs like this: if the activities are implemented, and their assumptions hold, then the outputs can be delivered. If the assumptions of the outputs hold, then the purpose can be achieved, and if its assumptions hold, then the goal can be achieved.

Log frames and annual operation plans are successfully used to plan and measure performance. However, there are two major preconditions for their successful use. One is that in order to measure impact (i.e. progress in conservation), at the onset of the project, there should be baseline socio-economic and ecological studies and long-term monitoring programs designed and funded. A long-term scientific monitoring program demands the place-based commitment of established research organizations. In cases where the community is primarily responsible for conducting the monitoring (e.g., stream visual assessments), there is concern that monitoring may become haphazard or stop altogether over time unless there are incentives to continue the process and guidance to maintain its quality. These incentives may range from monetary compensation to partnerships (e.g., technical support), and all these options should be explored.

A second major problem with the applicability of log frames is that, depending on the flexibility of the funding agency, log frames can limit the ingenuity and adaptability of project managers. In conservation, opportunities knock on doors sometimes shortly and once, e.g. the availability of a piece of land for sale for conservation sometimes is ephemeral, and if the donor is bureaucratic and inflexible, the opportunities will be lost. In addition, when funding agencies believe blindly in log frames, project implementers may be wrongly judged unsuccessful if they have not followed the logical sequence of events of the log frame even though they may have achieved conservation objectives.

4.5.2 About partners and communication

Stakeholder Involvement: The approach taken for stakeholder involvement and lessons learned from this approach.

The term stakeholder includes people who live within the corridor as well as people whose professional or financial lives are linked to the corridor. The latter group might include policy makers, investors, researchers, industry owners, or educators, among others. A wide range of stakeholders was involved in project design and implementation in all possible ways. Through town meetings, reunions with producer associations, talking with local, state, and national officials, hosting workshops and supporting baseline research, Maquipucuna tried to engage stakeholders in all phases of a project, from design through implementation.

This intense level of stakeholder involvement leads to a strong sense of community ownership of projects, and it leads to stable support (though not necessarily financial) from the local and national government. However, it is extremely time- and labor-intensive and thus limits how many communities a project can engage. In addition, interests can be very different, even contradictory, among stakeholders.

One approach is to aggregate communities that share similar interests and then work with a group of representatives from each community. That was the approach taken with coffee, and it worked because there was a strong incentive to participate. A better market for their coffee was a powerful incentive. However, this approach may not be effective when stakeholders have differing goals or when an over-riding market incentive is missing.

Communities with stronger social fabrics make stronger partners for conservation

A strong social fabric—which includes responsible leadership, good capacity to establish dialogues among community members, accountability of the local authorities, good access among community members to decision-making or for influencing decision, capacity to set long term goals, and pride in their community—makes a fundamental difference. Training had most impact on communities with higher degrees of social organization. For example for those communities, training generated economic opportunities faster, as was the case of Yunguilla for which a field trip to an example community cheese factory was sufficient motivation to start their own cheese factory. Objectives of projects should be adjusted according to an analysis of social capital of the communities.

Projects must consider other keys aspects, especially being realistic when setting entrepreneurship goals in rural communities. Specifically, they must assess precisely their capacity and needs to consistently deliver such quality goods and services, as ecotourism, coffee, cocoa, and others for the global market. Reaching economies of scale in marketing and commercialization is a requirement for financial sustainability, which most rural communities are not capable of achieving on their own.

Partnerships – Communities or NGO's

During early planning efforts for the Corridor, Maquipucuna involved a large number of stakeholders, conservation NGOs, government officials, scientists, and communities. Indigenous communities in possession of large holdings of forestland were involved in later stages of planning and implementation.

Despite the initial enthusiasm of some national and international NGOs, stronger relationships resulted at the grass-roots level because Maquipucuna's leading role faced competitiveness and resistance from the larger NGOs that had their own agendas. The larger NGOs were reluctant to share information about their projects, and existing geographic information was not readily shared. There were also cases of local NGOs unwilling to collaborate, such as NGOs in the Cotacachi Committee, because this was a World Bank project, and the World Bank in previous years had funded the Mining Assessment Study, which they opposed. To outweigh these difficulties, Maquipucuna could have used a more distinct and consistent communication strategy. For example, more funds explicitly allocated to public relations at the institutional level may have achieved more NGO supporters.

International nature conservation organizations play an important role in conservation, and it is partly due to their influence that areas such as the Chocó Andean Corridor have been recognized as global conservation priorities. However, without knowing, they can undermine their positive impact, when instead of strengthening local nature conservation organizations, they compete for the attention of stakeholders or for funds from bilateral and multilateral sources and international foundations. Competing for the attention of stakeholders means that international organizations often raise expectations that they will fund more projects that they can actually afford which creates division, undermines homegrown conservation initiatives or at least makes communication more difficult among local conservation organizations and community organizations which are called to compete for those funds. Bilateral and multilateral aid and funds from international foundations are increasingly being earmarked geographically; consequently, international organizations have opened offices in developing countries for which the aid is earmarked, thus competing for funds with local NGOs. Numerous local organizations have a high degree of scientific and technical expertise in conservation, which in addition to increased access to communication and information through the internet; make them very capable of carrying out conservation projects successfully such as an ecoregional conservation approach for Northwest Ecuador. However, funding agencies often have the perception that international organizations are better prepared to implement ecoregional conservation projects. Effective conservation requires long-term place-based commitments and strategies, which local conservation organizations are in a best position to deliver more cost effectively; therefore, local organizations should be strengthened through the creation of endowments and improved capacity to administer projects and for long-term monitoring programs including the management of the databases generated and interpretation of the results for adaptive management. International conservation organizations can still play an important role in local conservation. They can continue working creating awareness internationally, participate in the strengthening of local organizations, lobby for international policies in favor of conservation and sustainable development and mobilize funds from private individuals and corporations in developed nations, rather than competing with local NGOs for the limited funds available from bilateral and multilateral organizations and international foundations.

Partnerships – change and instability of governments can influence results

Without question, the government must be a key player in an eco-regional strategy for conservation, and Maquipucuna had experience in dealing with different instances of the government, yet had mixed results in this project. Planning and introducing long-term commitments into government policy and, especially, budgets are difficult challenges. Maquipucuna tried to get the National Planning Office, then under the jurisdiction of the Vice Presidency of the Republic of Ecuador, to participate in the definition of the conservation guidelines for the Chocó Andean Corridor and to use that framework to organize conservation and development initiatives in the northwestern provinces of the country. The office of planning was actually very interested in participating in the definition and adopting the guidelines, however, the end of the presidential term arrived (end of year two), and by the time the new government was established, the World Bank grant was over. A similar situation occurred with FM's environmental database. The intention was to get the Ministry of Environment to include the Chocó Andean information system within the National Environmental System at the Ministry of Environment. An alliance of 13 NGOs was pursuing this initiative. Maquipucuna would have been the node for the Chocó Andean Region. However, after the change in presidency in January 2003, for the next year and a half new Ministries of Environment were appointed, on average, every three months. With such a high degree of governmental change and uncertainty, the initiative failed.

Collaborating with the government in discrete instances was easier. Co-sponsoring the First National Congress of Protected Areas in July 2003, Maquipucuna and the Ministry of Environment interacted positively. Maquipucuna ran the National Workshop on Corridors that produced the national principles or guidelines for Conservation Corridors. Another example is Maquipucuna's prominent role as providing a representative to serve as Vice-President of the Board of Directors of the Green Vigilance, a national organization to control illegal logging supported by the Minister of Environment and four other NGOs and where the Ministry of Environment is by default the president.

With more stable and locally invested governments, such as the Municipality of the Quito Metropolitan District, the experience was more generally positive. The municipality was an instrumental partner for reforestation and will continue supporting reforestation even after GEF funding. The municipality purchased the plants produced by Maquipucuna and the communities, and Maquipucuna provided technical assistance and monitored reforestation.

Partnerships – Research Institutions

One of the most cost effective ways to mobilize knowledge from north to south was through the partnerships created between the Fundación Maquipucuna and other research institutions, such as the University of Georgia. For example, the University of Georgia (UGA) is a Land Grant Research Institution and as such is a multidisciplinary institution with incalculable academic and practical resources for a complex eco-regional endeavor as the Chocó Andean Corridor. Besides UGA, Maquipucuna also interacted with several research centers and universities across the globe (INIAP-Ecuador, USAIDs CRSP-IPM, University San Francisco de Quito, UTE and PUCE in Ecuador, and various ones from England, Sweden, Japan, USA, Germany, Holland, and Switzerland). Outstanding are the collaborations with the University of California at Davis (botanical studies have continued for 15 years) and Oxford University (Avian Monitoring).

Partnerships – Funding agencies, The World Bank

The World Bank's GEF staff, both in Washington and in Quito, played a constructive role during the planning phase of the Corridor project. Their advice was insightful and professional, and Maquipucuna benefited greatly from the interaction.

However, the great political power of the WB could have served the Chocó Andean Corridor better in the face of such threats as the OCP pipeline and the illegal land speculation issues. However, WB seems only willing to provide limited political support to such small projects as Medium Size GEFs. For future GEF projects, WB should allocate emergency funds to deal with contingencies, instead of reallocating project funds.

Because for most eco-regional conservation projects, three years is just not sufficient time to reach sustainability, World Bank and GEF should have a more active role in the identification of opportunities for continuing funding, tying up existing projects with funding, even credit opportunities in the Bank, thus enhancing project opportunities for sustainability.

Finally, WB uses advanced administration and management tools from which smaller institutions could learn if there was a mechanism of training for NGO and project managers.

4.5.3 About funding and sustainability

Successful planning must make long-term core funding a major priority. Three- or even five-year grants are too short to establish a sustainable development process at an ecoregional scale. Short-term grants have more impact on small project areas—but the limits of piecemeal solutions should be recognized and generally avoided because they are not an efficient use of resources. Solid, market-oriented business plans that internalize environmental costs are essential for sustainable ecoenterprises, and fortunately, funding agencies are more commonly recognizing this need. The plans need to establish an endowment fund at the onset of the projects and start eco-enterprises with adequate liquidity to maintain continuity in projects as short-term grant funds come and go.

Most successful conservation related activities are those that received a substantial capital investment in infrastructure combined with training, operating capital, and market support. In my experience, contrary to this successful empirical formula, most multilateral and bilateral aid projects currently allocate about 70% of the grant or non-reimbursable funds to training and consultancy fees, only a small fraction of the grants is available for infrastructure (about 30%), and generally they do not fund working capital. Funding external consultants and training, in the absence of substantial investments in infrastructure and working capital, does little to help local communities in their creation of man-made capital or wealth which is the foundation for sustainable production. Conservation projects would have more chances of being sustainable if funding agencies invested more in infrastructure and working capital. It is suggested that funding agencies invert their funding priorities' ratio from the 70/30 (consultancies and training to infrastructure and working capital) to a 30/70.

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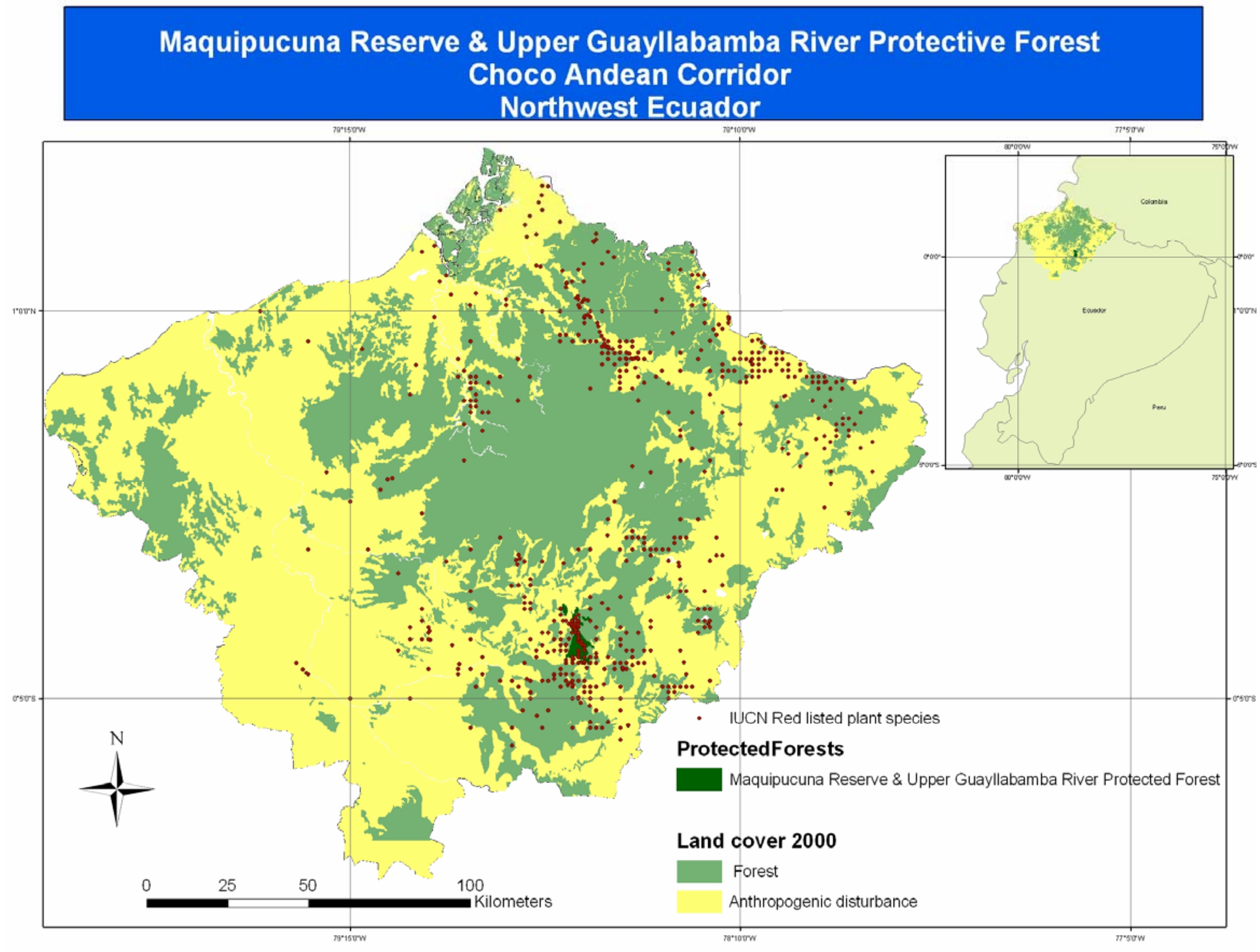

Figure 4.1 Maquipucuna Reserve and the Upper Guayllabamba River Watershed Protected Forest.

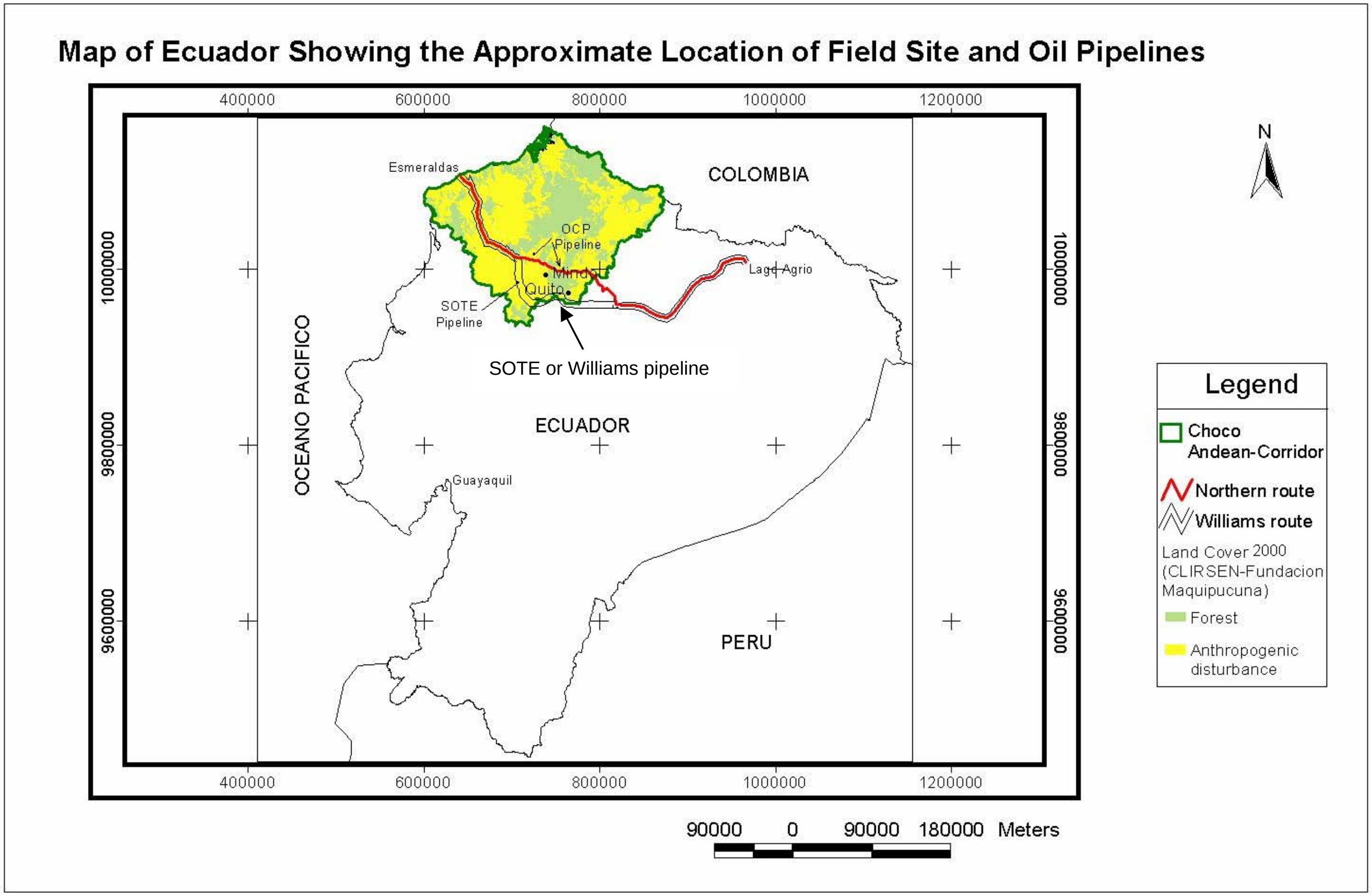

Figure 4.2 Location of the new heavy crude oil (OCP) pipeline using the northern route and crossing pristine forests of the Chocó Andean Corridor.

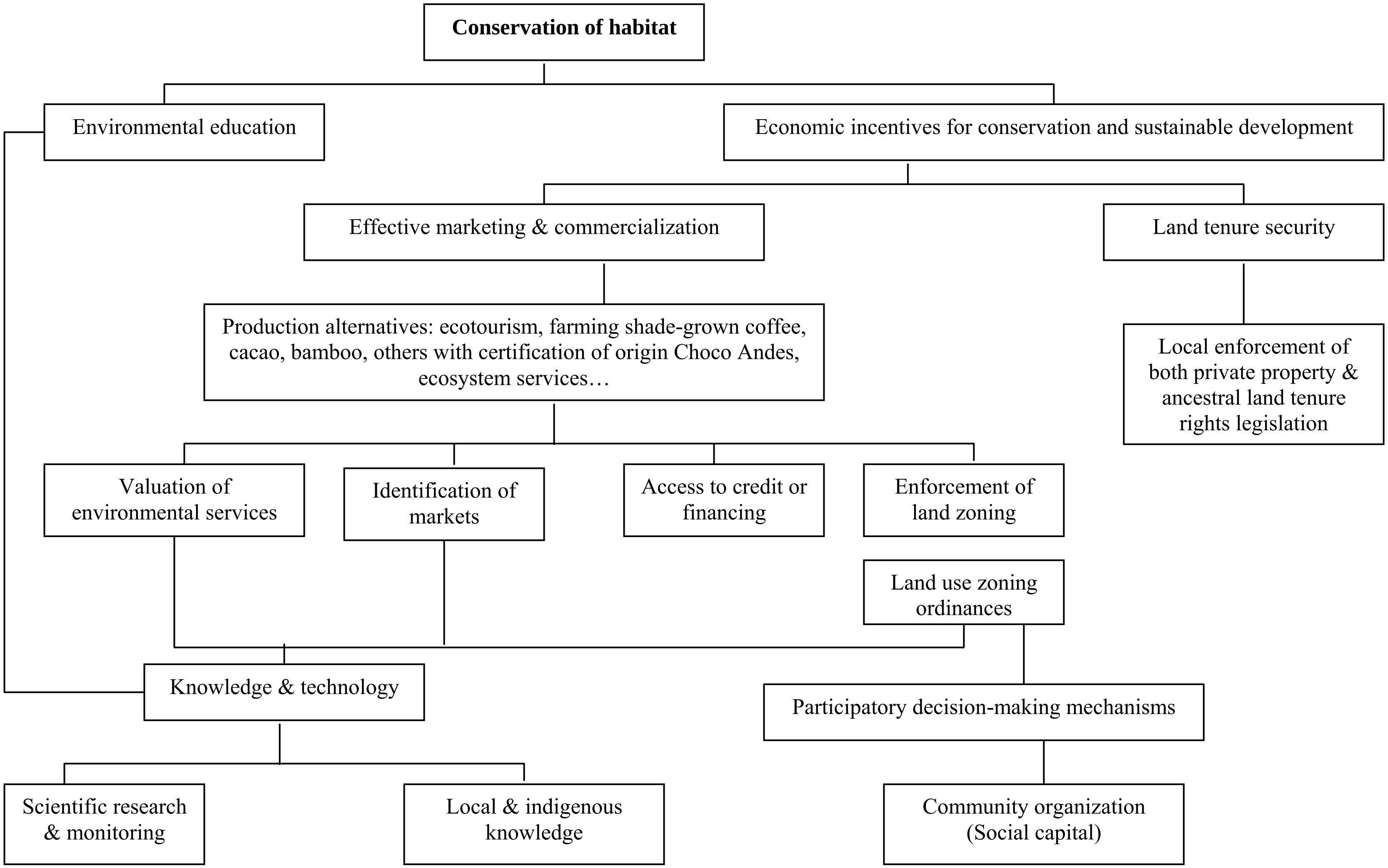

Figure 4.3 Conceptual operational framework of the Chocó Andean Corridor: elements for conservation and sustainable development in the local sub-system. Although this is a complex system with checks and balances, it has been simplified and reads from bottom to top, from elemental to consequential.

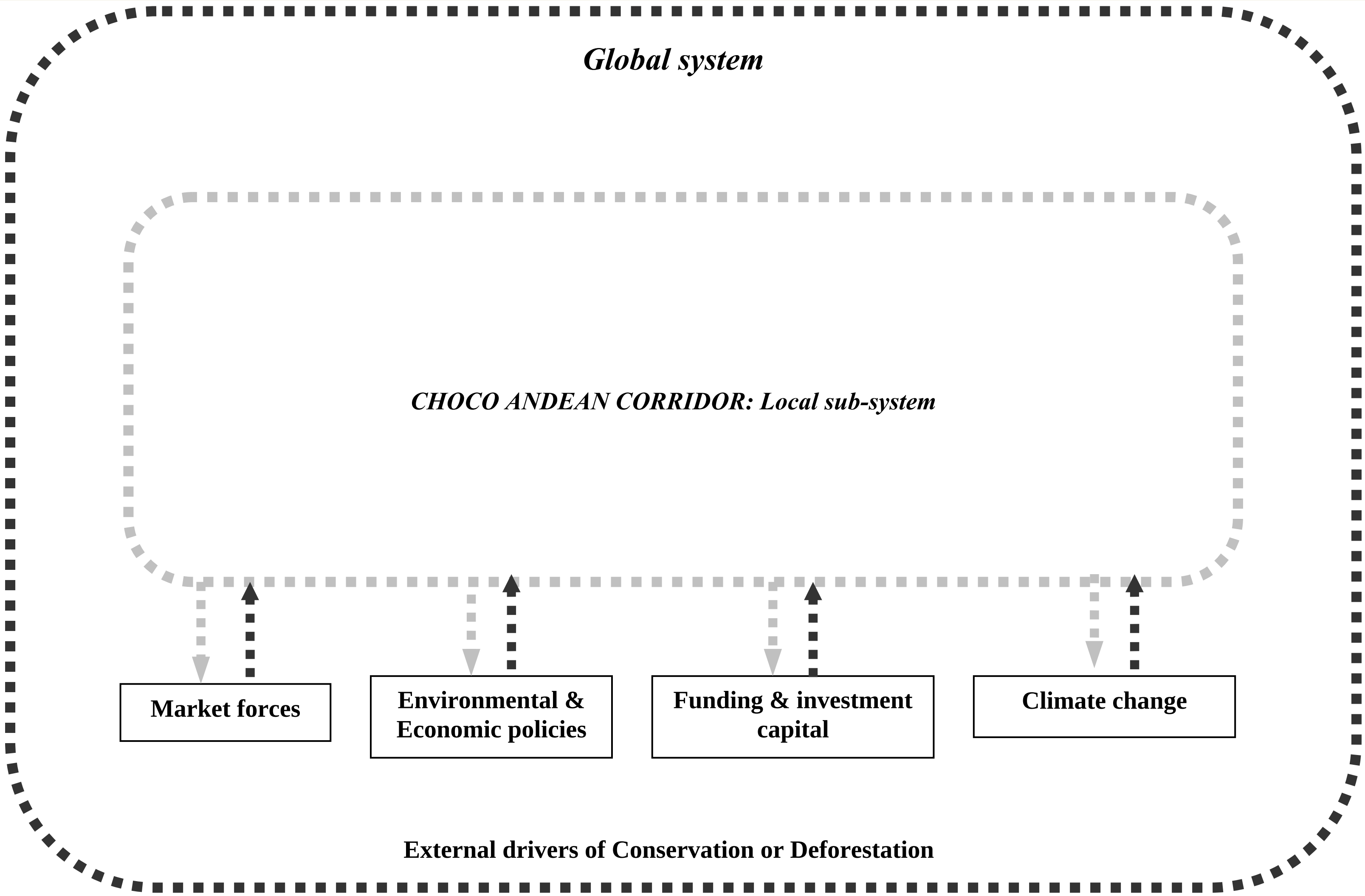

Figure 4.4 Conceptual operational framework of the Chocó Andean Corridor: global system.