Forest quality in the southwest of Mexico City. Assessment towards ecological restoration of ecosystem services

Thesis submitted in partial fulfilment of the requirements of the degree Doctor rer. nat. of the Faculty of Forest and Environmental Sciences, Albert-Ludwigs-Universität Freiburg im Breisgau, Germany

By

Víctor Ávila-Akerberg

Freiburg im Breisgau, Germany
2009

Dean: Prof. Dr. Heinz Rennenberg
First supervisor: Prof. Dr. Werner Konold
Second supervisor: Prof. Dr. Albert Reif

Date of disputation: December 9th 2009

Acknowledgements
This thesis is dedicated to the forests in the area under study and to my family and friends!

Thanks to Dr. Werner Konold, for accepting me as a PhD student, having trusted on my research, for always being there whenever I needed him, and for encouraging and supporting my trips to courses and conferences around the world, vielen Dank!

I would like to thank Dr. Albert Reif for being my second supervisor and for the given advice and comments on the thesis.

I would like to thank Dr. Lucia Almeida, for having taught me so many things, for believing in me and together having achieved so much in the Magdalena river watershed.

My great appreciation goes to Dr. Jorge Meave del Castillo, for advising me and have shared part of his enormous experience and patience on scientific writing.

Special thanks go to Esther Muschelknautz, for always being there to answer the administrative questions, attending and organizing the milestones and the extra-curricular courses in the International PhD Program "Forestry in transition".

During the last three years of my life, I have met and shared moments with many wonderful persons. It is difficult to put/organize all the names here, and I hope not to forget to mention anyone, thank to all of you for being there!

All my group of friends from the first MEG/FEM generations: Liviucu, Luli, Sabine, Kate, Manolives, Jorgiño, Yvonne, Diana, Kasia, Juan Carlos and family (Inka, Lukas, Maya), Christopher, Sabaheta, Karol, Vered, Amy, Weyna, Ana Lucía.

My friends in Mexico: Pablo Ortíz, Pablo Gesundheit, Adrián, Diego, Iura, Beto, Edurne.

My friends, related to the time spent in Germany: Ricardo, Paola, Renato, María, Rafael, Liliane, Oxana, Tatiana, Yadrith, Carlos, Riccardo, Zuzana, Tatsiana, René, Raghav, Lawrence, Pawanjeet.

All the people in Mexico, my colleagues and friends from the Mountain Ecosystems Laboratory and from the Science Faculty: Inti (thanks a lot for the help with the field work!), Verónica, Paula, Fiorella, Yedith, Juan, Carlos, Madai, Myriam, Fabiola, Mónica, Mariana, Julieta, Alya, Bety Ludlow, Bety González; José Luis Villarruel, Osvaldo, Hogla, Cintia, and all the van drivers.

My colleagues and friends from the Institut für Landespflege: Sabine Schellberg and family (Johannita, Joe and Uwe), Christoph, Karl-Heinz, Steffen, Kristina, Timea, Anne, Irene, Carolin, Sandra, Benoit, Peter, Harald, Franz, Akiyo, Oliver, Tatjana, Silke, Claude, Ilona, Patrick, Gerd, Claudia, Reiner, Evelyn, Manuel, Mirjam, Mattias, Katharina, Thomas, Dessi.

My family, who has always been providing me motivation, emotional support and confidence, you know how important you are to me. Thanks to my mother Marianne, my father Rauliño, sisters Diana and Claudia, brothers Martín, Andrés, and Oscar, and nephews Ramón, Iván, Bruno, Camila, Renata and the youngest Nicolás; I love you!

Special thanks and acknowledgements to my partner and company, for all her love and support, thanks Tanya!

Last, but not least, I want to thank the Mexican National Council for Science and Technology (CONACyT) and the German Academic Exchange Service (DAAD), for the given scholarship and the administrative support.

INDEX

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIXES

1. Introduction

1.1 Problem statement and objectives

Mexico, a developing country in the neotropics, is territory for an enormous cultural and biological diversity. It also faces enormous social disparities and environmental problems, which threaten human well being and biodiversity loss.

Mexico City, the capital and socio-economic center of the country, is one of the most populated cities of the world. Nowadays, it represents an urban area, where most of the natural landscapes have been modified, but still has forested areas in the surroundings that are threatened by the enormous pressure such a human concentration represents.

Mexico City is the central, urban core of the Federal District, located in an originally closed hydrologic basin, known as the basin of Mexico. The Federal District, although it encloses one of the biggest cities of the world, it still has important protected areas on its southwestern part, mainly, which represent more than half of its territory. However, the larger metropolitan area of the capital extends into other neighboring states, largely filling the area of the basin of Mexico (FENN et al. 2002).

The urban and demographic growth of the metropolitan area of Mexico City represents an enormous challenge for environmentalists, if one can imagine the ecological consequences of approximately 20 million people occupying the same space. The forests in the southwest of Mexico City are under daily threat from various causes of deterioration, often irreversible, including the pressure of real estate interests, the separation of parcels of agricultural land, and the conflicts of land ownership, among others. The vegetation and the wild flora and fauna have been directly affected by illegal felling, the incidence of wildfires, the lack of technical management, land clearance for cultivation, uncontrolled livestock production and pollution of the air, soil and water, all of which result in deterioration of the ecosystems and the loss of biodiversity.

Many ecosystem services, direct or indirect benefits we humans get from nature, are essential for our daily lives. The water consumed in Mexico City comes mostly from the underground aquifer, which is then recharged with the water infiltrated in the forested mountains around it. It is mainly for this reason that the City authorities have recently become conscious and greatly interested on the integral conservation of the area, using the analysis of its vegetation as a prelude to the evaluation of the present state of conservation of the zone and as a basis for the formulation of management alternatives.

This research intends to show some of the relations between vegetation, environmental variables, phytodiversity, its use and the direct and indirect benefits that this area provides to the inhabitants of Mexico City. In order to achieve this, a recent concept called forest quality, developed for the assessment of sustainable forest management at the landscape scale, was used as a guide.

General objectives

1. Design and implement a methodology for the assessment of "forest quality".
2. Generate an assessment of the forest quality in the southwest of Mexico City.
3. Give management proposals towards ecological restoration and conservation of the forests and their environmental services.

Research questions

1. What are the environmental goods and services provided by these forests to the City?
2. What are the main social and ecological problems for the conservation and functioning of these forests?
3. Is forest quality a useful principle (concept) for the ecological restoration of ecosystem services?

1.2 Expected outcome and research structure

This research is expected to contribute in regards of developing a specific methodology to evaluate forest quality at the landscape level. It gives a detailed diagnose with a proposal of general management guidelines towards ecological restoration and conservation of the forests southwest of Mexico City. This is expected to allow the implementation of a program with the stakeholders and the decision makers.

Conceptually, there are just a couple of applied studies using the principle of forest quality in the world, and nobody has used it in Mexico. This work is expected to contribute on the clarification of the concept and its potential use.

Empirically, this project expects to contribute with the use of field, laboratory, qualitative and quantitative methods. This research is sustained on a hard field basis, consisting of ecological, management and people perception data. Together with an extensive review and use of the available literature that deals with the covered topics.

In order to achieve the objectives of this thesis, the research process is divided in six parts. The first (Chapter II) reviews the main covered topics: the history and use of criteria and indicators for sustainable forest management and the theoretical framework for the ecological restoration of ecosystem services. The second (Chapter III) is a detailed description of the most important aspects of the area under study: the southwest of Mexico City, more precisely, the Magdalena river watershed and the conservation area of Magdalena Contreras Municipality. The third (Chapter IV) is a characterization of the flora and vegetation present in the study area, having as results the floristic list, the vegetation and land use units map, and a phytosociological table that allowed the classification of four forest communities and their associations based on the plant composition data. The fourth (Chapter V) is the processing of the field data to get the indicators of the main ecosystem services provided by the forests in the area, as well as the analysis of the perceptions of the stakeholders on their relative importance. The fifth (Chapter VI) integrates the information of chapters IV and V put into the different criteria and indicators of the principle of forest quality. These indicators were weighted according to expert opinions and synthesized into an index that was spatially interpolated to produce a map of forest quality. The last part (Chapter VII) comprises the interviews made to the main stakeholders on their perceptions about the allowed activities, environmental problematic and environmental education in the area. General guidelines of a management proposal towards the conservation and ecological restoration of the main ecosystem services were developed.

A diagram with all the research structure can be observed in Fig. 1. The time line can be seen in the right side, and each block in the diagram was needed to complete the blocks further up.

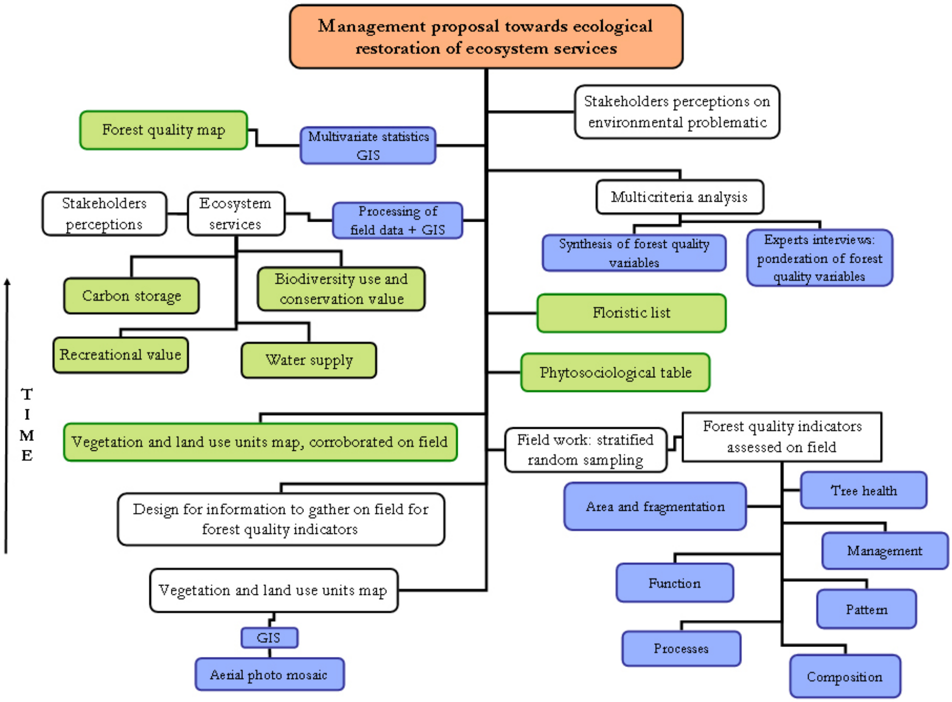

Fig. 1 Research design diagram. It should be seen starting on the bottom and following the main axis as a reference to time. Blocks in blue and white represent methodological and conceptual steps. Blocks in green represent products of this research, having the ending aim in orange, which integrates all the research components.

2. Conceptual framework and historical background

2.1 Criteria and indicators for the assessment of sustainable forest management

The loss and degradation of natural forests, and the associated loss of biodiversity, are now widely recognized as a global environmental concern. Protecting biodiversity has been one of the most important issues in the environmental and forest policies since 1990's. The United Nations Conference on Environment and Development (UNCED) in 1992 recognized the need to develop indicators to enable countries to make informed decisions regarding sustainable development (Chapter 40 of Agenda 21).

Developments in forestry over the past decade have focused on progress towards sustainable forest management (SFM), an approach that encompasses environmental, economic and socio-cultural management objectives (VÄHÄNEN 2004). This has been reflected by the increase of policy initiatives developed over the past 20 years aiming to reduce forest losses, and support the implementation of SFM. These include the Convention on Biological Diversity (CBD), the Forest Principles and Chapter 13 of Agenda 21, the UN Forum on Forests (UNFF) and the many international processes developing criteria and indicators for SFM.

The specific toolset developed to describe and help monitor progress (or lack of it) towards SFM is called criteria and indicators (C&I). They form a tool for assessing trends in forest conditions and management. They provide an implicit definition of what SFM means and a common framework for monitoring, assessing and reporting on progress towards SFM. The utilization of C&I is seen as a promising opportunity to increase the understanding of SFM among forest managers, thus directly and indirectly benefiting populations and decision-makers (VÄHÄNEN 2004).

C&I list the main factors that influence the health and productivity of a forest (criteria) and suggest indicators that, if measured over time, will help managers assess the extent to which management practices are consistent with the sustainability of forests and of forest-dependent communities.

When choosing indicators it is clear that no single indicator will be adequate to summarize information on all aspects of sustainable development. Instead, a picture will have to be built up from a range or portfolio of different indicators which together provide an approximate picture of the degree of sustainability. Each indicator should be chosen to capture as much information as possible (CBD 1997).

During the decade following UNCED, many initiatives have sought to identify indicators of sustainable development (see Tab. 1). The International Tropical Timber Organization (ITTO) has had a pioneering role in both developing and implementing C&I (POKORNY & DESMOND 2004). The pan-European C&I were adopted on the expert level in 1994 and they were formally endorsed in 1998. The Montreal process was launched in 1993 and its C&I were concluded in 1995. In the same year, eight countries in the Amazon region initiated the Tarapoto proposal. The UN Food and Agriculture Organization (FAO) and the UN Environment Programme (UNEP) supported three C&I processes launched in the mid-1990s: the African Dry Zone process covering the sub-Saharan area, the Near East process, and the Dry Forest Asia initiative. In addition to these, C&I have been developed in Central America under the Lepaterique process launched in 1997 and in Africa under the support of the African Timber Organization (ATO).

C&I are the focus of considerable policy work at the international level; since the original C&I for the sustainable management of natural tropical forests were first developed, similar processes have been initiated for a number of ecological zones and regions. Currently, about 150 countries (see Fig. 2) are participating in these processes (FAO 2001). While the different processes share similar objectives and overall approach, they differ in structure and specific content. To date, most existing C&I processes measure forest condition at either a national level or at the level of an individual stand or forest management unit level (Tab. 1).

Tab. 1 Diagram showing the main C&I for SFM initiatives and the scales they have been used for

Initiative	Scale	Initiated	C&I	Forests	Members
ITTO (International Tropical Timber Organization)	Global, national	1992 Yokohama, Japan	7 C, 66 I	Tropical	57 countries, Producers and consumers of tropical timber
Tarapoto, Tratado da Cooperação Amazônica	Regional, national	1995 Tarapoto, Perú	7 C, 47 I	In the Amazon	Amazonian countries
Montreal Process	Regional, national	1995 Santiago, Chile	7 C, 67 I	Temperate and boreal	12 countries
MCPFE, Helsinki or Pan-European	Regional, national	Helsinki, Finland 1993 Lisbon, Portugal 1998	6 C, 101 I	Temperate, Mediterranean and boreal in Europe	41 countries
Dry Forest Asia Initiative	Regional, national	1999 Bhopal, India	8 C, 49 I	South Asia and Mongolia, China, Myanmar, Thailand	9 countries
Dry Zone Africa Process	Regional, national	1995 Nairobi, Kenya	7 C, 47 I	Dry of Africa	30 countries
African Process (African Timber Organization-ATO)	Regional, national	1993 Libreville, Gabon	26 C, 60 I	Tropical of Africa	14 countries
Lepaterique Process	Regional, national	1997 Tegucigalpa, Honduras	8 C, 53 I	Of Central America	7 countries
FSC (Forest Stewardship Council)	Global, enterprises	1993 Oaxaca, Mexico	61 C, 167 I	Mostly private	44 countries and many institutions
IUFRO	Global	1892 Berlin-Eberswalde		All in the world	700 organizations from 110 countries
CIFOR	Global, FMU		24 C, 98 I	In developing countries	31 countries
Forest quality	Landscape	1998 Lausanne, Switzerland	7 C, 45 I	All in the world	

C&I are not an end in themselves; the crucial thing is that they are applied, and that management is adapted accordingly so that the forests remain capable of delivering the goods and services required from them. Considering the current scientific knowledge in the research field of C&I for SFM, major conceptual and methodological problems remain to be addressed.

There is a need for the development, refinement, and testing of different sets of C&I for SFM at the local level for similar forest types, based on comprehensive and cost effective field data. There is also a need for methodology and case studies for the development and testing of indicator, verifiers and norms in a regional or local context (MROSEK et al. 2006).

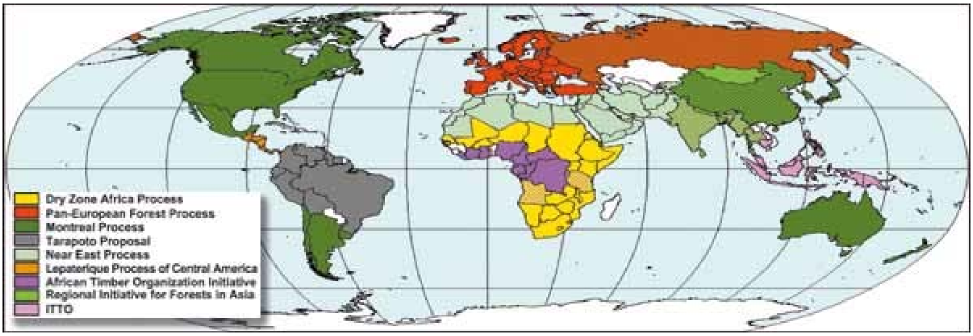

Fig. 2 International processes and initiatives of C&I for SFM. Source: FAO (2006)

2.1.1 International Tropical Timber Organization

The concept and development of the first C&I for SFM only began in the late 1980s, by the International Tropical Timber Organization (ITTO). ITTO was established under the auspices of the United Nations in 1986 in order to increase worldwide concern for the fate of tropical forests. ITTO's origins can be traced back to 1976 when the long series of negotiations that led to the first International Tropical Timber Agreement (ITTA) began at the fourth session of the United Nations Conference on Trade and Development (UNCTAD) as part of that organization's Programme for Commodities. The eventual outcome of these negotiations was the ITTA in 1983, which governed the Organization's work until 1996, when it was superseded by the ITTA of 1994. The next and most recent ITTA is from 2006 and it is expected to come into force in the near future (ITTO 2009).

Understanding and harmonizing approaches to these processes is important for ensuring the consistency of forest management policies across the globe. As part of its contribution to the global process, and in partnership with FAO and others, ITTO supported Guatemala's National Forest Service in the organization of the International Conference on Criteria and Indicators for Sustainable Forest Management in February 2003. A follow-up international expert consultation was held in the Philippines in March 2004, also in collaboration with FAO. A third international workshop was held in Poland in June 2006, in collaboration with the Montréal Process, the Ministerial Conference on the Protection of Forests in Europe (MCPFE) and FAO (ITTO 2009).

2.1.2 Montréal Process

The Working Group on C&I SFM of temperate and boreal forests at the national level, called Montréal Process, was formed in Geneva in 1994. Membership in the working group is voluntary and currently includes countries from both hemispheres, having a wide range in natural and social conditions. This amounts to 60% of all of the forests of the world.

Participants in the Working Group include Argentina, Australia, Canada, Chile, China, Japan, the Republic of Korea, Mexico, New Zealand, the Russian Federation, the United States of America and Uruguay, which together represent 90% of the world's temperate and boreal forests. Several international organizations, non-governmental organizations and other countries also participated in meetings of the Working Group (THE-MONTRÉAL-PROCESS 2008).

The Montréal Process C&I are intended to be applied, at the national level, to all the forests of a country, across all types of land ownership. They consider SFM in a holistic way, taking into account all forest goods, values and services. By endorsing these C&I, each participating country has made a commitment to work toward the sustainable management of all of its forests.

The release of the Montréal Process C&I in Mexico in 1995 provided a valuable tool for evaluating SFM. In 1997, Mexico produced its First Approximation Report using the Montréal Process C&I. In 2001, Mexico decided to establish a national mechanism to encourage the participation of other institutions. Mexico is currently able to report nationally on 54% of the Montréal Process indicators. It is anticipated that an additional 24% of indicators will be reported in the medium term and 22% in the long term (CONAFOR 2006).

2.1.3 Center for International Forestry Research (CIFOR) and International Union of Forest Research Organizations (IUFRO)

Two global organizations that have been directly related with the formulation, testing and improvement of different C&I for SFM are CIFOR and IUFRO (PRABHU et al. 1996; MENDOZA et al. 1999; RAISON et al. 2001).

CIFOR was created in 1993 and IUFRO in 1892 as non-profit, non-governmental international research organizations. CIFOR is a center that conducts internationally relevant research, so as to serve its mission of poverty alleviation and environmental protection. CIFOR was the first international research effort that to tested and compared the effectiveness of C&I for SFM at the forest management unit level (SPILSBURY 2005). IUFRO's objectives are to promote international cooperation in forestry and forest products research and standardization of research techniques.

Both international organizations are devoted to forest research and related sciences, that has contributed to the promotion of the use of science in the formulation of forest-related policies, with specific research on C&I for SFM (RAISON et al. 2001).

2.1.4 Forest quality, sustainable forest management assessment at the landscape level

In 1998, the WWF (World Wide Fund for Nature) and the IUCN (International Union for the Conservation of Nature) initiated a contribution with the École Polytechnique Fédérale of Lausanne. The objective of this association was to develop a C&I toolset to evaluate forest quality at the landscape level. The C&I proposed by WWF and IUCN utilizes the forest quality as the principle and subdivides criteria in three overlapping categories: forest authenticity, environmental benefits and social and economic benefits (Tab. 2). These criteria, at the same time, contain indicators and verifiers of what can be evaluated in field to recognize the quality and present condition of a given forest ecosystem. Forest quality is defined as the "significance and value of all ecological, social and economic components of the forest landscape" (WWF & IUCN 1999). It measures forest conditions at the landscape level, considering the way in which people, forests and ecology interact in a region.

Tab. 2 Forest quality criteria definitions (WWF & IUCN 1999)

Criteria of forest quality	Brief description
Authenticity	A measure of ecosystem integrity and health in the broadest sense. It concentrates on current ecosystem function, regardless of the forest's history, and thus also has relevance to disturbed forests.
Environmental benefits	Mainly indirect benefits: carbon sequestration, water infiltration, biodiversity conservation, etc.
Other social and economic benefits	Other interactions between forests and human societies. Wood and game, living or recreation; hard to measure values such as the cultural, aesthetic and spiritual values of particular forest types or locations.

The concept of forest quality as a C&I tool for the assessment of SFM is more recent than the other international initiatives. It surged as a need to cover the fundamental scale that had not been addressed: the landscape level.

2.2 Ecological restoration of ecosystem services

Although the notion of an ecosystem is ancient, ecosystems first became a unit of study less than a century ago, when TANSLEY (1935) provided an initial scientific conceptualization, and R. Lindeman did the first quantitative study in an ecosystem context in the early 1940s (LINDEMAN 1942). The first textbook built on the ecosystem concept, written by E. Odum, was published in 1953 (ODUM 1953). Thus the ecosystem concept is a relatively new research and management approach.

Human societies derive many essential goods from natural ecosystems, including seafood, game animals, fodder, fuel wood, timber, etc. These goods represent important and common parts of the economy. What has been less appreciated until recently is that natural ecosystems also perform fundamental life-support services without which human civilizations would survive. These include the purification of air and water, detoxification and decomposition of wastes, regulation of climate, regeneration of soil fertility, and production and maintenance of biodiversity, from which key ingredients of our agricultural, pharmaceutical, and industrial enterprises are derived. This array of services is generated by a complex interplay of natural cycles powered by solar energy and operating across a wide range of space and time scales.

These services can be classified in four (MA 2005): 1. provisioning services such as food and water, e.g. direct goods; 2. regulating services such as flood and disease control, pollination; 3. cultural services such as spiritual, recreational, and cultural benefits; and 4. supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.

The Millennium Ecosystem Assessment (MA) assessed the consequences of ecosystem change for human well-being. Their findings provide a state-of-the-art scientific evaluation of the condition and trends in the world's ecosystems and the services they provide, as well as the scientific basis for action to conserve and use them sustainably (MA 2005).

The loss of vital ecosystem functions and services reduces biological resilience and adaptability, further increasing our vulnerability to the adverse impacts of global climate change (DAILY 1997). Ecological restoration is a critical tool in addressing impacts on ecosystem services, like global climate change, enhancing the extent and functioning of carbon sinks as well as reducing greenhouse gas emissions.

By ecological restoration is it meant "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2009). Forest landscape restoration is based in eco-region conservation and is defined as a planned process that aims to regain ecological integrity and enhance human well being in deforested or degraded landscapes (WWF & IUCN 2000). This approach helps achieve a balance between human needs and those of biodiversity by restoring a range of forest functions within a landscape and accepting the trade-offs that result (DUDLEY et al. 2005).

3. Research area: the southwest of Mexico City

3.1 Mexico

3.1.1 Brief historical and social conditions

Mexico is bordered by the United States to the north and Belize and Guatemala to the southeast, having an area of 1,972,550 km^2, five times bigger than Germany. It hosts a great cultural and biological diversity. It has been the center of great civilizations: the Mayas, the Olmecs, and later the Toltecs and Aztecs.

The Aztec empire was conquered in 1519–1521 by Spain and it was ruled as part of the viceroyalty of New Spain for the next 300 years. It was until 1810, when Mexicans first revolted, but the independence just came in 1821. From 1821 to 1877, there were two emperors, several dictators, and enough presidents and provisional executives to make a new government on the average of every nine months (COSÍO-VILLEGAS 2004). Mexico lost the state of Texas (1836), and after defeat in the war with the United States (1846–1848), it lost the area that is now California, Nevada, and Utah, most of Arizona and New Mexico, and parts of Wyoming and Colorado under the Treaty of Guadalupe Hidalgo (MEYER et al. 2003).

In 1855, Benito Juárez began a series of reforms, including the disestablishment of the Catholic Church, which owned vast property. The subsequent civil war was interrupted by the French invasion of Mexico (1861) and the crowning of Maximilian of Austria as emperor (1864). He was overthrown and executed by forces under Juárez, who again became president in 1867 (MEYER et al. 2003). The years after the fall of the dictator Porfirio Díaz (1877–1880 and 1884–1911) were marked by political-military strife and trouble with the United States (JOHNS 1997). Since a brief civil war in 1920, Mexico has enjoyed a period of slow gradual agricultural, political, and social reforms.

Following World War II, the government emphasized economic growth (MEYER et al. 2003). During the mid-1970s Mexico became a major petroleum producer, however, it accumulated a huge external debt because of the government's uncontrolled borrowing on the strength of its petroleum revenues (COSÍO-VILLEGAS 2004). The collapse of oil prices in 1986 cut Mexico's export earnings. In 1994, Mexico joined Canada and the United States in the North American Free Trade Agreement (NAFTA), and in 1996, it became a founding member of the World Trade Organization.

In 1995, the U.S. agreed to prevent the collapse of Mexico's private banks. In return, the U.S. won virtual veto power over much of Mexico's economic policy. In 1997 the Revolutionary Institutional Party (PRI), with complete political power since the revolution, lost control of the lower legislative house and of Mexico City, in a surprising upset. In elections held in 2000, the PRI lost the presidency, ending 71 years of one-party rule. The right winged party Partido Acción Nacional (PAN), has governed the country for the last 10 years. The left winged Revolutionary Democratic Party (PRD) rules the government of the Federal District and other States. PRD and PRI represent the main opposition, and the recent political changes in Mexico, together with the international commitment, have influenced an increased attention in the environmental agenda of the country.

In terms of the legal and institutional environmental framework in Mexico, much has been done in the last two decades. An international meeting on the problems of the knowledge and conservation of biodiversity was held in 1992, to discuss the main issues covering the critical aspects of our present knowledge of biodiversity, their current risks, and the possible consequences of these, as well as the appropriate actions to be taken to safeguard its conservation. As a result of this meeting, the inter-ministerial National Commission for the Knowledge and Use of Biodiversity (CONABIO) was created. Mexico signed the Convention on Biological Diversity (CBD) in 1993, after participating in the Rio Conference, but it already had established the General Environmental Act in 1989 (LGEEPA). The signature of CBD strengthened the legal environmental framework, which has been reviewed and updated. Some environmental institutions have been created, decentralized from the Federal Environmental Ministry (SEMARNAT), like the National Commission of Protected Areas (CONANP) and the National Forest Commission (CONAFOR) in 2001.

3.1.2 Megabiodiversity

Biodiversity is not evenly distributed among the world's more than 170 countries. A very small number of countries, lying wholly or partly within the tropics, contain a high percentage of the world's species. These countries are known as megabiodiversity countries, and twelve have been identified: India, Brazil, Colombia, Ecuador, Peru, Mexico, Madagascar, Zaire, Australia, China, Indonesia and Malaysia. Together, these countries contain as much as 60 to 70% of the world's species (SARUKHÁN & DIRZO 2001).

Biodiversity in Mexico is enormous, with an estimate of 22,800 vascular plant species, of which 52% are considered endemic (RZEDOWSKI 1991a). Mexico contains the greatest diversity of pine and oak species in the world, with 49 pine taxa representing about half of all known pine species (STYLES et al. 1993) and between 135 to 150 oak species (NIXON 1993). It is the Latin-American country with the most ecosystem types and more than 4,000 vertebrates distribute within the country: 1,738 marine fishes, 961 birds, 693 reptiles, 439 mammals and 285 amphibians (MITTERMEIER et al. 1997).

3.1.3 General situation of the temperate forests in Mexico

Despite their importance in terms of biodiversity, ecology, and economy, Mexican forests are threatened by an alarming rate of deforestation. Until the beginning of the twentieth century, 52% of the total surface of Mexico was covered by forests and jungles, together with shrub lands of less than 3 m in height. In the mid 1980's, loss of forest cover amounted to an estimated 668,000 ha per year, which is equivalent to the removal of 1.29% of the total forest cover per year (MASERA et al. 1997). The National Forest Inventory of Mexico in 2000, registered 33% of forest cover, a reduction of 36%. The cover of the main forest vegetation types in that year was: dry forest (10.9%), pine and oak forest (7%), rainforest (5.1%), conifer forest (3.9%), cloud forest (0.9%), mangrove (0.4%), palm forest (0.06%) and gallery forest (0.005%) (PALACIO-PRIETO et al. 2000).

Today losses in temperate forests are also high and amount to 167,000 hectares per year (0.67% per year for coniferous forests and 0.64% for broadleaf forests; MASERA et al., 1997). For temperate forests, most land conversion has been due to deliberate forest fires, clearing to open agricultural lands and pastures, and for fuel-wood harvest (CAIRNS et al. 1995; MASERA et al. 1997). Temperate coniferous forests represent today 16.9 million ha (33% of all forests) and are mostly dominated by pine species (MASERA et al. 1997).

The last Federal Administration of Mexico (2000-2006) established the Strategic Forest Program (PEF 2025), but it was just until 2003 when the General Act for the Sustainable Forest Development was published, followed by the correspondent regulation in 2005. In the actual administration (2006-2012), the main program to support and subsidize the forest sector is called "Pro-Árbol", which has the objective to combat poverty, recover forest area and increment the productivity of forests and jungles in Mexico.

Around 80% of the forests in Mexico are owned by 8,500 communities ("comunidades" and "ejidos"), with an estimated population of 12 million inhabitants. The Agrarian Reform Act of 1915 and the constitution of 1917 laid the groundwork for dramatic changes in Mexico's land tenure system (MERRILL & MIRÓ 1996). These documents established that the nation retained ultimate control over privately held land, which could be expropriated and redistributed in the public interest to campesinos (e.g. farmers or rural people).

The "ejido", or communally farmed plot, emerged as the uniquely Mexican form of redistributing large landholdings after the independence. Under this arrangement, a group of villagers could petition the government to seize private properties for rain-fed holdings. Assuming a favorable review of the petition, the government then expropriated the property and created an "ejido". The State retained title to the land but granted the villagers, now known as "ejidatarios", the right to farm the land, either in a collective manner or through the designation of individual "parcelas". "Ejidatarios" could not sell or mortgage their land but could pass usufruct rights to their heirs. In cases where villagers established that they had collectively farmed the land in question before its eventual consolidation into a hacienda, the government created an agrarian community ("comunidad agraria"). "Comuneros" (members of agrarian communities) had largely the same rights and responsibilities as "ejidatarios" (MERRILL & MIRÓ 1996).

A reform of land tenure rules in 1992 gave Mexico's 3 million "ejidatarios" formal title to their land, enabling them to lease or sell their plots if a majority of members of their "ejido" agreed. Nowadays, from all the "comunidades" and "ejidos" with forest wood resources, only 2,417 (28%) had commercial use activities in 2002 (SIMULA et al. 2005). The GDP from the forest activities represented only 1% of the national total in 2003 and this percentage has oscillated from 0.5% to 1.3% in the last 25 years (CAIRNS et al. 1995).

The national wood production has diminished from 9.4 million m^3 of round wood in 2000, to 7.8 million in 2004. The Mexican environmental police (PROFEPA) estimated that the use of industrial illegal wood in Mexico is around 80% compared to the legal one. The registered legal wood production comes from conifers (82%, mainly pine), oaks and other broadleaves (12%), and only 1.4% comes from tropical trees (SIMULA et al. 2005). The national production is not enough for the local market, and Mexico has to import wood, mainly from the United States.

3.2 The basin of Mexico City

3.2.1 History, population and definitions

In developing countries, the lack of job opportunities in rural areas, decline in subsistence economies, and hope of a better life have given rise to the modern megalopolis (FENN et al. 2002). Unfortunately, urban infrastructure, institutions, and the natural resource base are often inadequate to support these populations.

The basin of Mexico City (BMC) is a large hydrological defined unit enclosing one of the biggest cities in the world: Mexico City and its Metropolitan Zone. It is integrated by 84 municipalities of four different political administrative units: the Federal District, and the States of Mexico, Hidalgo, Tlaxcala, and Puebla. Mexico City represents the most important social, economic, and spatial unit within the basin, concentrating 93 per cent of the basin's population (AGUILAR et al. 1995), thus, the basin of Mexico City and Mexico City are almost synonyms in demographic terms, but the latter is a subset of the former in geographic terms.

The BMC has been one of the most densely populated areas of the world for a long time. During the height of the Teotihuacan Culture (Middle Horizon, A.D. 300-750), the basin had a population of around 300,000 inhabitants, and at the time of the Spanish Conquest (A.D. 1519) the population was around 1.2 million people, which is much higher than the population densities of any comparable region in Europe at that time (WHITMORE & TURNER 1986; WHITMORE et al. 1990). At this time, dikes and sluices controlled the entire lake system, and lakes Chalco, Xochimilco, and the south-west portion of Texcoco were taken to chinampa cultivation (wetland or raised field cultivation) and much of the surrounding land was terraced and irrigated (SANDERS et al. 1979; WHITMORE & TURNER 1992).

The conquest originated a series of changes that followed from a drastic decline in the Amerindian population and the introduction of new biota and technologies from Europe (WHITMORE & TURNER 1992). Ultimately, the central lakes were drained as modern Mexico City expanded and land uses throughout the basin changed during colonial and post-colonial times. Today, metropolitan Mexico City has completely transformed the basin (EZCURRA 1990), the lakes are gone and much of the basin is paved or lies under structures of some type. The city's water must be partially pumped from elsewhere, and its effluent must be pumped out.

Mexico City is a spatially continuous urban area, originally contained within the boundaries of the Federal District, but during the 1950s spreading beyond into adjacent municipalities of the State of Mexico. The current urban area of Mexico City encompasses all 16 subunits or delegaciones of the Federal District and 21 municipalities in the neighboring State of Mexico. The urban area, therefore, does not coincide with political administrative divisions. The metropolitan zone of Mexico City corresponds to the territorial extension of the old central city in the Federal District into the urbanized political-administrative units contiguous to it (AGUILAR et al. 1995).

The population of the Federal District was 8.7 million in 2005, with a density of 5,871 inhabitants/km^2. The population of the metropolitan zone of Mexico City reached 19.2 million in 2005 (INEGI 2005). The city's population growth was phenomenal during most of the 20th century, promoted by migration from the provinces and a high birth rate (GARZA 2000).

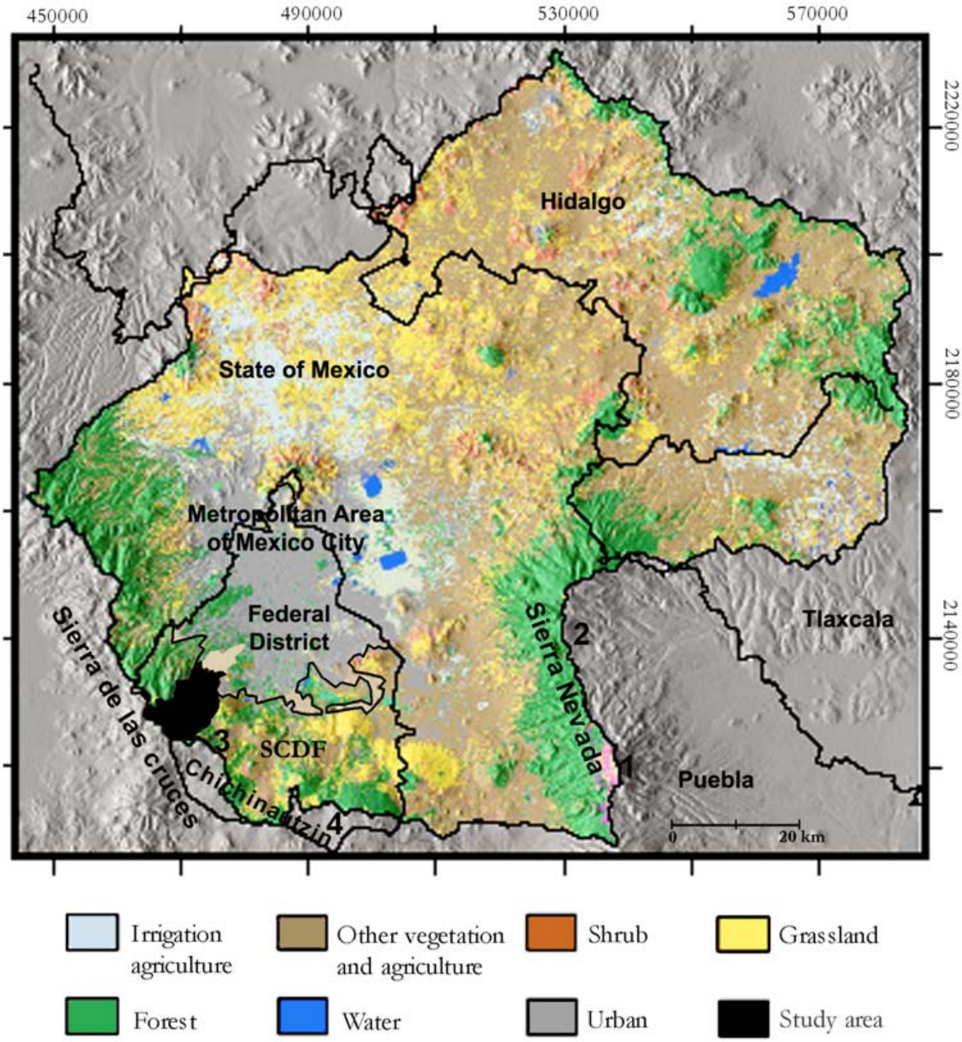

Fig. 3 Localization of the basin of Mexico City, the metropolitan zone of Mexico City, the Federal District, the conservation area of the Federal District (SCDF) and the study area. Volcanoes: 1 Popocatépetl, 2 Iztaccíhuatl, 3 Ajusco and 4 Pelado (modified from CARRERA-HERNÁNDEZ *2007).*

3.2.2 Climate, hydrology and water use

The basin of Mexico City lies on the southern edge of the Transverse Volcanic mountain range, an upland formation of Late Tertiary origin. It is a naturally closed (but now artificially drained) hydrological unit of approximately 9,600 km², the lowest part, a lacustrine plain, averages about 2,240 m asl. About 700,000 years ago, obstruction of drainage by volcanic material caused several lakes to form on the floor of the basin, with a total area of about 2,000 km^2, and connected during periods of high water (EZCURRA 1990).

Water, like air, is a vital resource without substitute. Its supply, allocation, and disposal present numerous challenges, all of which must be met to support the population in growing metropolitan regions. The water requirements of the nearly 20 million residents present a formidable challenge to those responsible for providing water and wastewater services. Surface water within the basin of Mexico City is very limited, most of the previously existing lakes have been dried out and the water of the remaining has bad quality (MAZARI-HIRIART et al. 2001).

Mexico City gets the required water from three main sources: 71% comes from the ground aquifer, 26.5% from the Lerma (State of Mexico) and the Cutzamala (Guerrero State) watersheds, and the rest from the few superficial sources left in the basin of Mexico City, like the Magdalena river. The exploitation of the basin's ground aquifer system started in 1847, when the first well was drilled (ORTEGA & FARVOLDEN 1989). Bringing water into the valley from elsewhere is becoming impractical and too expensive.

The basin is surrounded on three sides by a succession of volcanic sierras (Chichinautzin to the south, the Sierra Nevada to the east, and the Sierra de las Cruces to the west). The highest peaks, "Popocatépetl" and "Iztaccíhuatl" (at 5,465 m and 5,230 m, respectively, see Fig. 3) lie south-east of the basin, but many other peaks reach elevations of around 4,000 m.

The aquifer is recharged in the mountains surrounding the basin. The total recharge volume is estimated to be 25–50% of the precipitation (25% in "Sierra las Cruces", 35% in "Sierra Nevada", and 50% in "Sierra Chichinautzin"). Of this volume, about half flows toward the basin of Mexico City, the rest moves outward to other basins (HERRERA-REVILLA et al. 1989).

Recharge volume is certainly below 50 m^3/s, which is the rate of extraction, because the aquifer is becoming depleted (HERRERA-REVILLA et al. 1989). Additional lowering of the water level in the aquifer will cause an increase in flow from the sierras, because of the increased gradient. The aquifers are recharged with approximately 700 million cubic meters annually, but nearly double that amount is extracted. Nevertheless, the basin still relies on aquifers to obtain 72% (52.2 m3/s) of its water (JIMÉNEZ-CISNEROS et al. 2004), which over-exploitation is the root of recent water shortages, as well as the cause of the City's sinking (JACMCWS 1995).

While the volume of water in storage is quite large, its quality is vulnerable to degradation from all the activity above it. Lack of wastewater treatment and insufficient control over hazardous wastes have placed the aquifer and water distribution system at risk of contamination. Since ground water exploitation first began in the last century, falling ground water levels have resulted in an average subsidence of 7.5 m in downtown Mexico City (FENN et al. 2002).

3.2.3 Antique and present vegetation in the basin of Mexico City

Before the rise of the Aztec State, the lacustrine system at the bottom of the basin covered approximately 1,500 km². Before human transformations, nine major environmental zones existed in the basin: the lake system, an important resting habitat for migratory water birds; the saline lakeshore, characterized by halophytes; the deep-soil alluvium, covered by sedges and swamp cypresses; the thin-soil alluvium, dominated by grasses and agaves; the upland alluvium, occupied by oaks and acacias; the lower piedmont, cloaked by low oak forests; the middle piedmont, covered by broadleaf oaks; the upper piedmont, occupying elevations above 2,500 meters and characterized by oaks, alders, and madrones; and the sierras, occupying sites above 2,700 m asl and harboring temperate plant communities of pines, fir, and junipers (SANDERS et al. 1979). Little of these original ecosystems now remains (mainly some grasslands with agaves, and the temperate forests in higher elevations).

Nowadays, the total forested area in the BMC is 156,000 ha (RODRÍGUEZ-FRANCO & MAGAÑA 1991), and the majority distribute on the surrounding mountains. The main factors affecting forest vegetation in the BMC are the high demographic pressure, illegal cutting, forest fires, insect attack, soil erosion, uncontrolled grazing, and irregular settlements. The highest occurrence of forest fires in Mexico occurs within the basin of Mexico City. Every year, there are approximately 7,600 forest fires in the country, of which 43% occur in this basin (RODRÍGUEZ-FRANCO 2002).

The loss of forested area due to changes in land use, from forest to agriculture, urbanization, industrial development and road expansion have impacted 13,000 ha (CORENADER 2003).

3.2.4 Land possession regime

Historically, there were 83 "ejidos" and 7 "comunidades" in the Federal District, to which 54,400 ha had been given. Although, mainly because of the urban expansion towards community lands, today only 33,938 ha remain as communal property (CORENADER 2003). The social property within the Conservation Area of the Federal District, without considering the losses due to the urban area expansion and invasions, can be seen in Tab. 3.

The expansion of the urban area towards communal properties has been vertiginous in the last 20 years. This has transformed rural areas into urban, and an environmental problematic has developed. It is though necessary to implement policies that promote the reversion of the urban over the rural tendency, so that cultural, biological and ecological values that still exist will not disappear. In the Conservation Area of the Federal District, 806 human settlements have been found. From these, 86 are legal and 804 are illegal, giving a place to live to more than 59,000 families (CORENADER 2003).

Tab. 3 Social property areas by municipality inside the conservation area of the Federal District

Municipality	Communities	Originally given area (ha)	Actual area (ha)
Gustavo A. Madero	9	4,181	543
Cuajimalpa	3	3,953	1,869
Alvaro Obregón	3	589	460
M. Contreras	6	6,358	4,997
Tlalpan	12	23,248	20,067
Xochimilco	6	2,056	582
Milpa Alta	5	1,795	1,794
Tláhuac	7	4,889	3,412
Iztapalapa	13	4,282	129
Total	64	51,355	33,855

Source: National Agrarian Registry of the Federal District, 2009.

3.3 Magdalena Contreras municipality and Magdalena river watershed

3.3.1 History and population

For this research two criteria were considered for the selection of the study area: a political one for taking the conservation area of Magdalena Contreras municipality and a hydrological in order to consider the whole area of the upper Magdalena river watershed. Most of the Magdalena river watershed lies inside the Magdalena Contreras municipality (78%), and a small area in the highest parts belongs to Álvaro Obregón municipality (5%) and Cuajimalpa municipality (17%).

The area is inside the BMC, situated on the western slopes of “Sierra de las Cruces”, with an altitudinal interval from 2,400 till 3,870 m asl and an area of 6,400 ha (Fig. 4).

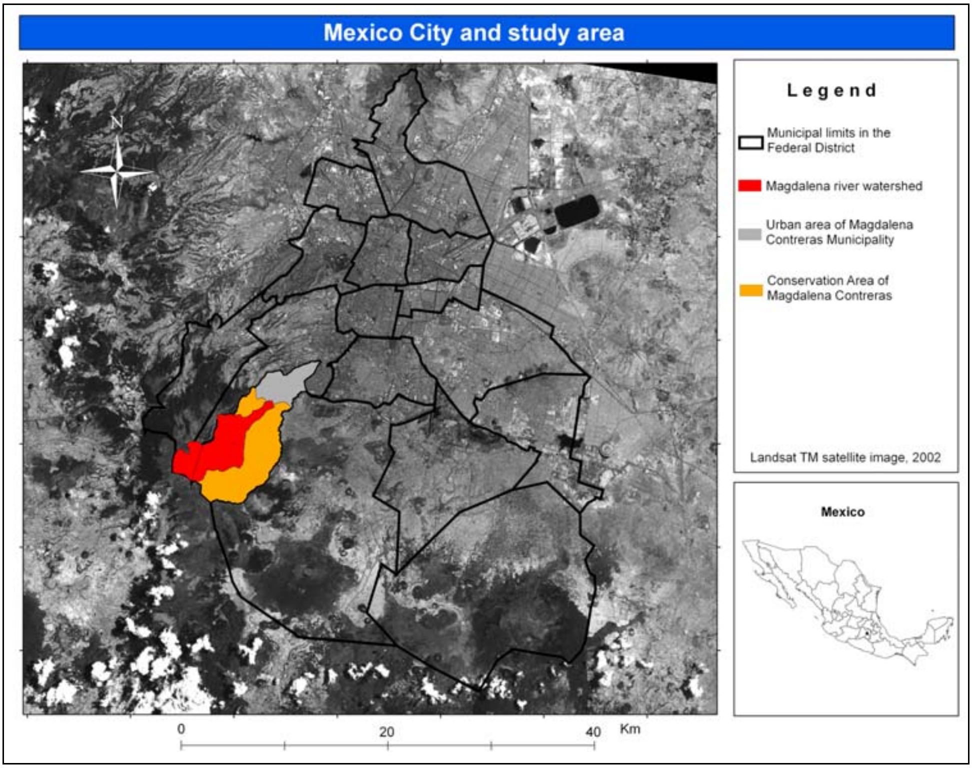

Fig. 4 Localization of the upper Magdalena river watershed and the Magdalena Contreras Municipality.

3.3.2 Geology and soil

The study area presents different evolution phases which are directly related to the origin of the basin of Mexico City (ONTIVEROS-DELGADO 1980). This zone is formed by extrusive igneous material, product of volcanic eruptions from the Tertiary and Quaternary (ÁLVAREZ-ROMÁN 2000). Its basement is constituted by massifs from the "sierra de las Cruces", from the beginning of the Tertiary, going till the Upper Tertiary. This sierra is one of the main active focuses of the Transmexican Volcanic Belt which was formed as a consequence of the pacific emissions of acidic lava. The Magdalena river watershed is a result of block faults that leave abrupt regular banks where the river packs in narrow margins (ÁLVAREZ-ROMÁN 2000).

The majority of the soils are Andosols of the humic, molic and ocric types with a mixture of Lithosols and Pheozems.

3.3.3 Climate and hydrology

The lower parts, between 2,530 and 2,800 m asl, have the climatic subtype C (w_2) (w) (b) i'g (Köppen modified by GARCÍA 1988), which corresponds to a temperate sub humid, the wettest of the sub humid climates, with a rainy season during the summer. The summer is cool and long, the average temperature oscillates between 12 and 18° C, the temperature of the coldest month between -3 and 18°C and the warmest month between 6.5 and 22° C, with low thermic oscillation and a Ganges pattern for temperature (e.g. the hottest month is before the summer solstice and the temperature pattern is intertropical). In the higher parts, from 2,800 till 3,500 m asl the climate is Cb' (w_2) (w) (b') i g, differing from the latter for having an annual mean temperature between 5 and 12 ° C with thermic oscillation of less than 5° C, meaning isothermal (Köppen modified by GARCÍA 1988).

The highest rains fall in the period from may till October, with monthly precipitations higher than 250 mm in July. May is the month with the highest temperatures, and January with the coldest (ÁLVAREZ-ROMÁN 2000). The annual precipitation is around 800 mm in small patches of lower altitudes, but most of the area has an annual precipitation between 1200 and 1500 mm.

Inside the research area there are two main rivers: the Eslava and the Magdalena, which run parallel in different watersheds until they meet in the urban area. The Magdalena river has a total length of 21,6 km, from which 15,2 km run along the forested area of the watershed (ÁVILA-AKERBERG 2004), from its birth at ca. 3,600 m asl until the beginning of the urban area at ca. 2,470 m asl (Fig. 6). Further downstream, the river runs through the urban area until it reaches the Anzaldo dam and it is afterwards drained and directed to the Churubusco river (see Fig. 5). The waters of Magdalena and Eslava rivers continue its drained way to finally go out the basin of Mexico City through the artificial tunnels of the "Great Drainage Canal", constructed in 1954.

The water demand of Mexico City's inhabitants is 72.5 m^3/s, from which 1.45 m^3/s (2%) comes from surface waters (JIMÉNEZ-CISNEROS et al. 2004), like the Magdalena and Eslava rivers. They are both accumulation of flows of water from the higher precipitation in the mountainous areas. Though, their natural currents have been modified by the use of different types of dams (rock filled metal cages, soil, and rock). The former use of the Magdalena river for the generation of electricity in the four "Dynamos", had flow deviations into canals to gain a steeper water fall.

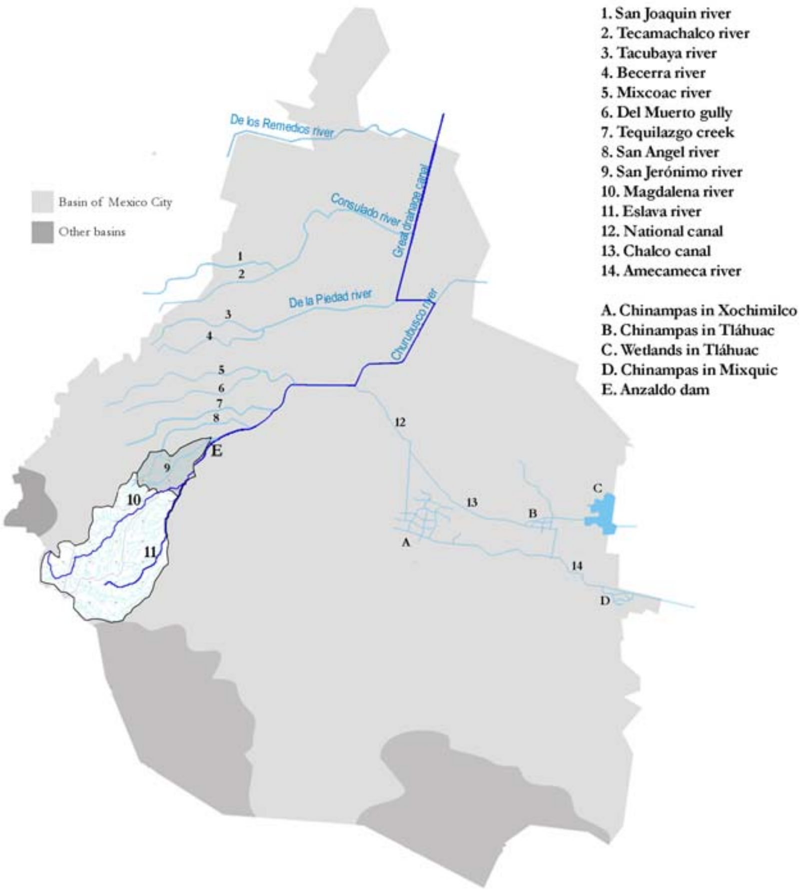

Fig. 5 Main rivers (drained and superficial), canals, dams and wetlands of the Federal District. In darker blue, the flow pattern of the waters of Magdalena and Eslava rivers.

The Magdalena river is one of the most important water bodies of Mexico City, because it is the last living river (with year round water and not drained in its upper parts) with fairly good water quality until it reaches the urban area (CANTORAL-URIZA et al. 1999). Its permanent water volume is approximately 1 m^3/s, and its maximum flow in the rainy season can go up to 20.1 m^3/s. Though, only a fifth of its flow is used and the rest goes directly to the sewage system.

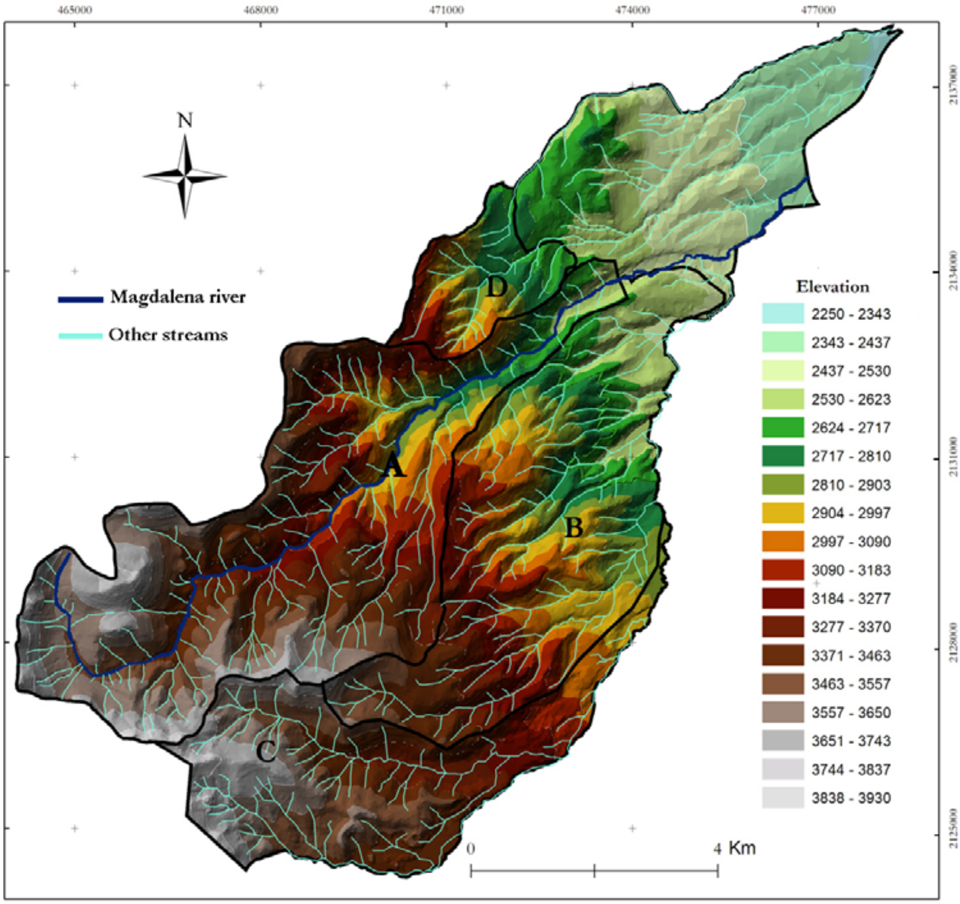

Fig. 6 Hypsometry and watersheds in study area: A Magdalena river, B Eslava river, C Viborillas and D Texcalatlaco. Magdalena river and other streams.

3.3.4 Legal status and protection history

The Federal District has an approximate area of 149,830 ha and it can be divided in two, considering the land use types: urban development area and ecological conservation area. The surface of the Ecological Conservation Area in the Federal District is 87,204 ha, corresponding to around 59% of the total area, of which nearly 75% are of social property (i.e. community or cooperative).

The Ecological Conservation Areas in the Federal District provide fundamental environmental services for the existence of the City. These are mainly mountainous zones covered with forests and areas that are utilized for agriculture. The protection of these areas is indispensable for the conservation of the biodiversity and the maintenance of a good environmental quality in Mexico City, since their existence permits the continuation of ecological processes and functions of vital importance. Among others: the refill of aquifers, oxygen production, microclimate regulation, erosion control, barriers against wind, dust, particulated contaminants and noise, a refuge for biodiversity, recreation, environmental education and scientific research (CORENADER 2003).

The conservation area is threatened daily by diverse factors of deterioration, many times irreversible, among the ones that they excel the pressure of the real estate interests, the presence of irregular settlements (that occupy near 3,208 ha), the growth of the rural settlements, the atomization of agricultural plots, the conflicts in the possession of land, an agrarian crisis that is currently maintained and the poverty of its settlers (CORENADER 2003). In a direct way, the vegetation and the wild fauna have been affected by the illegal deforestation, the incidence of fires, the lack of technical management, the opening of land for agriculture, the uncontrolled stockbreeding and the contamination of air, soil and water, which result in the deterioration of the ecosystems and the loss of biodiversity. It is estimated that the Federal District loses 240 ha covered with vegetation every year (CORENADER 2003).

The Magdalena Contreras Municipality has 76% of its territory inside the Ecological Conservation Area and several protected areas within. The oldest protected area decree is from 1932, when it was declared "Zona Protectora Forestal Bosques de la Cañada de los Dinamos" 3,100 ha covering the area of the Magdalena river watershed. The second decree came in 1947 when the establishment of the "Zona de Protección Forestal del río Magdalena" declared the protection of 500 m to each side of the Magdalena river along twelve km, from its origin, until the beginning of the urban area. But, in 2000 the "Programa General de Ordenamiento Ecológico" of the Federal District, considered only 215 ha of the Magdalena river watershed as protected (Fig. 7). Other protected areas inside Magdalena Contreras Municipality are: "Lomas de Padierna" Protected Area, and the Ecological Community Reserves of the "Ejido de San Nicolás Totolapan" and the "Community of San Bernabé Ocotepec".

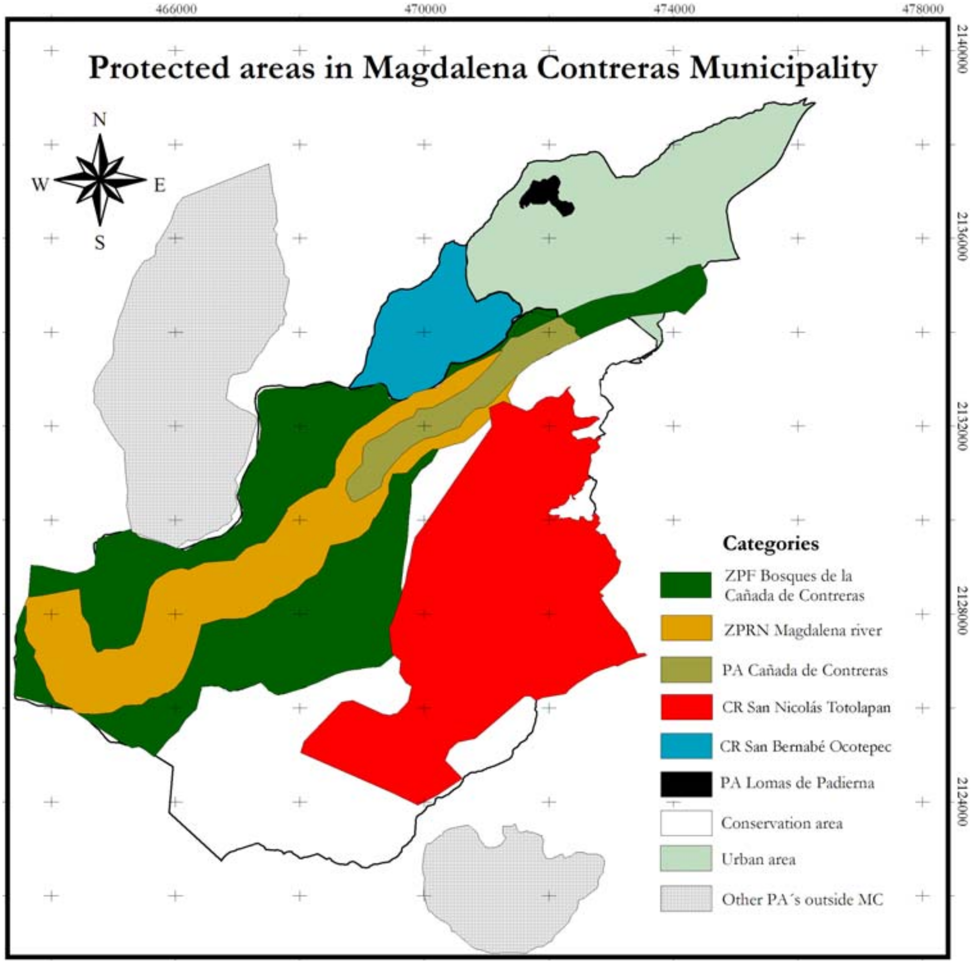

Fig. 7 Protected areas within Magdalena Contreras Municipality. ZPF="Zona Protectora Forestal", ZPRN="Zona de Protección de Recursos Naturales", CR=Community Reserve, PA=Protected area

3.3.5 Land possession regime

The land possession regime of the area is mainly of communal property. Most of the upper Magdalena river watershed belongs to the "Comunidad of the Magdalena Atlitic" with around 2,350 ha and 2,792 community members. In terms of area, the second biggest landowner community is the "Ejido of San Nicolás" with 2,060 ha and 336 ejido members. Other communities with some land possession in the study area are: "Ejido San Bernabé Ocotepec", "Ejido Santo Tomás Ajusco", and "Comunidad of Magdalena Petlacalco".

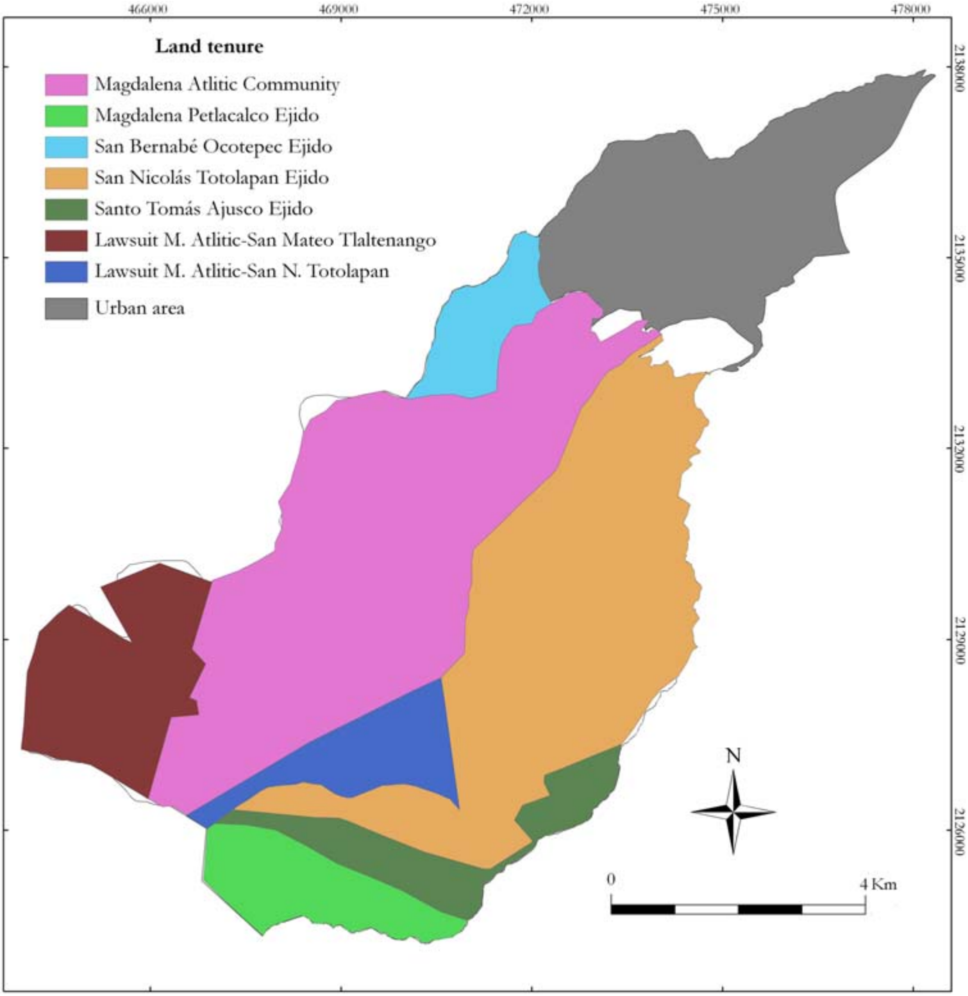

Fig. 8 Land possession regime within the study area. Source: modified from Magdalena Contreras Municipality (2009)

4. Phytodiversity, phytosociology and plant communities' spatial distribution in the southwest of Mexico City

4.1 Summary

The spatial distribution, flora and phytosociology of the forests present in the conservation area of Magdalena Contreras municipality and Magdalena river catchment were characterized. A legend with 16 categories was used to make a map scale 1:10,000 of the vegetation and land use units of the area. The dominant forest of the area is *Abies religiosa* (46%), followed by three classes of *Pinus hartwegii* forest (29%), the *Quercus* forest (8.3%), grassland (7.2%), mixed forest (1.3%), human settlements (0.8%) and the cloud montane forest (0.2%), among others. In an area equivalent to 0.0032% of the total extension of the country, it is possible to find all the temperate forests present in Mexico, with different levels of disturbance.

The inventory of the flora in the area resulted in 95 families, 281 genera and 534 species. The most important plant families in terms of species and genera numbers are: Asteraceae, Brassicaceae, Poaceae, Leguminosae, Rosaceae, and Lamiaceae. The genera with the most species are *Salvia* (13), *Ageratina* (10), *Stevia* (9), *Pinus* (8) and *Quercus* and *Senecio* with 7. Herbs dominate in number of species (393), followed by trees (53) and shrubs (50). Ten plants included in the NOM-059-SEMARNAT-2001, the Mexican classification for endangered plant species, were recorded including three endemic species: *Acer negundo* var. *mexicanum, Furcraea bedinghausii, Dahlia scapigera.* The plant species richness of this area represents ca. 23% of the total flora in the basin of Mexico City, and ca. 2.2% of the country's flora. Because of this, the area should be considered a rich phytodiversity refuge.

Following the phytosociological school of Zurich-Montpellier, 117 relevés of 25 x 25 m were made. These revealed the existence of three plant communities, corroborated with an agglomerative hierarchical classification analysis. The first is a *Pinus hartwegii* community, which is monospecific and open, occurring in the higher parts of the area between 3,400 and 3,870 m asl. It has three associations: two with *Calamagrostis tolucensis* and the other with *Festuca tolucensis*. The second community is a dense forest of *Abies religiosa* extending between 2,750 and 3,500 m asl and has three associations: with *Thuidium delicatulum*, with *Roldana angulifolia*, and with *T. delicatulum* and *Acaena elongata*. The third community is a mixture of *Quercus* and mixed forest, growing between 2,470 and 3,100 m asl and represented by the associations of *Quercus laurina- Q. rugosa and Q. rugosa-Q. laurina.*

4.2 Introduction

4.2.1 Vegetation and floristic diversity of Mexico

Mexico has examples of nearly every plant community known in the world. Its biological diversity derives from its geological past, its physical spread, topography, diverse climate and its position within two biogeographic regions: Nearctic and Neotropical (RZEDOWSKI 1978). Its mosaic of vegetation includes the subhumid temperate zone with an area of ~33 million hectares, in which grow different types of vegetation such as coniferous forests, mixed forest and *Quercus* forest. It is characterized by having holarctic elements, mainly in the tree layer, whereas the elements of the shrub and herb strata are neotropical, forming a complex mosaic with the indigenous elements (RZEDOWSKI 1978). The montane cloud forest, which normally extends over the humid temperate zone, represents a transition between the tropical and temperate regions (RZEDOWSKI 1970). This ecological zones constitute a habitat of enormous biological and biogeographical importance because they are distributed chiefly along the great mountain chains of the country (TOLEDO & ORDÓÑEZ 1998), such as those that surround the basin of Mexico City (BMC).

The BMC is within an endorrheic catchment, of volcanic origin and with an area of ~7500 km^2. It holds different vegetation types, mainly classified as temperate sub-humid, which contain ca. 2% of the plants of the planet, around 2,500 species(DE RZEDOWSKI & RZEDOWSKI 2001). It is a natural region that has been modified by a long succession of human interventions, such as deforestation, which have gradually changed its landscape (MUSSET 1992; GUTIÉRREZ DE MACGREGOR ET AL. 2005). The occupation of its land has been a function of physical, demographic, economic, political, social, administrative and technical factors. These have brought the establishment of one of the largest cities in the world, now referred to as 'Greater Mexico City' or the Metropolitan Zone of Mexico City, which includes the Federal District and 41 suburban municipalities (MAZARI-HIRIART et al. 2001). In spite of the growth of the urban sprawl that has occurred in this city in recent decades, there are still localized areas of ecological reserves, mainly to the south and the south-west of the Federal District, covering 58% of the area (CORENADER 2003). The area under study has an important part of this remnant vegetation, covering ~6400 ha of the Conservation Area of the Federal District.

Antecedents

A wide range of studies reflect the need to identify the types of vegetation that surround the basin of Mexico City (BMC). The floristic studies in the center of Mexico first started in 1787 and 1788, with the explorations of Sessé and Mociño in various parts of the BMC such as Tacubaya, San Ángel, Contreras and Desierto de los Leones in the Federal District (DE RZEDOWSKI & RZEDOWSKI 2001). In the

19th century, "Introducción para una flora del Valle de México" by RAMÍREZ (1899) was one of the first contributions to the knowledge of the environmental conditions of the region. Since that publication, the most important contributions have been those of REICHE (1923), who studied the broad plant communities of the forests around Mexico City, MARTÍNEZ AND MATUDA (1953-1972), who studied the flora of the State of Mexico, and SÁNCHEZ (1969) compiled the flora of the basin of Mexico City.

Other contributions to knowledge of the ecology of the BMC are those made by MADRIGAL (1967), who studied the *Abies religiosa* forest from a floristic and structural perspective. MELO & OROPEZA (1975) mapped the plant cover of the region, and RZEDOWSKI (1970; 1975; 1979) gave a general view of the flora and vegetation of the whole area, presenting a synopsis of the most striking characteristics of the principal types of vegetation of the region and an analysis of the vegetation of the cloud montane forest. More recently, VELÁZQUEZ & CLEEF (1993) have examined the plant communities on the volcanoes Tláloc and Pelado and the relationship of these communities with some environmental variables. MELO & ALFARO (2000) provided a brief description of the forests within Mexico City, and RZEDOWSKI C. DE & RZEDOWSKI (2001) updated and described the flora of the BMC. More specifically for the area, NIETO DE PASCUAL (1995) summarized the structure and composition of the *Abies religiosa* forest in the Magdalena river watershed. However, none of these publications presents data regarding the complete and actual flora, cover and spatial distribution of the plant communities of the MRW+MCCA.

Because these forests face an enormous anthropic pressure, it is very important to study their phytodiversity, assessing its spatial distribution and aggregation within plant communities. The objective of the present chapter is to describe the flora, phytosociology and spatial distribution of the forests in the area under study.

4.3 Method

4.3.1 Floristic list

The recollection of plant exemplaires was done between 2004 and 2008, in 117 field sample plots and during the walks and visits to the area. For every collected plant the spatial location, altitude, and vegetation type were registered.

The plants were herborized, labeled and taxonomically identified[1], when possible, to the species level with help of the specialized floras for the area (BEETLE 1983, 1987; ESPINOSA G. & SARUKHÁN 1997; CALDERÓN DE RZEDOWSKI & RZEDOWSKI 2001). For the botanical determination the classification proposed by CRONQUIST (1988) was used for dycotiledons and from DAHLGREN (1985) for monocotyledons. The synonyms and nomenclature of the scientific names were verified by reference to the database of the Missouri Botanical Garden (www.mobot3.org). The recollected material was deposited in the herbarium of the Science Faculty of UNAM (FCME).

The weed and exotic plant species were determined consulting the works of ESPINOSA & SARUKHÁN (1997) and CALDERÓN DE RZEDOWSKI & RZEDOWSKI (2001). A coefficient analysis on the relations between the total number of species and genera in the Asteraceae family against the whole flora was made to prove the sampling intensity (RZEDOWSKI 1991a).

A bibliographic review was made to gather the information of the authors that have worked with the flora in or around the area. The works of MADRIGAL (1967), SÁNCHEZ (1969), LUIS-MARTÍNEZ (1985), NIETO DE PASCUAL (1995), SILVA *ET AL.* (1999) and DE RZEDOWSKI & RZEDOWSKI (2001) were consulted, and it was possible to find that the flora of the area could be higher (681 spp.) than what has been found so far.

The phytogeographic affinity at the genus level was defined following the criteria in Tab. 4 and consulting the work of MABBERLEY (1987), WILLIAMS (1951), WILLIS (1973), and ALMEIDA-LEÑERO (1997).

Tab. 4 Phytogeographic distribution areas used for the genera (modified from ALMEIDA-LEÑERO, 1997)

Components	**Elements**	**Distribution areas of the elements**
Temperate	Wide temperate (WTe)	Temperate and cold from both hemispheres
	Holarctic (HA)	Temperate and cold from the Northern Hemisphere
	Nearctic (NA)	Temperate and cold from North America
	Austral antartic (AA)	Temperate and cold from the Southern Hemisphere
Cosmopolitan	Cosmopolitan (CO)	Temperate and tropical from both hemispheres
Tropical	Wide tropical (WTr)	Tropical from America, Asia and Africa
	Neotropic (NT)	Tropical from America
Mexico	Endemic (MX)	Mexico

[1] Special thanks to the specialists Dr. Susana Valencia Ávalos (Fagaceae), Biol. Ramiro Cruz Durán (Fabaceae), Dr. Martha Martínez (Euphorbiaceae) and MSc. Rosa Ma. Fonseca (Pinaceae and Rosaceae) for their help with the identification of plant exemplaires. Thanks to Myriam Rubio Palacios, Lilia Alvarado García and Madai Velasco Vázquez for their support on field and processing of the collected botanical material.

The life forms were determined according to the plant's physiognomy described in DE RZEDOWSKI & RZEDOWSKI (2001) and to the position of the buds (sensu Raunkiaer). The life forms found were: tree, shrub, herb, low growing (between 0-5 cm), epiphyte and climber; and Phanerophyte, Chamephyte, Hemikryptophyte, Cryptophyte and Therophyte.

4.3.2 Vegetation mapping

The GIS ILWIS 3.2 (Integrated Land and Water Information System) was used to generate the vegetation and land use units map. Aerial color georreferenced photos from 2005 were gathered into a mosaic for the photointerpretation of the different categories (see Tab. 5).

For the description of the used categories in the classification of the vegetation, a hierarchical and inclusive legend was made. Although, it is good to remark, that some elements like the soil, vegetation, elevation, atmospheric pressure, etc., characterize for having gradual changes over the terrestrial surface, so even that they are conceptually definable units, have gradual instead of discrete limits, so that their spatial delineation will never be completely precise (MALCZEWSKI 1999).

Topography (altitude, slope and aspect) and the different green tonalities (e.g. fir forest had the darkest green tone), textures (eg. rounded textures for the oak forests), and pattern shapes (eg. square polygons for agricultural lands) of the aerial photographs, along with the field work for further differentiation and corroboration, allowed the categorization for the vegetation and land use units map (photos of main vegetation types and land uses in Fig. 9).

Tab. 5 Categories used in the photointerpretation for the vegetation and land use units map

Legend category	Description
Pinus hartwegii forest	>60% cover of *Pinus hartwegii*
Pinus hartwegii-Grassland	>30-<60% cover of *Pinus hartwegii*
Grassland-*Pinus hartwegii* forest	<30% cover of *Pinus hartwegii*
Abies religiosa forest	Dense appearance, dark green tone
Disturbed *Abies religiosa* forest	Open appearance, <30% of *Abies religiosa* in the canopy
Mixed forest	A combination of tree species dominating the canopy: *Abies religiosa* *Pinus* sp., *Quercus* sp., *Cupressus lusitanica*, etc.
Pinus sp. forest	Pine forest with other than *P. hartwegii* species dominating the canopy
Disturbed *Pinus* sp. forest	Like Pinus sp. forest, but with <30% cover of the canopy
Cloud montane forest	Presence of certain species (RZEDOWSKI 1970): *Viburnum stenocalyx* *Alnus acuminata, Quercus laurina, Acer negundo var. mexicanum, Sambucu nigra, Clethra mexicana*, and *Cornus disciflora.*
Furcraea bedinghausii shrubland	An azonal community of small palms only distinguishable on field
Pinus-Quercus forest	Combined dominance of the canopy between *Pinus* sp. and *Quercus* sp.
Quercus sp. forest	In the lowest parts, bordering the urban area, the oak forest with a canopy cover of >60%
Disturbed *Quercus* sp. forest	Oak forest with canopy cover <30%
Forest plantation	Planted forest of *Cupressus lusitanica* and *Eucalyptus globosus*
Gallery forest	Forest associated with the river in the lowest parts
Grassland	Due to deforestation or the topographic characteristics of the terrain these are areas without trees and a few shrubs
Football pitch	Flat areas with grassland converted into soccer fields
Infrastructure	Constructions for camping and surveillance
Rocks	Bare rocks exposed on cliffs
Mine	Extraction of rocks and sand for construction materials
Agriculture	Square polygons, close to the urban area
Human settlements	Groups of small houses. Supposedly not legally settled.
Plant nursery	Two places within the study area, growing native tree species mainly

4.3.3 Phytosociological table

The method developed by the Zürich-Montpellier school of phytosociology (BRAUN-BLANQUET 1932; MUELLER-DOMBOIS & ELLENBERG 1974) was used. Following the criteria of minimal sampling area for temperate forests (MATTEUCCI & COLMA 1982), 117 plots of 25 × 25 m were done using a stratified random sampling based on the forest types recognized in the vegetation and land use units map. For each sample site the plants were listed and the percentage cover by each stratum and by each species was estimated in relation to the total area.

In total 360 plant species, including phanerogams, ferns and mosses, were collected and identified in the sampled plots. Species data were used in this analysis because they are indicative of ecological conditions in contrast with other higher taxa (VELÁZQUEZ & CLEEF 1993). To identify and separate the information into vegetation communities and associations, a hierarchical and agglomerative classification method (Cluster analysis) using PCOrd 4 (MCCUNE & MEFFORD 1999)

Fig. 9 Photos of the main vegetation and land use types

was applied. As distance measure the relative of Sörensen was used together with Ward's method for group linkage.

4.4 Results

4.4.1 Flora

The study registered a total of 95 plant families with 281 genera and 534 species present in the area (App. 1). The most important families in terms of species numbers were: Asteraceae 21%, Lamiaceae 4.9%, Poaceae 4.5%, Caryophyllaceae 4.3, Brassicaceae 3.9% and Rosaceae 3.4% (Tab. 4), while the families with the most genera are: Asteraceae 18.4%, Brassicaceae 5.4%, Poaceae 5.1%, Fabaceae 3.6%, Rosaceae 3.6% and Lamiaceae 3.2%. The genera with the most plant species are *Salvia* (14), *Ageratina* (10), *Stevia* (9), *Pinus* (8), *Quercus* (7), and *Senecio* with 6.

In regard to life forms, the herbs are the most abundant (393 spp.), followed by trees (53), shrubs (50), low growing (24), epiphytes (8), and climbers (6). Hemikryptophytes represent the majority (201 spp.), followed by Phanerophytes (132), Cryptophytes (77), Therophytes (66), Chamaephytes (55) and Parasites (3).

For the geographic affinity at the level of the genera, it was found that the Cosmopolitan affinity includes the majority of the plant species (129), followed by the Neotropical (116), the Holarctic (115), the Wide temperate (99), the Wide tropical (44), Nearctic (12), Endemic (11) and Austral antarctic (8).

Tab. 6 Best represented plant families in the MRW+CAMC, Mexico, D. F.

Family	# of genera	%	# of species	%
Asteraceae	51	18.4	114	21.6
Brassicaceae	15	5.4	21	3.9
Poaceae	14	5.1	24	4.5
Leguminosae	10	3.6	17	3.2
Rosaceae	10	3.6	18	3.4
Lamiaceae	9	3.2	26	4.9
Ericaceae	7	2.5	8	1.5
Scrophulariaceae	7	2.5	11	2.1
Apiaceae	6	2.2	9	1.7
Solanaceae	6	2.2	17	3.2
Caryophyllaceae	5	1.8	23	4.3
Commelinaceae	5	1.8	9	1.7
Crassulaceae	5	1.8	10	1.9
Orchidaceae	5	1.8	7	1.3
Rubiaceae	5	1.8	8	1.5

By growth form the families with the most plant species are: in herbs Asteraceae with 88 species, Lamiaceae with 26, Poaceae 24, Caryophyllaceae 20 and Brassicaceae with 19. For shrubs Asteraceae with 22 species, and Rosaceae and Saxifragaceae with 3 species each; for trees, Pinaceae 9 species, Fagaceae with 7 and Betulaceae 4.

Ten species were found to be on a category of risk according to the "Norma Oficial Mexicana 059-SEMARNAT-2001" (DOF, 2002), from which three are also endemic to Mexico: *Furcraea bedinghausii*, *Acer negundo* var. *mexicanum* and *Dahlia scapigera* (Tab. 7). In contrast, other species are favored by disturbance, so that it is common to find them along paths and roads as well as near to agricultural lands. Within these kind of species, some of the most common were: *Acaena elongata*, *Achillea millefolium*, *Ageratina petiolaris*, *Cerastium nutans*, *C. vulcanicum*, *Drymaria laxiflora*, *Erigeron galeottii*, *Geranium seemannii*, *Senecio cinerarioides* and *Sigesbeckia jorullensis*. The total of ruderal and weed plant species in the area was 83.

Tab. 7 Plant species of the area listed in the NOM-059-SEMARNAT-2001 (red list for Mexican species)

Family	Species	Nom-059
Aceraceae	*Acer negundo* L. var. *mexicanum* (DC.) Standl. & Steyerm.	Protected
Agavaceae	*Furcraea bedinghausii* K. Koch	Threatened
Asteraceae	*Dahlia scapigera* (A. Dietr.) Knowles & Westc.	Protected
Cupressaceae	*Cupressus lusitanica* Mill.	Protected
Cupressaceae	*Juniperus monticola* Martínez	Protected
Ericaceae	*Comarostaphylis discolor* (Hook.) Diggs var. *discolor* (Hook.) Diggs	Protected
Fabaceae	*Trifolium wormskioldii* Lehm var. Ortegae (Greene) Barneby	Threatened
Fabaceae	*Erythrina coralloides* DC.	Threatened
Lauraceae	*Litsea glaucescens* Kunth	Protected
Orchidaceae	*Corallorhiza macrantha* Schltr.	Protected

The ratio species/genera (s/g) for the Asteraceae family was 2.23, while the s/g ratio for the total flora was 1.91, giving a difference of 0.31.

4.4.2 Vegetation and land use units map

The *Abies religiosa* (sacred fir) forest predominates in cover, with more than 44%, from which 2.6% could be distinguished as disturbed (see distribution in Fig. 10 and areas in Tab. 8). It is followed in area by the three distinguished categories of *Pinus hartwegii* forest; no relationship was found between these three categories with the altitude, slope or aspect, so they might be representations of levels of disturbance. The *Quercus* forest extends over an area of 511 ha and in transitional zones towards the fir forest the mixed forest is present with an area of 91 ha. It is in the area of the *Quercus* forests that most of the human settlements concentrate and it represents the border that separates the study area with the urban area of Mexico City.

The cloud montane forest occupies two separate small polygons, giving a total area of 13 ha. The forest plantations covered an area of 9 ha in 7 polygons and the main tree species used is *Cupressus lusitanica*, although there is an abandoned tree nursery where *Eucalyptus* sp. trees are growing.

Grassland is the most fragmented unit, with 189 polygons distributed mainly in the lower parts, but with the larger polygons in the higher parts. They represent abandoned agricultural land, deforested land and natural grasslands. The *Furcraea bedinghaussi* shrubland is an azonal community that can be found in steep slopes of some hills within the distributional area of the fir forest. The area identified in the map represents one of the biggest communities of this plant, though only covering less than five hectares.

There are two main plant nurseries in the area, one has been established for some years and produces native tree species, mainly. The second one was recently finished and it is also intended to produce native tree species. Human settlements occupy an area of 44 ha, and agricultural lands represented 3% of the total area.

Tab. 8 Vegetation and land use units area and polygon number

Vegetation and land use unit	Area ha	Percent	Number of polygons
Pinus hartwegii forest	1335	20.50	14
Pinus hartwegii- Grassland	244	3.75	19
Grassland-Pinus hartwegii *forest*	306	4.70	20
Abies religiosa forest	2890	44.37	13
Disturbed *Abies religiosa* forest	172	2.63	39
Pinus sp. forest	65	1.00	9
Disturbed *Pinus* sp. forest	18	0.27	6
Mixed forest	91	1.39	3
Pinus-Quercus forest	30	0.45	1
Quercus sp. forest	511	7.84	8
Disturbed *Quercus* sp. forest	57	0.88	44
Cloud montane forest	14	0.21	2
Forest plantation	9	0.15	7
Gallery forest	9	0.13	1
Grassland	471	7.24	185
Furcraea bedinghausii shrubland	5	0.07	1
Agriculture	204	3.13	21
Human settlement	44	0.68	17
Plant nursery	2	0.03	3
Infrastructure	6	0.09	11
Football pitch	11	0.17	2
Mine	2	0.04	3
Rocks	18	0.28	14
Total	6514		

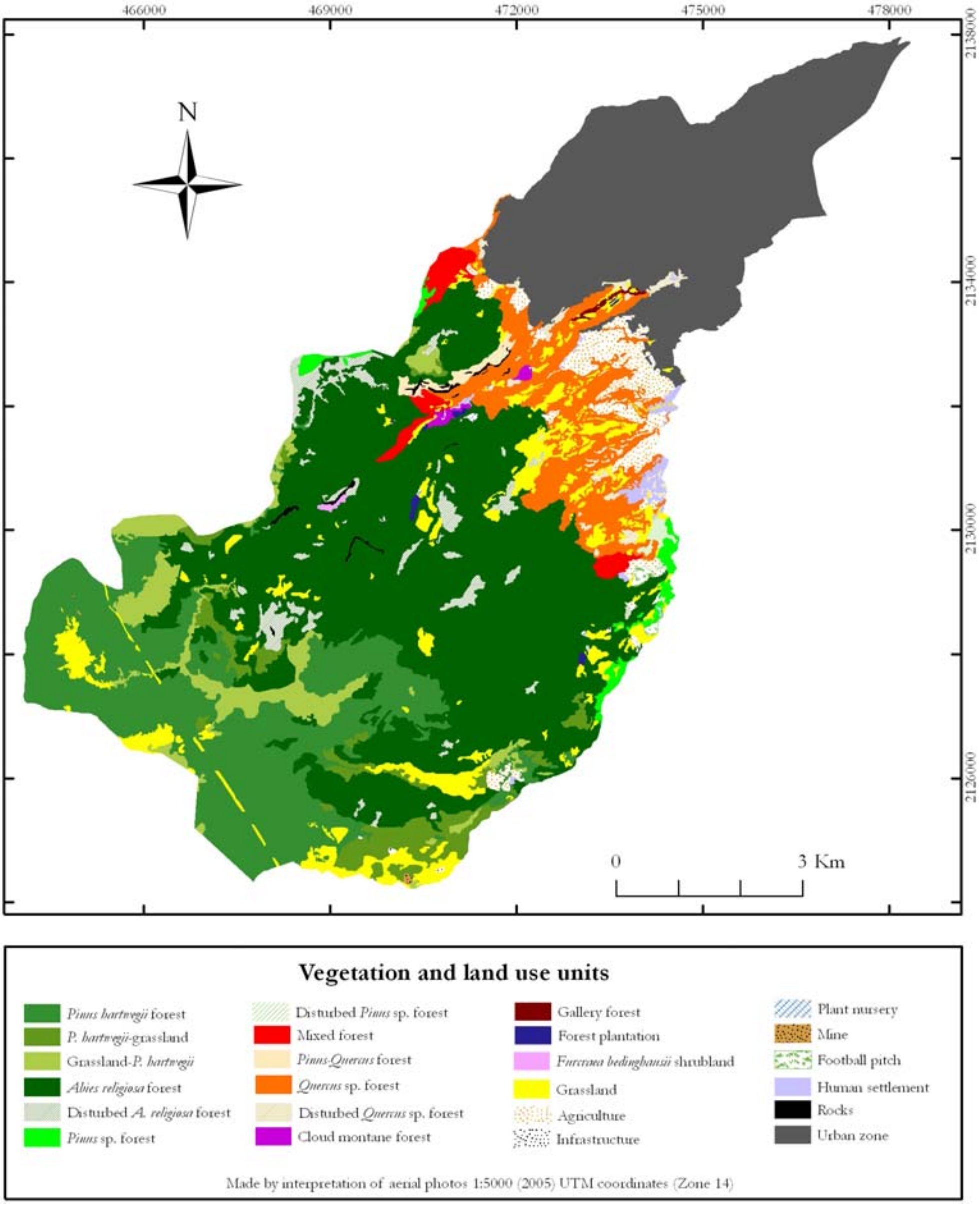

Fig. 10 Vegetation and land use units map of the upper Magdalena river watershed and the conservation area of Magdalena Contreras Municipality

4.4.3 Phytosociology

Three plant communities were recognized: *Pinus hartwegii*, *Abies religiosa*, and a complex of mixed and *Quercus* forest. Overall, these communities included ten associations (see Fig. 11; a synthetic phytosociological table for the tree communities is presented in App. 2).

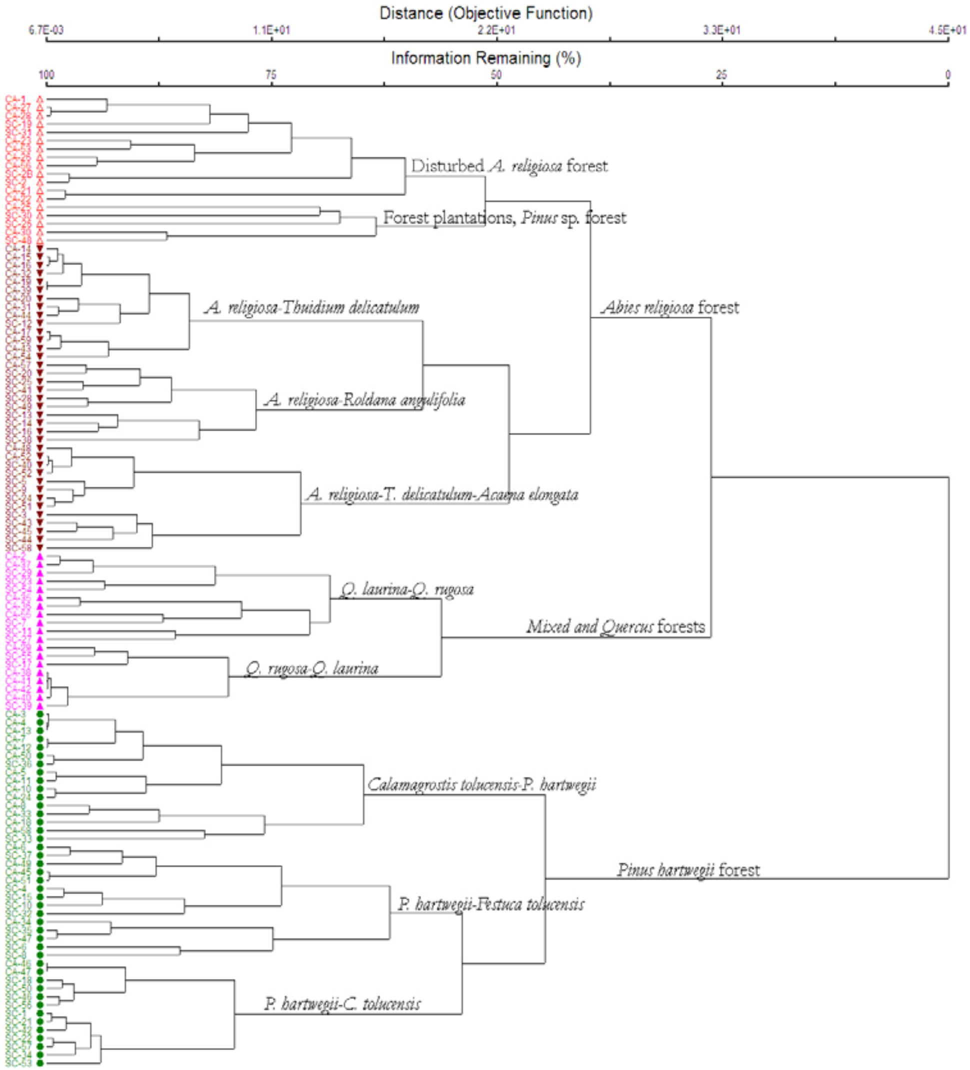

Fig. 11 Cluster composition dendrogram, showing the three plant communities and ten associations.

The *Pinus hartwegii* community forms a complex isolated from the other communities of the area, whereas the whole complex of *Abies religiosa* community and the mixed forest and of *Quercus* are part of a bigger cluster (Fig. 11).

Pinus hartwegii **Community**
This is found in the highest parts of the area, above 3,300 m asl. Though developing preferentially on slopes with a gradient of <15%, at some sites this forest occurs on slopes of up to 55%.

This is an open community, with vegetation representing 80% of the cover, while the remaining 20% is bare earth and rocks. It is characterized by the dominance of a monospecific arboreal stratum comprising *Pinus hartwegii*, and with the herbaceous stratum dominated by gramineous species, the main ones being *Calamagrostis tolucensis* and *Festuca tolucensis*, with which it forms plant associations.

Other species that accompany this community are *Vaccinium caespitosum* in the shrub layer, *Cirsium jorullense* ssp. *jorullense, Eryngium carlinae* and *Penstemon campanulatus* in the herbaceous layer, and *Alchemilla vulcanica* in the low growing stratum.

In some cases there are individuals parasitized by *Arceuthobium vaginatum*, a parasite of *Pinus hartwegii*, but these account for a low percentage of the cover. In some protected and north-facing gullies an ecotone forms between this forest and that of *Abies religiosa*.

Calamagrostis tolucencis–Pinus hartwegii **Association** (Sample type CA-12)
This association is characterized by the presence of a closed herbaceous stratum principally with *Calamagrostis tolucencis* (3-35%). The tree layer is open, with not more than 40% cover, but in average 20%. The cover for the low growing layer is <1-10%, with the shrubby layer being the least represented. The vegetation covers an average of 70%, while the remaining 30% is bare soil and rocks. Other species that characterize this association are *Muhlenbergia quadridentata, Alchemilla vulcanica, Vaccinium caespitosum* and *Oxalis corniculata* in the herbaceous layer and *Oxylobus arbutifolius* in the shrubby layer.

This association occurs between 3425 and 3750 m asl. The slope varies, with a minimum gradient of 5% and a maximum of 75%.

Pinus hartwegii-Festuca tolucensis **Association** (Sample type SC-47)
This association is characterized by the co-dominance of *Pinus hartwegii* with 10-70% in the tree layer and *Festuca tolucensis* with <1–70% cover in the herbaceous layer and.

This stratum achieves up to 90–100% maximum cover in some zones, with a minimum of 12%.

For the low growing stratum the cover is generally low, with the exception of some zones that have 35–70% cover. The percentage cover of the vegetation averages 75% and the bare soil up to 20%. Among the species within the herbaceous stratum but contributing less to its cover are *Arenaria lycopodioides*, *Commelina orchioides, Erigeron galeotii, Helenium scorzonerifolium, Oxalis alpina* and *Trisetum altijugum*. The shrub *Senecio cinerarioides* occurs often with covers from <1-8%. This association is found between 3260 and 3800 m asl, on slopes that vary from 3% to 60%.

Pinus hartwegii-Calamagrostis tolucensis **Association** (Sample type SC-50)
This association differs from the first for having a close canopy with *P. hartwegii* covering 50-95 %. The codominant in the herbaceous layer is *C. tolucencis*, with covers from 40 to 80 %.

The low growing stratum is well represented in most of the relevés, with covers of 1-70 %. The percentage cover of the vegetation averages 90%. The typical species in the herbaceous stratum are: *Penstemon campanulatus, Muhlenbergia quadridentata, Cirsium jorullense* ssp. *jorullense* and *Senecio roseus*. The shrub layer is represented by *Baccharis conferta* and *Acaena elongata*. This association extends from 3360 up to 3710 m asl on slopes of 3-30%.

Abies religiosa **Community**
This occurs in the central part of the area between 2750 and 3500 m asl. It develops preferentially on very steep slopes that can reach a gradient of up to 75%.

It is characterized by a dense forest represented principally by a tree, moss and shrub layers, with the dominant species being *Abies religiosa, Thuidium delicatulum, Roldana angulifolia* and *Acaena elongata*. These form plant associations of *A. religiosa-T. delicatulum, A. religiosa-R. angulifolia,* and a *A. religiosa-T. delicatulum-A. elongata*, which characterize this community. Additionally, two other associations form part of this community, one being disturbed *Abies religiosa* forest, and the last a combination of forest plantations and *Pinus* sp. forests.

Other species that accompany this community with less cover are *Symphoricarpos microphyllus*, *Solanum cervantesii*, *Cestrum thyrsoideum* and *Roldana barba-johannis* in the shrub layer and *Alchemilla procumbens*, *Sibthorpia repens* and *Salvia elegans* in the herbaceous layer.

On average, this community forms 60% of the plant cover. However, this reaches 100% of cover in some zones in which the forest is exceptionally dense. Records of high percent cover for bare soil are present in the association of disturbed *A. religiosa* forest; but, in general these values are low, with an average of 8%.

A. religiosa-T. delicatulum **Association** (Sample type CA-17)

This association is dominated by *A. religiosa* and *T. delicatulum*, which can cover up to 90% and 60%, respectively. The shrub layer can cover up to 80%, with a minimum of 10%. The tree layer is closed, with average covers of 60%. The herbaceous stratum covers less than 40%. The low growing stratum covers up to 60% but on average it has lower cover values of around 15%. The vegetation covers 70% and the bare earth 15%.

In the shrub layer *Roldana angulifolia*, *Acaena elongata* and *Roldana barba-johannis* occur, with low cover values. Important components of the herbaceous stratum are *Stellaria cuspidata*, *Asplenium monanthes*, and *Monotropa uniflora*. A common component of the low growing stratum is *Sibthorpia repens*. This association occurs between 2950 and 3500 m asl and develops on slopes that can range from nearly flat areas, with a gradient of only 5%, to slopes with a gradients of up to 65%.

A. religiosa-Roldana angulifolia **Association** (Sample type SC-25)
This association is dominated by *A. religiosa* and *R. angulifolia*, which can cover up to 80% with a minimum of 10%. The shrub layer can cover up to 95%, with a minimum of 20%. The tree layer is closed, with covers that can reach 70% or as low as 15%. The herbaceous stratum covers only 40% at most, with a minimum of <1%. The low growing stratum covers up to 30%. On average, the vegetation covers 90% and the bare earth 5%.

The low arboreal stratum is represented by *Salix paradoxa* and *Buddleia parviflora*. In the shrub layer *Ageratina rivalis* occurs, although with less cover. Important components of the herbaceous stratum are *Physalis coztomatl* and *Sigesbeckia jorullensis*. The association occurs between 2900 and 3500 m asl and develops on slopes that can range from nearly flat areas, with a gradient of only 6%, to slopes with a gradients of up to 75%.

A. religiosa-Thuidium delicatulum-Acaena elongata **Association** (Sample type CA-52)
The tree layer represented by *A. religiosa* has a maximum cover of 90% and a minimum of 40%. The shrub layer has a maximum cover of 90% and minimum of 15%. The dominant species for this stratum is *Acaena elongata*, which can cover up to 80%. The herbaceous stratum has an average of 60% in cover and the low growing

layer 40%. The percentage of terrain with plant cover is high (90%), but the occurrence of bare soil can also be high (70%).

The herbaceous stratum includes as frequent species: *Drymaria laxiflora, Geranium potentillifolium, Senecio toluccanus* and *Packera sanguisorbae*. The frequent shrubs, sometimes with high covers, are: *Roldana barba-johannis*, *Cestrum thyrsoideum* and *Symphoricarpos microphyllus*. This association is found between 3070 and 3580 m asl, ranging from steep slopes of 65% to almost flat areas with gradients of 3%.

Disturbed *Abies religiosa* **forest Association** (Sample type CA-21)
This is characterized by low cover values of *A. religiosa* (<1–60%) most of the times accompanied by *Senecio cinerarioides* (<1–40%). The shrub layer gives 25–50% cover. The herbaceous stratum is next in importance, with 3–15%, and lastly the low growing layer with 3–20%. The maximum proportion of bare soil is 40%. In this association *Salix paradoxa* can occur as a component of the canopy. In the shrub layer *Acaena elongata*, *Ribes ciliatum*, *Roldana barba-johannis* and *Symphoricarpos microphyllus* occur with low covers. The herbaceous layer includes *Stellaria cuspidata*, *Penstemon campanulatus*, *Castilleja arvensis, Cinna poiformis* and *Fragaria mexicana*.

This association occurs between 3115 and 3430 m asl, on very steep slopes with a maximum gradient of 60% and a minimum of 35%. It coincides with the "disturbed *Abies religiosa* forest" unit interpreted in the map.

Forest plantations and *Pinus* spp. **forests Association** (Sample type CA-25 and SC-26)
This is a community represented by a plantation of *Cupressus lusitanica* and of *Pinus patula*, and a natural forest of *P. teocote*, which represents a small patch within the area. Both plantations are characterized by a dense canopy and a poor understory, represented by a few shrubs. The *P. teocote* forest occurs on a shallow soil still covered by a layer of volcanic rocks.

A species that occurs in most of the subtypes of this Association is *Solanum cervantesii*. The association distributes from 2540 up to 2960 on mostly flat areas of less than 10%.

Community of mixed forest and of *Quercus*
This community occurs in the lower parts of the area and it develops on steep slopes with gradients varying between 10% and 75%. It is characterized as a community with a dominant tree layer consisting of a mixture of species that is determined by the climatic conditions of the region. These species include *Quercus rugosa*, *Q. laurina*, *Alnus jorullensis* ssp. *jorullensis*, *Pinus patula*, *P. pseudostrobus*, *A. religiosa*, *Arbutus xalapensis* and *Cupressus lusitanica*.

Overall, the tree layer represents up to 90% of the cover, followed by the shrub layer which varies between 2% and 60% of the cover. The herbaceous layer can cover up to 80%, whereas the low growing layer normally covers less than 1%. It is a closed association with an average of 90% vegetation and 10% bare soil.

Within this community there are two plant associations: *Q. laurina-Q. rugosa* and *Q. laurina-Quercus rugosa.* Other species that accompany this community are *Cestrum thyrsoideum* and *Ageratina rivalis* in the shrub layer, and *Adiantum andicola, Castilleja arvensis, C. tenuiflora* and *Salvia concolor* in the herbaceous layer.

Q. laurina–Q. rugosa **Association** (Sample type SC-23)
This association is dominated by *Q. laurina* (7–60% cover) and *Q. rugosa* (1–50% cover). It has a closed tree layer with 70–100% cover. The shrubby and herbaceous layers do not provide more than 10% cover, and the low growing layer is hardly represented since it covers not more than 2%. On average, there is 80% vegetation and 20% bare soil.

There is a lower arboreal stratum with *Clethra mexicana* and *Meliosma dentata*. The main component of the shrub layer are *Ageratina rivalis* and *Symphoricarpos microphyllus*. The herbaceous layer includes *Adiantum andicola*, *Salvia concolor*, *Stachys coccinea* and *Conopholis alpina*. This association extends between 2690 and 2990 m asl on very steep slopes with gradients of 15% to 75%.

Q. rugosa-Q. laurina **Association** (Sample type CA-41)
This is a semi-closed association characterized by the dominance of *Q. rugosa* with up to 90% cover, and Q. laurina with up to 30% cover. Overall, the tree layer provides 35% to 95% cover, followed by the shrub layer which can cover up to 70% but has a minimum of 5%. The herbaceous layer is less important, reaching up to 15% cover. The percentage of vegetation is high, with a mean of 90%, and the occurrence of bare soil is low, with a mean of 10%.

For this association, the tree layer is represented by *Q. rugosa and Q. laurina* mainly*,* but it is common to find *Buddleia cordata, Prunus serotina* and *Clethra mexicana* also. The herbaceous layer is represented by *Asplenium monanthes*. Two climber species, *Rubus pumillus* and *Smilax moranensis*, are typical of this association. Occurring in the shrub layer are *Cestrum thyrsoideum* and *Ageratina rivalis*.

This association occurs between 2700 and 2960 m asl on steep slopes with gradients of 33% to 75%.

4.5 Discussion

4.5.1 Phytodiversity

The results of this study show that the area is one of the most important localities as a conservation refuge in the basin of Mexico City. It is possible to find all the main temperate vegetation types of the country and the floristic richness is bigger or similar to other areas nearby (ÁLVAREZ DEL CASTILLO 1987; CORNEJO-TENORIO et al. 2003; SÁNCHEZ-GONZÁLEZ & LÓPEZ-MATA 2003; MEDINA-LEMUS & TEJERO-DÍEZ 2006).

In terms of species numbers, the herbs predominate, which corresponds to what RZEDOWSKI (1978) and CORNEJO-TENORIO ET. AL. (2003) have found for the temperate forests in Mexico. Though, when the cover is considered, the shrubs dominate, which could be an indicator of disturbance in the area, explained by the gaps generated in the canopy that allow more light to come in stimulating shrubs growth.

The Asteraceae family, with 114 species, is the best represented, followed by Lamiaceae, Poaceae, Brassicaceae, Rosaceae and Leguminosae. This pattern of floristic dominance has also been described in other studies with similar vegetation types, like in the National Park "Lagunas de Zempoala" (BONILLA-BARBOSA & VIANA-LASES 1997), in the Popocatépetl Volcano (ALMEIDA-LEÑERO 1997), in San Juan Nuevo Paranguricutiro (MEDINA-GARCÍA et al. 2000) and the Biosphere Reserve of the Monarch Butterfly (CORNEJO-TENORIO et al. 2003).

It has been suggested that where the Asteraceae family plays an important roll, the ratio genera/species is similar with the one of the total flora. For the area studied, this ratio is 2.3, which, when multiplied by the total number of genera found, it gives a total of 621 species, a relatively much higher number than the one found (531 spp.). This may indicate that some plant species have disappeared, that there are problems with synonyms, or that the inventory of the flora is still incomplete. When reviewing the works of other authors that have collected material in and around the area, it was possible to find out that the total flora should be higher (681 spp.). So it is fundamental to keep monitoring the flora of the area and this can help as a tool for conservation strategies.

The presented results show the fundamental roll that these forests are playing as a conservation area for the Mexican flora, not only because of their rich flora but also because of its relatively high number of endemic (ca. 86 spp.) and of threatened or endangered plant species (10 spp.). The plant endemism found in the area presents similar proportions with the previous assessments of the flora in the central mountains of Mexico, as compared to the results of CORNEJO-TENORIO ET.

AL. (2003) and RZEDOWSKI (1991b). This high pattern of plant endemism has been explained as considering the mountains with temperate and semihumid climate of the central parts of Mexico as "ecological islands", and also due to the high environmental diversity and geological history of Mexico.

The Magdalena Contreras Municipality presents more than 78% of its territory within the conservation soil of the Federal District. The phytodiversity is high if we consider that it is the equivalent of 22% of the total flora in the basin of Mexico City or 2.2% of the estimated total flora for the country (VILLASEÑOR 2003).

4.5.2 Vegetation map and phytosociology

The area presents a mosaic of vegetation very similar to that reported by various authors for the mountains that surround the basin of Mexico City but with some differences in the altitudinal distribution. In addition, it has all the temperate vegetation types present in Mexico, the most important being the *Pinus hartwegii*, *Abies religiosa* and *Quercus sp.* forests.

As PALACIO-PRIETO et. al. (2000) have stated, the classification of the temperate vegetation types of Mexico emphasizes the generic composition of the canopy, without describing the great variety in composition and structure of the lower strata. It is then of importance to go further on the characterization of these vegetation types, using the tools of the phytosociological method.

In the area studied, the *Pinus hartwegii* forest is dominant at altitudes above 3300 m. This agrees with the results recorded for other areas of Mexico: by SÁNCHEZ-GONZÁLEZ & LÓPEZ-MATA (2003) for the Sierra Nevada; by ERN (1976) and ALMEIDA *ET AL.* (1997) for the volcanoes Popocatépetl and Iztaccíhuatl; by VELÁZQUEZ & CLEEF (1993) for the volcanoes Tláloc and Pelado; by ÁLVAREZ DEL CASTILLO (1987) for the volcano Ajusco; and by VILLERS-RUIZ *ET AL.* (1998) for the Nevado de Toluca.

This forest is open and monospecific, with a predominance of grasses of a tufted habit in the understory and virtually lacking a shrub layer; ÁLVAREZ DEL CASTILLO (1987) described a similar community for the forests of the Sierra del Ajusco. The genera *Festuca, Calamagrostis* and *Muhlenbergia* are the most characteristic components of the herbaceous layer, as was also found by RZEDOWSKI (1978) for the mountains that surround the basin of Mexico City. *Muhlenbergia* has been reported to be an indicator of wildfires (OBIETA & SARUKHÁN 1981; QUINTANILLA & CASTRO 1998; FLORES-RODRÍGUEZ 2006) and as being the genus with the highest number of cultivated or introduced species in Mexico (DÁVILA et al. 2006).

The associations recorded for the area coincide with the three categories of *P. hartwegii* used in the vegetation and land use map. The species of these associations also coincide with those reported by ÁLVAREZ DEL CASTILLO (1987) for the Ajusco and by ALMEIDA *ET AL*. (1997) for the Popocatépetl volcano.

In terms of altitude, below 3500 m and down as far as 2800 m asl *Abies religiosa* forest occurs, whose range of distribution is therefore wider than that reported by VELÁZQUEZ & CLEEF (1993) for the volcanoes Tláloc and Pelado, and by SÁNCHEZ-GONZÁLEZ & LÓPEZ-MATA (2003) for the Sierra Nevada, to the south of the basin of Mexico City. The *Abies religiosa* forest is the most widely spread community within the area, with almost 50% of the area considered in the present study. It is regarded as a homogeneous community in terms of the arboreal cover, which in most cases attains high values indicative of a dense forest. However, three associations of the *Abies religiosa* Community forest described in the present study, with low values for cover by the herbaceous and low growing strata, does not match the typical *Abies religiosa* forest characterized by a sparse shrub layer and a low growing stratum made conspicuous by the presence of mosses (ALMEIDA-LEÑERO 1997). The shrub layer of the fir forest in the area is represented principally by *Roldana angulifoia*, *Acaena elongata* and *Senecio cinerarioides*, and these species are used to describe the different associations; these in turn coincide with the descriptions by MADRIGAL (1967) and GÓMEZ (2003). It is important to note that *Acaena elongata* and *Senecio cinerarioides* are indicator species for disturbance (DE RZEDOWSKI & RZEDOWSKI 2001) by grazing and wildfire respectively (MADRIGAL 1967; FLORES-RODRÍGUEZ 2006).

Also, according to MADRIGAL (1967), *Senecio cinerarioides* is an important species in the process of succession of *Abies religiosa* forest when this has been modified by fire. The higher covers of *S. cinerarioides* within the *A. religiosa* forest were found on areas that showed clear evidences of recent fires (FLORES-RODRÍGUEZ 2006), with a high proportion of standing dead trees. These areas should be a priority for restoration efforts.

According to RZEDOWSKI (1978) and ÁLVAREZ DEL CASTILLO (1987), even though the *Abies religiosa* forests do not cover large areas of land they are outstanding among the plant communities dominated by conifers, remarkable for their majesty and beauty. Similarly, in the area the *Abies religiosa* forest is the dominant in most of the area and it represents an impressing vegetation type due to the height of the trees and in some parts being very dense.

In the lowest part of the area, between 2470 and 3170 m asl, the *Quercus* forests extend. It is worth emphasizing that in general the oak communities have complex relationships with the pine woods, with which they share ecological affinities, mixed forests of *Quercus* and *Pinus* being very frequent in Mexico. They can form dense pure stands, such as the association of *Quercus laurina* and *Q. rugosa* recorded in this study. However, very frequently in *Quercus* forests the tree stratum is shared by various species either of the same genus or of others, and so it is common to find oaks in association with *Abies* and with characteristic species of the cloud montane forest. This is, in fact, what is found for the area, in which the mixed forest with *Quercus* is one of the most complex communities in terms of both composition and floristic dominance, since this category includes certain elements of the cloud montane forest (sensu RZEDOWSKI 1970), such as *Clethra mexicana*, *Arbutus xalapensis* and *Garrya laurifolia*.

The mixed forest with *Quercus* is complex because of the diversity of the tree species that derive from different plant communities. In addition, it is the community with the greatest number (26) of ruderal and weed species (ESPINOSA G. & SARUKHÁN 1997), which is to be expected since they are distributed in the zone nearest to the urban sprawl.

The cluster diagram put closer together the *Abies religiosa* forest and the *Quercus*-mixed *f*orests communities, forming an ecotone between these groups; this agrees with the descriptions by MADRIGAL (1967), HERNÁNDEZ (1990) and GÓMEZ (2003), which establish floristic affinities between *Abies religiosa* and *Quercus* sp.

However, this category has not been used in the present study since some elements characteristic of the cloud montane forest, such as *Arbutus xalapensis, Alnus jorullensis* ssp. *jorullensis, Garrya laurifolia* and *Clethra mexicana*, occur only in a few small patches. The vegetation described by RZEDOWSKI (1970) as cloud montane forest is showing decreased cover in this region; this is a sign not only of the pressure exerted by human activity but also of climate change, since this is one of the vegetation types that is most vulnerable to climate change (VILLERS RUIZ & TREJO-VÁZQUEZ 1998).

Although this natural area occupies 4% of the Conservation Area designated by the Federal District, considerable reductions have occurred (EZCURRA 1990) as a result of the accelerated growth of the population of Greater Mexico City, which has gained land on protected areas such as the area under study. The increasing demands placed on natural resources and the change in land use have caused a considerable loss in the forest cover and in the benefits contributed by ecosystem services. Hence, it is important to study in detail its vegetation.

The phytosociology school has been used widely as a method for studying vegetation. However, few studies have used this method with the aim of ecosystem management. It has proved to be well suited for this. The information it has yielded on vegetation cover as well as on the presence and cover of each of the individual species that characterize the plant communities allows identification of the zones that should take priority for forest conservation and restoration.

The present study is the first analysis of the vegetation that has been carried out in the area with the aim of restoration and conservation. It has environmental importance, since the plant communities described above are the basis for subsequent studies of ecosystem services, climate change and restoration, themes that at present dominate scientific, political and social discussion. It is pretended to be of enormous use for the inhabitants and visitors of the area, since it will increase their understanding of the present forests. Parallel to this study, a botanical guide with the most frequent plant species detected is on the way to be published.

5. Environmental and other social and economic benefits provided by the forests in the southwest of Mexico City

5.1 Summary

The main ecosystem services and goods that the forests of the area provide to the inhabitants of Mexico City were assessed. A questionnaire to the main stakeholders of the area was applied to sense people's perceptions on their relative importance. Carbon storage in trees, biodiversity use and conservation, water infiltration potential and supply as well as the value and main activities and areas for recreation are shown and spatially represented.

Stakeholders recognized the existence of ecosystem goods and services provided by the forests of the area and considered the ones related to soil erosion control, clean water and habitat for plants as the most important. The area is an important biodiversity refuge represented by 1175 species (including plants, mammals, birds, amphibians, reptiles, fungi, algae and butterflies), from which 209 are considered useful and 39 are listed in a category of risk. The forests of the area are storing in average 101 tC/ha, with the *Quercus* and mixed forests, followed by the *A. religiosa* forest having the highest carbon content values. The soil type and the forest stands promote the infiltration of rainwater recharging the aquifer of the basin of Mexico City, and 500 l/s of the water from the area are supplied directly from two water treatment plants to neighborhoods in the urban zone. Recreation is also one of the most important ecosystem services. Mexico City's inhabitants visit the area, mainly on the weekends, to fulfill the need for less crowded and green spaces where they can develop activities such as trekking, play football, bicycling, etc. The recreational activities occur mainly near the access roads.

The understanding of the values and benefits provided by the forests of this protected area should be of fundamental importance to its management. The information here presented could allow the implementation of a more precise and well oriented ecosystem services payment program, as an economic instrument for the conservation and ecological restoration of the forests in the area. But it must be remarked that nature's intrinsic value should always be considered.

5.2 Introduction

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans, with their cultural diversity, are an integral component of many ecosystems. A well-defined ecosystem has strong interactions among its components and weak interactions across its boundaries and it represents a mentally isolated system organized as a result of the interactions and mutual adjustment of its components (TANSLEY 1935). A useful ecosystem boundary is the place where a number of discontinuities coincide, like in the distribution of organisms, soil types, catchments, or forest types.

Ecosystems have several functions that can be reconceptualized as ecosystem goods or services when human values are implied, thus being an anthropocentric concept (DE GROOT et al. 2002). Ecosystem goods (such as food) and services (such as water regulation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions (COSTANZA et al. 1997). These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth (DAILY 1997).

Like the term ecosystem itself, the concept of ecosystem services is relatively recent, it was first used at the end of the 1960s (e.g., KING 1966; HELLIWELL 1969). Research on ecosystem services has grown enormously within the last decade (eg., BINGHAM et al. 1995; COSTANZA et al. 1997; DAILY 1997; BALVANERA et al. 2001), and the field of ecological economics has witnessed an enormous increase of concern with the valuation of ecosystem functions, goods and services (DE GROOT et al. 2002).

The Millennium Ecosystem Assessment (MA) is an UNEP initiative that started in 2001 to assess ecosystem change and human well being. It considers both natural and human-modified ecosystems as sources of ecosystem services, and it uses the term “services” to refer both the tangible and the intangible benefits humans obtain from ecosystems, which are sometimes separated into “goods” and “services” respectively, because it is sometimes difficult to determine whether a benefit provided by an ecosystem is a “good” or a “service”. It took four years to finish MA and it is expected to contribute to improved decision-making concerning ecosystem management and human well-being, and to build capacity for scientific assessments of this kind at a global and national level (MA 2005).

Ecosystem services have been categorized in a number of different ways, including by: functional groupings, such as regulation, carrier, habitat, production, and information services (DE GROOT et al. 2002); organizational groupings, such as services that are associated with certain species, that regulate some exogenous input, or that are related to the organization of biotic entities (NORBERG 1999); and descriptive groupings, such as renewable resource goods, nonrenewable resource goods, physical structure services, biotic services, biogeochemical services, information services, and social and cultural services (MOBERG & FOLKE 1999).

People seek many services from ecosystems and thus perceive the condition of an ecosystem in relation to its ability to provide desired services. The ability of ecosystems to deliver services can be assessed by a variety of qualitative and quantitative methods. An assessment of the condition of ecosystems, the provision of services, and their relation to human well-being requires an integrated approach. This enables a decision process to determine which service or set of services is valued most highly and how to develop approaches to maintain services by managing the system sustainably.

The field of study of ecosystem services and their applicability for decision making has gained increased attention rapidly. Although most of the people now recognize ecosystems as providers of services, and our knowledge on the biophysical and social aspects has grown, there is still much to be done. At a local and national scale, relatively limited information exists about the status of many ecosystem services and even less information is available about the economic value of non-marketed services (MA 2003). Despite increasing attention to the human dimension in conservation, a rigorous, systematic methodology for planning for ecosystem services has not been developed. Flows of ecosystem services remain poorly characterized at local to regional scales. Leaders in both public and private sectors have been slow to incorporate ecosystem services into decision making (CHAN et al. 2006). Concrete examples on ecosystem functions-biodiversity-ecosystem services must be shown and methods for their valuation developed.

This chapter presents an example and a method for the assessment of ecosystem services at the landscape level. It considers people's perceptions to determine the most important goods and services that the forests in the southwest of Mexico City provide, and develops a method for their quantification and spatial visualization. It is expected to help as an easy to use tool for decision making in the sustainable forest management.

5.3 Methods

5.3.1 Stakeholders' interviews

A *vis a vis* questionnaire was applied to 57 stakeholders from different groups (land owners, authorities, academics, visitors, etc; App. 3). They were asked to assign the relative importance (1=high importance, 2=medium importance, 3=low importance, 4=none importance) of 20 of the previously identified goods and services provided by the forests in the area. Blank spaces were left to let people tell, if considered, of other services and goods not mentioned in the questionnaire, and their relative importance. A database was created in Microsoft Excel with all the answers from the different stakeholders. This information was processed and analyzed using descriptive statistics (average and standard deviation).

5.3.2 Carbon content

Procedures available for measuring carbon stocks in forests include, between others, estimation of tree or stand biomass based on forest inventory data. Two methods are normally used to convert field measurements of trees to biomass: allometric biomass equations, function of only diameter at breast height, or diameter and total height and biomass expansion factors (BEF's).

Some tree genera have irregular shapes, so the volume estimation has to be corrected using a constant, called morfic coefficient (MC), which refers to the relation between the volume of a tree and the volume of a perfect cylinder that has as base the transversal area of the tree at breast height and the normal height of the tree (AVERY & BURKHART 1994).

For the estimation of the carbon stocks in the forests of the area, a stratified (using the vegetation and land use units map) random sampling was made with 116 plots. Each sampling plot consisted of three 1000 m² circles of 17.84 m in radius (compensated according to the site's slope). It was decided to use circles because they have less border effect, eg. for the same surface, a circle has less perimeter than a rectangle. The shape and size used are the most common for forest inventories in Mexico. The diameter at breast height of all the trees >5 cm was measured as well as the total height of some of the characteristic trees in the plot. The estimation of carbon content per tree and plot was calculated using biomass equations based on coefficients established by previous authors (Tab. 9).

Following IPCC (2007) a ratio of 0.5 for the carbon content in tree biomass was used and the results were then extrapolated to hectares. A spatial interpolation in ArcView 3.2 (ESRI 1998) using the Inverse Distance Weighted algorithm (LAM 1983), nearest neighbors, with a grid size of 10 units, classified in 8 equal interval classes was made to create a carbon content map of the area. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell, weighting of nearby points is strictly a function of distance (ESRI 1998).

Tab. 9 Used formulae and coefficients for the estimation of carbon content in trees. Consulted authors in parenthesis.

<table>
<tr><th>Tree species</th><th>Allometric equations for height calculation</th><th>Wood density</th><th>Form Coefficient</th><th>Biomass Expansion Factor</th><th>Biomass formulae</th></tr>
<tr><td>Abies religiosa</td><td>$y=-0.004(D^2)+0.8427(D)$
$r^2=0.8427$
where: D=diameter at breast height
(Galeana-Pizaña 2008)</td><td>0.41
(INIFAP 2003)</td><td>0.586
(Ramírez-Fuentes 1988, cited in Nava-López 2006)</td><td rowspan="3">1.3
(Cairns et al. 1997)</td><td rowspan="6">Volume=(BA)*(h)*(FC)
(Grijpma 2001)
where:
BA=basal area (m^2)
h=height (m)
FC=form coefficient
Biomass=V*wd(Brown & Lugo 1992)
where:
V=volume (m^3)
wd=wood density(tons/m^3)</td></tr>
<tr><td>Cupressus sp.</td><td>$y=-0.011(D^2)+1.1228(D)$
$r^2=0.8385$
(Galeana-Pizaña 2008)</td><td>0.48
(IPCC 1994)</td><td rowspan="2">0.5
(Rojas-García 2008)</td></tr>
<tr><td>Pinus hartwegii</td><td>$y=0.0015(D^2)+0.3956(D)$
$r^2=0.8883$
(Espinosa-Pérez 2005)</td><td>0.496
(Rojas-García 2008)</td></tr>
<tr><td>Quercus laurina</td><td rowspan="3">Heights measured on field</td><td>0.627
(de la Paz Pérez-Olvera 2000)</td><td rowspan="2">0.68
Quercus robur, (Zazo-Muncharaz & Jiménez-Martín 2000)</td><td rowspan="2">1.6
(Macías-Vázquez & Rodríguez-Lado 2003)</td></tr>
<tr><td>Quercus rugosa</td><td>0.688
(de la Paz Pérez-Olvera 2000)</td></tr>
<tr><td>Other broadleaf's</td><td>0.6
(INIFAP 2003)</td><td>0.45
(INIFAP 2003)</td><td>1.4
(INIFAP 2003)</td></tr>
</table>

5.3.3 Biodiversity use and conservation

Biodiversity is the variability of living organisms. It includes diversity within and among species and diversity within and among ecosystems. Biodiversity is the source of many ecosystem goods, such as food and genetic resources, and changes in biodiversity can influence the supply of ecosystem services. Natural ecosystems provide living space for wild plant and animal species. These species and their role in the local and global levels provide most of the ecosystem functions; though the conservation of species rich habitats is a fundamental condition for the provision of ecosystem goods and services, directly and indirectly (DE GROOT et al. 2002).

Based on the floristic list presented in chapter four, a bibliographic review was made to find the plant species that are useful. The works of GARCÍA-GALVÁN (2008), VALDIVIA-MARTÍNEZ (2006), TORRES-PÉREZ (2005) and AGUILAR (1998) were reviewed to define the plants that have a direct use by humans (eg. edible, medicinal, etc.). From the phytosociological relevés, the useful plants were assigned per sampled plot and an interpolation of these values was made to create a map in ArcView 3.2 using the same characteristics as the carbon content map.

The research of CANTORAL-URIZA et al. (2009) and VILLARRUEL-ORTÍZ & CIFUENTES-BLANCO (2007) was used to present the biodiversity conservation value of the area.

5.3.4 Water use and infiltration

After precipitation occurs, water splits at the surface between direct runoff and infiltration. This split plays a very important role to hydrologic cycle, water resources, and the form of the surface erosion, stream flow. Soil water infiltration is controlled by the rate and duration of water application, soil physical properties, slope, vegetation, and surface roughness (VARADHAN & WILLIAMS 1998).

This ecosystem function refers to the filtering, retention and storage of water. The filtering function is mainly performed by the vegetation cover and soil biota. The retention and storage capacity depends on topography and sub-surface characteristics.

An index was calculated using the following variables measured on field: tree canopy cover, vegetation cover, recharge tubs cover (man made excavations of 1.5 m long, 0.5 m wide and 0.5 m deep, thought to promote water infiltration), altitude, aspect (standardized 270-360=4, 0-90=3, 180-270=2, and 90-180=1) as positive variables, and naked soil cover and slope as negative variables. All data were normalized by the mean and standard deviation and summed by 4 to make them all positive. It was assumed that more vegetation and tree canopy covers, higher altitudes (800 mm of precipitation in lower altitudes to 1,500 mm in higher

(JÁUREGUI 2002)), north-northwest aspects and more recharge tubs promote the retention and infiltration of water into soil. In contrast, a higher cover of naked soil and steeper slopes promote runoff. The different aspects of water as ecosystem service were analyzed.

An index between 0.5 and 18.2 was obtained and an interpolation map in ArcView 3.2 created, following the same characteristics as the previously described maps.

Water infiltration index = (percent tree canopy cover + percent vegetation cover + percent cover of recharge tubs + altitude + aspect) – (percent naked soil cover + slope)

5.3.5 Recreational value

Recreation is activity voluntarily undertaken, primarily for pleasure and satisfaction during leisure time (PIGRAM & JENKINS 1999). Recreation settings are areas that allow a given activity, such as sightseeing, picnicking, football playing, camping, rock climbing, etc., sometimes referred to destinations (DE LACY & WHITMORE 2006).

Based on the visits to the study area and the questionnaire applied to the stakeholders, a map with the main recreational destinations or areas was made. A recreational value was assigned to each of the sampled plots, considering: accessibility (distance to paved and dirt roads), security (proximity to surveillance centers or slums), scenic beauty (presence of natural forests in good condition, absence of car noise, absence of litter, presence of water in good quality). To each of these three criteria an arbitrary value between 0 and 10 was assigned by two persons familiar with the area (Inti Burgos and V. Avila-Akerberg) and then averaged. An interpolation of the recreational values per plot was made to create a map in ArcView 3.2 with the same characteristics as the previous maps mentioned.

5.4 Results

5.4.1 People's perceptions on ecosystem services

The perceptions of the interviewed stakeholders is summarized in Tab. 10. The people considered the services related to soil maintenance and clean water as the most important, followed by habitat for plants and animals, environmental education, climate stabilization, CO_2 sequestration and scientific research. Within the services that were considered to have a medium importance are the ones related to recreation like: inspiration for artists, walking, camping, to relax, etc. It was found that the least important services were game hunting, home for local people, cattle management and fuel wood extraction. Of all the interviewed people, 14 suggested other goods and services that the forests of the area provide. These were mainly related to water supply and clean air, having both a high importance.

Tab. 10 Stakeholders´ perceptions about the relative importance of the goods and services provided by the forests in the area.1=high, 2=medium, 3=low, and 4=none, ± 1 standard deviation.

Good or service	Import.	± SD	Good or service	Import.	± SD
Soil maintenance, erosion control	1.04	0.18	Adventure tourism	1.72	0.61
Clean water	1.04	0.18	Sports	1.71	0.60
CO^2 sequestration	1.21	0.45	Inspiration for artists, painters, etc.	1.36	0.54
Habitat for animals	1.16	0.36	Fuel wood	2.12	0.70
Habitat for plants	1.09	0.28	Sacred place	1.90	0.85
Climate stabilization	1.21	0.41	Employment source	1.69	0.74
Walking	1.47	0.57	Cattle management	2.61	0.78
Camping	1.74	0.69	Scientific research	1.21	0.45
Game hunting	3.39	0.52	To relax	1.26	0.44
Home for local people	3.07	0.75	Other: particle retention, beauty of the forest, rock and soil extraction, barrier for the urban zone, clean air		
Environmental education	1.13	0.33			

5.4.2 Carbon content

A total of 8,040 trees ≥5cm DBH occurred in the sampled plots across all forest types, yielding a mean density of 445.7 trees ha^{-1} across the landscape. Together with their measured and calculated heights, these data were used to estimate the carbon content. Structurally, the forests in the area have medium to low DBH's in average, representing young categories (Tab. 11). All DBH size classes are represented in an inverse J-shaped distribution, with the majority of individuals in the first categories, decreasing in number on higher categories.

Tab. 11 Structural synthesis per forest community and association. H=height (m), DBH=diameter at breast height (cm), number of trees per diameter class ($n/625m^2$) and BA=basal area (m^2/ha). Mean and standard error are shown.

	P. hartwegii			*A. religiosa*					*Quercus*		
Var.	*C.tol-*	*-F.tol*	*-C.tol*	*-T.del*	*-R.ang*	*-A.elo-T.del*	Dist.	Plant.	*Q.lau-Q.rug*	*Q.rug-Q.lau*	All
H avg	8.6	7.3	6.3	14.0	18.2	18.3	15.0	14.6	13.4	12.5	12.4
H se	4.5	4.8	4.6	7.0	10.3	10.0	7.4	5.2	6.7	4.8	6.5
DBH avg	19.8	16.8	14.7	27.6	28.0	31.8	28.4	28.8	24.4	28.6	24.2
DBH sd	9.5	10.3	9.8	18.1	18.9	20.5	18.1	13.6	15.2	15.0	14.6
5 to 15	7.5	18.6	40.8	15.6	9.8	11.6	5.3	8.2	11.2	6.9	14.2
15 to 25	3.8	5.8	7.1	6.0	4.8	5.3	2.8	6.1	8.4	9.7	5.8
25 to 35	2.5	1.9	2.2	1.9	2.4	4.3	1.9	6.0	5.3	6.5	3.2
35 to 45	1.1	1.6	1.9	2.2	2.8	2.9	1.3	4.0	2.3	1.4	2.0
>45	0.3	0.7	1.0	4.6	4.3	5.3	3.0	3.6	3.5	2.8	2.7
BA	7.9	8.0	9.0	34.3	8.8	18.3	14.4	20.3	17.6	40.8	17.0

On average, the forests in the area store 101±82 tC/ha. By forest communities, it was found that the *Quercus* and mixed forests are storing the most

(166±180 tC/ha), though having considerable differences between plots, followed by *A. religiosa* forests (108±80 tC/ha), and *P. hartwegii* the least (27±20 tC/ha). Some differences were found between forest associations (see Fig. 12).

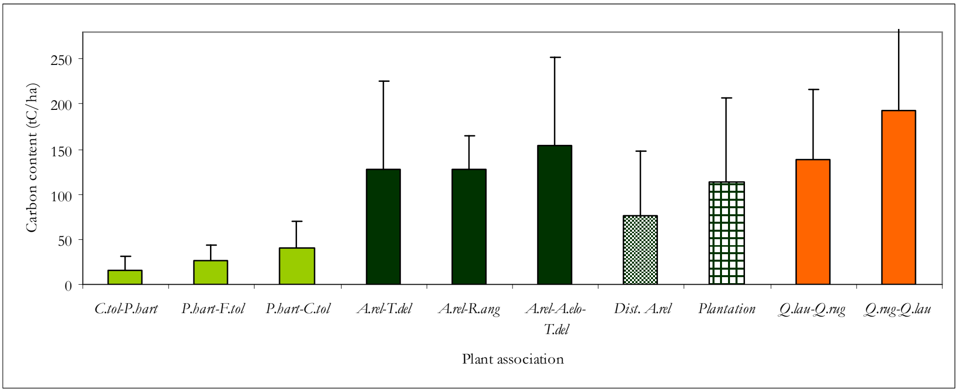

Fig. 12 Carbon storage per forest association. Mean ± SE are shown.

Extrapolating the average carbon content values to the areas of the different forest communities, it could be estimated that a total of 608,770 tons of C are being stored in the trees of the area. The *A. religiosa* forest is storing the most, mainly because it extends over more than half of the total area, but also because it presented high carbon contents per plot. The *P. hartwegii* associations are storing the least, but they should have a big sequestration potential due to a higher proportion of smaller trees.

Tab. 12 Total carbon stored in the trees of the different forests of the area and their relative commercial value.

Forest	**Area (ha)**	**Avg. C C. (t/ha)**	**Total C C. tC**	**If $10 USD/tC…**
P. hartwegii	1886	40.5	76418	$764,184
A. religiosa	2890	136.4	394234	$3,942,341
Quercus	702	166.0	116481	$1,164,811
Disturbed *Abies*	172	76.7	13152	$131,517
Plantations	75	113.2	8485	$84,851
		Total	608770	$6,087,705

The monetary value of the total carbon stored could ascend to more than 6 million USD, only considering the biomass of trees bigger than 5cm in DBH and taking as a reference the international average value of 10 USD/tonC (KOLLMUSS & BOWELL 2007).

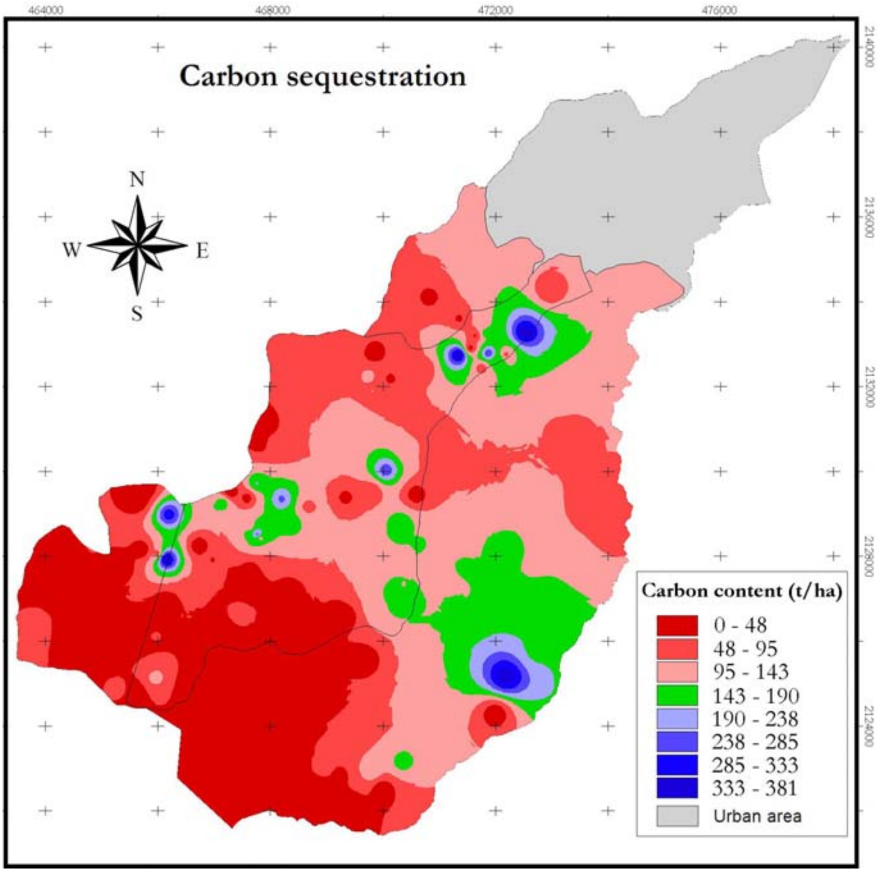

Fig. 13 Spatial interpolation of the carbon storage values from the field plots.

Spatially, the areas with the highest carbon storage values more or less represent the distribution areas of the *A. religiosa* and *Quercus* forests, having peaks in specific places. It is clear that the least carbon content values coincide with the distribution of the *P. hartwegii* forests.

5.4.3 Biodiversity use and conservation

From the floristic list presented in chapter four, it was found that within the collected and identified plant species of the area, 167 are considered to be useful (see App. 1 for individual species uses). Nine categories of use for plants were found: edible, for construction, medicinal, ornamental, as fuel wood, instrumental, fodder, toxic/magical and for handicrafts (Tab. 13). Some plants were found to have more than one use (eg. medicinal, edible and ornamental), but the majority are considered to have only one use. Most of the useful plants found in the literature are considered to be medicinal.

Tab. 13 Number of useful plants per category of use. Note that there are species with more than one use.

Use	Plant spp.	Use	Plant spp.
Handicrafts	1	Ornamental	41
Construction	2	Fodder	22
Edible	19	Instrumental	5
Medicinal	115	Magical/toxic	6
Fuel wood	15	Total	167

Spatially, the interpolated map showed that more useful plants can be found in the western parts of the studied area, in medium altitudes coinciding with the distribution of *A. religiosa* forest. The areas with lower number of useful plants were found to be in higher altitudes but also near the urban area.

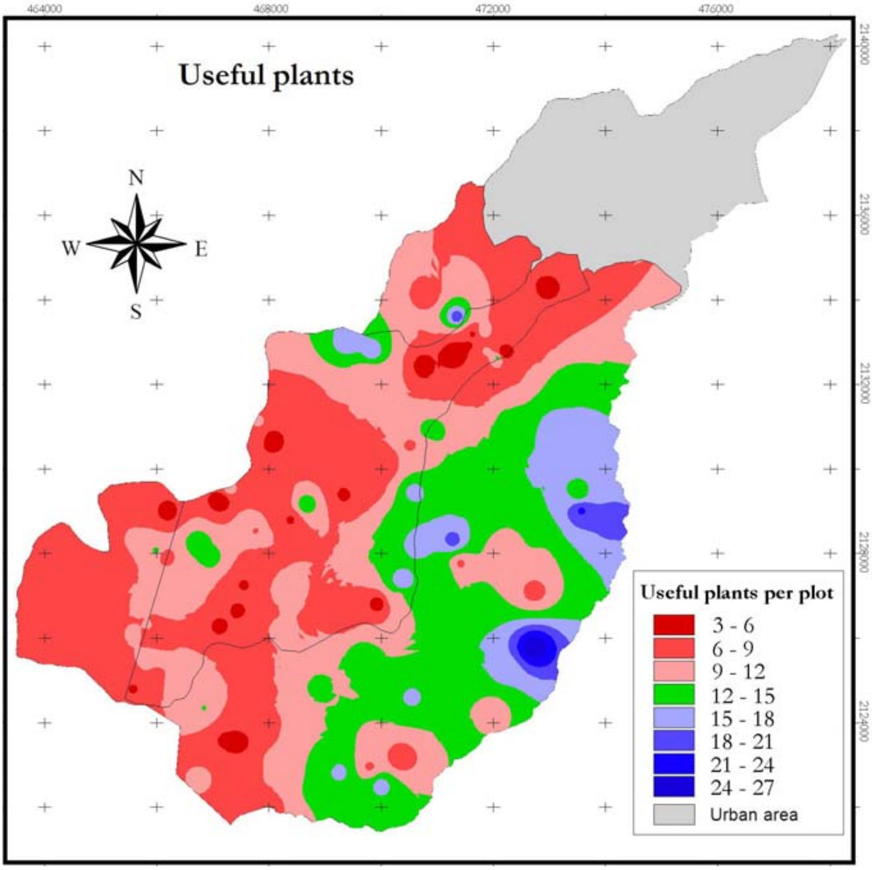

Fig. 14 Spatial interpolation of the useful plants found per field plot.

From the work of CANTORAL-URIZA ET AL. (2009) it can be said that the area is an important biodiversity refuge with 1175 species (see Tab. 14), from which 212 are considered useful and 39 are listed in a category of risk. Mexican biodiversity is represented by 1107 species of birds (CONABIO 2006), 530 mammals (CEBALLOS et al. 2006), 361 amphibians (CONABIO 2006), 804 species of reptiles (FLORES & CANSECO 2004), 1827 species of butterflies (LUIS-MARTÍNEZ et al. 2003), 23,522 vascular plants (VILLASEÑOR 2003), 2,200 species of macromycetes (VILLARRUEL-ORDAZ pers. comm. 2009), and algae 2281 species (NOVELO-MALDONADO pers. comm. 2009), which make a total of 32,632 species. Then, the biological richness of the southwest of Mexico City represents 3.6% of the total country's biodiversity for these groups of organisms. LUIS MARTÍNEZ (1985) concluded that the Magdalena river watershed is the area with the highest diversity of butterflies in the whole basin of Mexico City.

Tab. 14 Biodiversity of the area, in terms of species numbers, species that have a direct use for humans and species in the "Mexican red list".

Group	Species number	% of country	Useful	In a category of risk (NOM-ECOL-059 2001)
Plants	534, of those 528 vascular plants (this work)	2.2	167	10
Algae	108	4.73	-	-
Fungi	85 identified and 305 morphospecies (VILLARRUEL-ORDAZ & CIFUENTES-BLANCO 2007)	9.53	27	4
Butterflies	36	2.0	-	-
Amphibians and reptiles	26	2.2	-	14
Birds	128	11.6	18	9
Mammals	40	7.5	-	2

5.4.4 Water use

There are several ecosystem services related to water in the area. The Magdalena river represents one of the main attractions for visitors, and its waters are being used for consumption, agriculture irrigation and for trout breeding. In terms of water provision, the Magdalena river watershed generates 20 million m^3 per year (0.65 $m^3 s^{-1}$; JUJNOVSKY-ORLANDINI 2006), and considering that the area under study represents more than the double in area, it could be estimated that around 40 million m^3 of water are generated every year. In terms of consumption, there is a direct use by the people living and offering recreational facilities in the area; there are two water treatment plants near the urban zone which provide around 500 l s^{-1} to some neighborhoods in Magdalena Contreras Municipality. For agriculture irrigation, the water is mainly being used to maintain plant nurseries (ornamental roses, edible and medicinal plants, and reforestation trees). In the Magdalena river watershed, there are seven families producing 25-40 tons of trout per year (RAMOS RAMOS-ELORDUY 2008), and in the rest of the area there are two more trout production places.

The water providing all these ecosystem services is being generated and stored in the higher parts, where it rains the most (JÁUREGUI 2002), vegetation cover is high (mainly in the *A. religiosa* forest), and slopes are not so steep. Though, most of the water from the Magdalena and Eslava rivers ends up being part of the sewage.

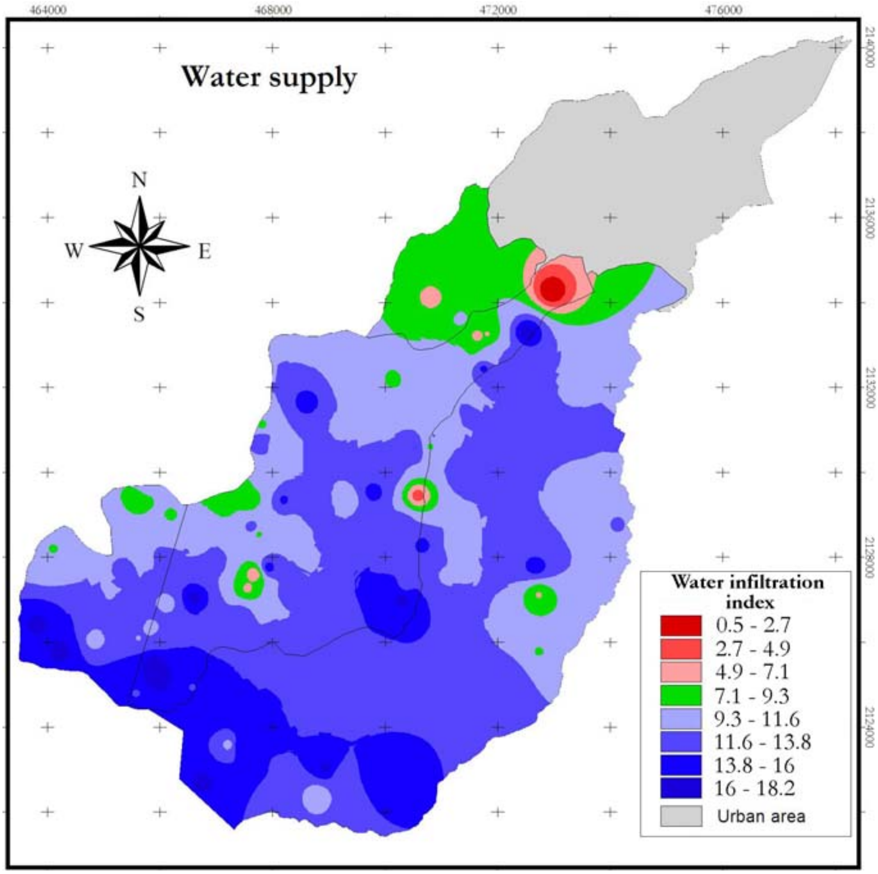

Fig. 15 Spatial interpolation of water infiltration potential per field plot.

5.4.5 Recreational value

One of the main benefits that the area provides is the opportunity as a space for recreational activities. Mostly during the weekends, lots of visitors from the City spend part of the day going to restaurants, to do cycling, to play football, trekking, etc. Most of the recreational activities take place near access roads to the area, where most of the services (restaurants, guards and security, football fields, paintball war) concentrate. On the weekends, a symbolic fee is charged to the people visiting the area, by car, in the Magdalena river watershed (0.3 €/car), and into the Community Reserve of the Ejido of San Nicolás (1 €/car). Most of the people's concentration coincide with the blue areas of the map, which host most of the visitors going to the area. Far away from the main paved roads it is difficult to find visitors, they tend to concentrate where it is accessible.

The potential for more recreation activities is considerable. There are many areas where land owners could benefit from providing recreation opportunities without harming the forests. Examples of this activities would be wild life observation and camping. The recreational value was partly given by the degree of accessibility and this can be seen in the interpolated map. There are many dirt roads that allow displacement by proper vehicles further into the area.

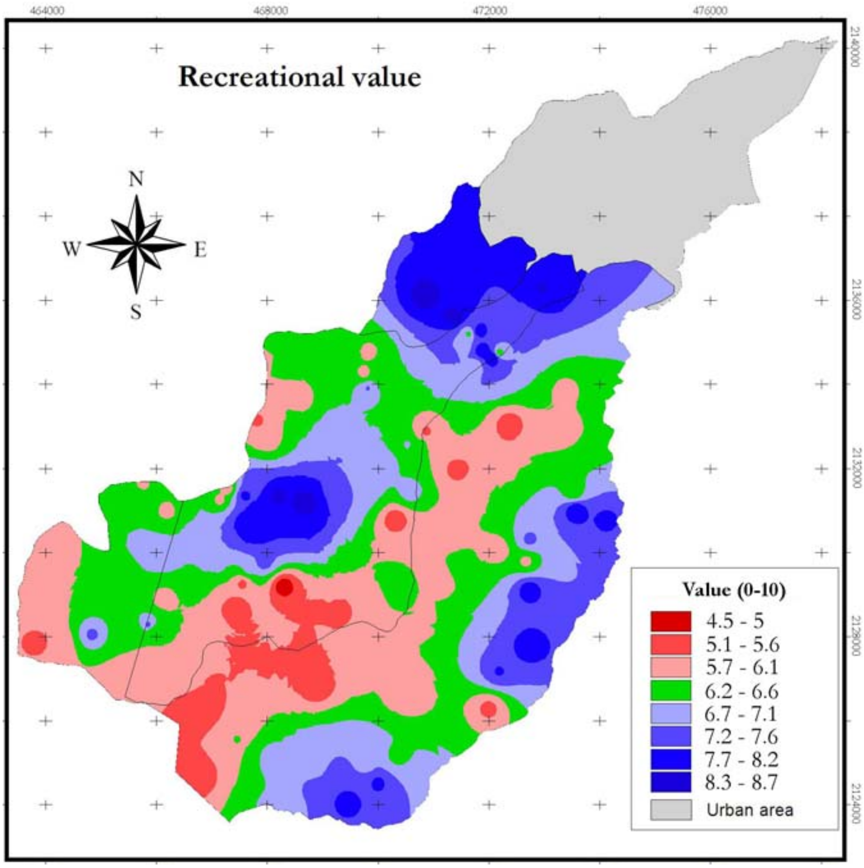

Fig. 16 Spatial interpolation of the recreational value per field plot.

5.5 Discussion

5.5.1 Perceptions on ecosystem services

The degradation of natural ecosystems threatens human well being and economic development sustainability. These problems include water scarcity, biodiversity loss, climate change, etc. Ecosystems provide critical services for the functioning of natural and human systems, for example cleansing, recycling and renewing biological resources.

To understand how the social actors that are responsible in the decision making within ecosystems conceive their relation with them and how they value the different services through several activities is a fundamental task, recognized as essential to formulate strategies for the sustainable forest management in protected areas (WALTER et al. 2002; LOCKWOOD 2006). It is recognized in the recent literature, that a standard method to analyze the social valuation of ecosystem services in human populations is lacking (DAILY 2000) and it is expected to develop innovative proposals to get a closer understanding on how people value the natural systems they depend from.

Of all the stakeholders interviewed, none argued or had problems to recognize the mentioned processes and functions of ecosystems as goods or services and their relative importance. This should suggest that people are aware of the importance of the forests in the area as sources of goods and services, as can be seen on the weekends, when they agree to pay a symbolic entrance fee to the different recreational areas. Ecosystem services, despite being a recent topic, is now a fundamental part of the ecological agenda. People have become used with the concept and its values, specially when they relate it to climate change, as it was found in this research, climate stabilization and CO_2 sequestration within the most important. It is now one of the main given arguments when asking people why to do conservation and ecological restoration.

For the interviewed stakeholders it is clear the conservation roll of the area, as they considered game hunting and home for local people the least important services. People are aware of the illegality of these activities, though they are still happening, specially the establishment of new human settlements, putting a land use change pressure on the border between the urban and the conservation area.

There is still a difficulty to understand the direct and indirect benefits provided by nature; the services exist, though the link of them to daily human activities is not easy to assume by most of the people. Environmental education and sensibilization in this sense is fundamental in order for the ecosystem services concept to be an effective conservation tool.

5.5.2 Carbon sequestration

IPCC (SOLOMON et al. 2007) estimated that the emissions of Mexico (435 million metric tons of CO_2 and 4.05 per capita) account for 1.6% of the global carbon emissions in our planet. Forests are the terrestrial ecosystem that store and capture the biggest amount of carbon and represent 90% of the total annual carbon flow in the atmosphere and Earth surface (APPS et al. 1993; DIXON et al. 1994).

One of the great contributions that the forests in the southwest of Mexico City make to the wellbeing of the inhabitants of the capital, especially for those who live on the outskirts to the south of the area, is that they act as a lung, sequestering CO_2 and filtering out part of the environmental pollution that is produced in the urban area. The presence of plant cover and processes such as the cycling of material through leaf fall and decomposition have as additional benefits the purification of the air by means of the capture and storage of carbon in soils and the tree biomass.

The carbon storage values found in this work coincide with other previous works, although there are some differences (see Tab. 15). This is useful to show that each area has its own specific characteristics, where several variables influence the results in the estimation of forest carbon contents. It would not be precise to assume similar carbon content values for the same vegetation types in different areas. Variations on the methodologies will also influence the calculations, so it is important to come to a general agreement for using standard coefficients and formulae.

Tab. 15 Previous carbon storage studies in similar vegetation types. The general average carbon content in tons per hectare is shown.

Author	Locality	Altitude	Vegetation (tC/ha)
DE JONG et al. (1995)	Chiapas, Mex.	800	Pinus (120), Pinus-Quercus (135)
MASERA et al.(1997)	Mexico in general	-	Conifers (70), broadleaf's (53)
ORDÓÑEZ (1999)	Nuevo San Juan, Michoacán, Mex.	1500-3250	P. pseudostrobus (63)
Valenzuela (2001)	Ajusco, Mexico City		A. religiosa (201)
FRAGOSO-LÓPEZ (2003)	Tancítaro, Mich., Mex.	1382-3580	A. religiosa (57), Pinus (19), Quercus (22)
ROJAS-GARCÍA (2004)	La Malinche Volcano, Tlaxcala-Puebla, Mex.	3370-3660	P. hartwegii (100)
This study	Southwest of Mexico City	2470-3870	P. hartwegii (40), A. religiosa (136), Quercus (166)

ROJAS-GARCÍA (2004) found a significative higher carbon content on the *P. hartwegii* forest in "La Malinche Volcano" which is localized ca. 110 km to the east of the area under study. This could suggest that there is an important degree of disturbance/human influence in the forests of the southwest of Mexico City that has diminished the trees with higher diameters, as the tree species are the same and the altitudinal intervals in both cases are very similar.

Even though the *P. hartwegii* forests showed the least carbon content values, they have the greatest potential for future carbon sequestration. Most of the trees were found in the smaller diameter categories and these individuals represent an enormous option for the fixation of CO_2 in the coming years. The forests of *A. religiosa* had the greatest carbon content values but the natural regeneration was not found abundant in most of the sampled field plots. Thus, it should be promoted, removing abundant covers of shrub species that compete with *A. religiosa* seedlings.

As a protected area, the Magdalena river watershed and the conservation area of Magdalena Contreras Municipality, should keep acting as a carbon sink, sequestering carbon permanently. Carbon management can provide an excellent vehicle for further channeling funds into sustainable development and forest conservation and restoration activities while playing a key role in mitigating climate change (ORREGO 2005).

5.5.3 Biodiversity use and conservation

Most of the stability, functioning and productivity of an ecosystem come from biodiversity. There is a close relationship between biodiversity and the ability of an ecosystem to provide goods and services (DE GROOT et al. 2002). Species richness then generates a big inter-specific interaction which determines the functioning and productivity of ecosystems. Ecosystem processes are susceptible to several factors that can alter their functional dynamic, like the anthropic actions or the invasions by exotic species. It has been found that there is a high dependence between biological diversity within an ecosystem and the capacity to resist disturbance, so to say, "more diverse ecosystems tend to be more stable" (TILMAN 1997).

By providing living space to wild plants and animals, natural ecosystems are essential to the maintenance of the biological and genetic diversity on earth (DE GROOT et al. 2002). Including the use of ecosystem services in conservation, has the potential to protect biodiversity (CHAN et al. 2006). It is important to remark that for an area representing less than 0.0003% of the total area of the country, it is possible to find all the temperate vegetation types present in Mexico and a relatively high biodiversity, represented by ca. 3.6% of the country's known biodiversity.

And the floristic inventory is still believed incomplete (ÁVILA-AKERBERG et al. 2008). Further field work has to be made and clarify possible taxonomic synonyms. VILLARRUEL-ORDAZ (personal communication 2009) suggests that there should be a 1:3 ratio between plant and fungi species. This would mean that the area should have between 1800-2000 species of macromycetes, from which only 15% have been found so far (300 morphospecies).

Around 17.8% of the species within the area are considered to have a use, and I believe there are uses that still remain unknown. But, some uses are contrary to the conservation of the biodiversity of the area. The use of animal species is mainly for ornamental singing birds, which are trapped in the forests and sold to be kept in small cages in houses. Fungi are also very attractive to collect for local people, but as it was perceived during the stakeholders interviews, people feel a decline in the amount of this resource.

Plants represent the group with the highest number of useful species, mainly for medicinal purposes. These are still being used by elder people, who keep the accumulated knowledge gathered and passed by from generation to generation. But as it might be common elsewhere, the newer generations tend to loose this knowledge and prefer to use products from the pharmacy. Environmental education is needed in this regard, to let people know and remember of all the actual and potential uses of nature's elements, but also on the way to make it sustainable. More and better surveillance of the area is fundamental, to protect threatened species and avoid overexploitation of the known useful plants and animals.

5.5.4 Water use and aquifer recharge

The relationship between forests and water flows is complex and requires rigorous studies to obtain credible measurements. The method here presented for the evaluation of water is far from being precise, but it gives a clear and simple idea of where to emphasize management towards conservation and restoration of this ecosystem service.

Despite the little information available for Mexico, among the public, civil society organizations and government officials, there is a strong perception that forests do indeed play an important role in protecting water resources (MUÑOZ-PIÑA et al. 2005). As said, most of the water consumed in Mexico City (ca. 70%, MAZARI-HIRIART et al. 2001), is being extracted from the ground aquifer, which in turn recharges with the water infiltrating in the forested areas around the urban area. It has been shown that the mountains that enclose the basin of Mexico City are the main recharge areas of the basin's regional aquifer system (EZCURRA et al. 1999; MAZARI-HIRIART et al. 2001). The spatial distribution of potential aquifer recharge in the basin of Mexico City is not uniform, as the largest rates are found in the south, where rainfall is influenced by topography and where soils have large permeability values (CARRERA-HERNÁNDEZ 2007). Most of the rainfall happens in the uppermost parts of the area and it has been promoted to retain the water for a longer time with the use of recharge tubs and dams, mainly. Though, there is still a big amount of water from the Magdalena river and other creeks, that is just being let to flow through the urban area where it gets polluted with sewage and discharge waters. CANTORAL-URIZA ET. AL. (1999) and BOJORGE-GARCÍA (2002) found that the quality of the water in the Magdalena river watershed is fairly good in the middle and uppermost parts, decreasing in quality as one goes down in altitude. Although the main driver of aquifer recharge is rainfall, by itself it can not be used to estimate the spatial distribution of potential aquifer recharge as vegetation, topography and soils also play an important role.

According to CARRERA-HERNÁNDEZ (2007), aquifer recharge in the BMC has not been negatively influenced by urban growth. This is due to the fact that the urban area of Mexico City is mainly covered by lacustrine deposits, where recharge cannot easily take place. In this regard it can be said that the Basin's geological environment has protected the aquifer: the lacustrine deposits with their low conductivity values have protected the aquifer from pollution, while the mountainous terrain, where recharge occurs, is protected from urban growth due to its topographic relief (CARRERA-HERNÁNDEZ 2007).

The Mexican program for Payment of Hydrological Environmental Services seeks to become an interface between the forestry and water policies. Designed to complement both policies by providing economic incentives to avoid deforestation in areas where water problems are severe. They consist on direct payments to landowners with primary forest cover (well conserved forests) given at the end of the year, once it has been proven that they were not deforested. Part of its innovative approach is that it is funded through an earmarked percentage of the federal fiscal revenue derived from water fees, creating a direct link between those who benefit from the environmental services and those who provide them (MUÑOZ-PIÑA et al. 2005).

5.5.5 Recreational value

Protected areas attract millions of people around the world. This will increase as people in this world increases, it becomes more crowded and natural areas become less common. Recreation within protected areas can have benefits, they can be used to educate people about conservation. The economic value of tourism from protected areas can benefit local communities and act as a stimulus for political support (DE LACY & WHITMORE 2006). Tourism from the people of Mexico City already represents a considerable income for local communities and it still has a bigger potential. Some environmental education is taking place in the form of visits from schools who follow guided tours where they learn about the biodiversity of the area and its importance on the provision of ecosystem services, broadly. The information given, often lacks precision and could be improved. It is expected to make the information generated here and in other works accessible for land owners and people in charge of the different environmental education programs.

An excessive tourism and recreational activities are a threat for the conservation of the forests in the area. People in charge of the management of protected areas have to be aware of the trends of recreational activities and tourism and their implication for a sustainable forest use. The most important areas in terms of provision of ecosystem services, should be kept for strict conservation, not promoting human affluence.

Final remarks

As GOLDMAN et al. (2008) found out, ecosystem services projects attract on average more than four times as much funding than biodiversity projects. And ecosystem services are also more likely to include productive landscapes and the people in them, expanding opportunities for conservation, and no less likely to include protected areas.

Values give meaning to protected areas, they provide the motivation for their creation, give direction to their management and allow evaluation of their effectiveness (LOCKWOOD 2006). A value that is expressed and measured in economic terms (eg. money) can be traded off for something else of value. Money provides a common standard that enables the relative economic benefits associated with different values to be compared. The benefits associated with non-tradable values cannot be expressed in economic terms, but it should always be remembered that all the ecosystem components have a value of its own sake, an intrinsic value.

The Federal Government of Mexico has established the commitment to promote forest conservation, in order to keep and improve the provision of ecosystem goods and services. It considers a priority to give an incentive to the maintenance of these goods and services through the "Pro-Árbol Program", granting economical supports under the payment for ecosystem services (PES) scheme, and designing strategies for the generation of local markets of ecosystem services (MUÑOZ-PIÑA et al. 2005).

Markets for ecosystem services are being promoted across the developing world. These markets have developed encompassed by claims that people need economic incentives to conserve ecosystems and their services (CORBERA et al. 2009). This perspective makes economic reasoning prevail over more traditional arguments for nature conservation based on existence and non-use values. However, these markets must be designed and implemented in ways that are fair to local people. Markets for ecosystem services aim to generate payments from people who benefit from the goods and services provided by ecosystems.

Because payments are based on the quantity of services supplied, PES programs must measure the ecosystem services, which represents a difficult task. Measurements depend on complicated ecological relationships that are often poorly understood. For example, the contribution of a hectare of forest to aquifer recharge depends on the vegetation, soil, hydrology, topography, and weather in the forest. Given the challenges involved in measuring ecosystem services, most PES programs use relatively coarse estimates (ALPÍZAR et al. 2007). The results of this research expect to contribute in a more precise estimation of the ecosystem services of the area and as a guide for other similar areas.

The area should be valuated and managed by its intrinsic value and by all the ecosystem goods and services that it provides to Mexico City. Due to its ecological importance as well as its vulnerability against the urban growth, it is fundamental to implement different projects under the integrative ecosystem management concept (CASTILLO 2000), that allows in short, medium and long terms, the conservation of the area.

Anyway, in terms of nature conservation and sustainable forest management, "we will make more progress in the long run by appealing to people's hearts rather than to their wallets" (MCCAULEY 2006).

6. Forest quality for the assessment of sustainable forest management in the southwest of Mexico City

6.1 Summary

Numerous attempts have been made to define criteria and indicators (C&I) for the assessment of sustainable forest management (SFM) at various levels (e.g. global, regional, national, forest management unit). In 1998, the WWF and the IUCN developed the forest quality C&I initiative for assessing SFM at the landscape level. The initiative relies on the forest quality principle and encompasses criteria from three categories: (1) forest authenticity, (2) environmental benefits, and (3) other social and economic benefits.

The aim of this chapter was to assess forest quality, integrating field and laboratory verifiers of forest composition, pattern, function, process, tree health, area and fragmentation, and management, as well as ecosystem services indicators. C&I, together with their verifiers, were weighed by a group of experts through a pair-wise multicriteria analysis. Overall, experts coincided in that forest composition and forest process are the most important indicators for forest quality assessment. This information was synthesized and analyzed through Canonical Correspondence Analysis and multicriteria evaluation. Fir (*Abies religiosa*) forest has the highest values for the forest quality indicators, whereas the *Pinus hartwegii* forest, typical of very high elevations, had lower values in general.

A forest quality map was produced through spatial interpolation and by integrating information for all indicators; this tool is expected to provide a solid yet flexible framework for decision making and monitoring of the sustainable forest management in the area.

6.2 Introduction

Most forests have already been modified by people. Complete ecological integrity (sensu KARR & DUDLEY 1981; NOSS 1995; WESTRA & LEMONS 1995) is already a historical concept in most cases. Many forests considered to have developed since the last ice age would have never existed without human disturbance (KÜSTER 2003). Even alleged "pristine" or "virgin" forests are now known to have suffered some degree of human influence, including exotic species introduction, changes in dominance, and canopy structure alteration, among others. Therefore, the distinction between "natural" and "disturbed" forests has lost importance relative to the knowledge on the degree and type of disturbance (CBD 1997).

Recently, there has been a growing perception that not only forest quantity, but also quality, is declining globally as a result of human action (WWF & IUCN 1999). In 1992, negotiations among parties at the UN Conference on Environment and Development (UNCED) resulted in the non-legally binding authoritative statement of principles for a global consensus on the management, conservation, and sustainable development of all forest types, also known as the "Forest Principles", as well as Chapter 11 of Agenda 21: Combating Deforestation (POKORNY & DESMOND 2004). Consequently, many attempts have been made to define criteria and indicators (C&I) as toolsets for the assessment of forest quality, and to monitor progress towards sustainable forest management (SFM) at the global, regional, national and forest management unit levels (e.g. ITTO, Montreal Process, Pan European Process, FSC, etc.). SFM has become the primary goal of forestry institutions worldwide (MENDOZA & PRABHU 2000b). Despite minor differences in its meaning, there is a general agreement among experts in that it involves the managing of forests to achieve "the production of continuous flow of goods and services without undue reduction of their inherent values and future productivity" (ITTO 1992). Sustainable forest management has become the primary goal of forestry institutions worldwide (MENDOZA & PRABHU 2000b). Despite minor differences in its meaning, experts generally agree that it involves managing forests for one or more objectives to achieve the production of continuous flow of goods and services without undue reduction of their inherent values and future productivity (ITTO 1992).

When assessing SFM with C&I, an indicator is a basic property of the system being assessed (in this case, a forest), which can be evaluated in several ways and by using different variables. These variables are the verifiers. A group of indicators, in turn, provide insight on a more complex, and often more abstract, property of the system, which is the criterion. Obviously, no single indicator will be adequate to summarize information on all aspects of forest biodiversity and ecosystem services. However, the use of different indicators to build up a better picture of any given criterion, and ultimately of the degree of forest quality, should be emphasized (DE LEO & LEVIN 1997). In order to capture as much information as possible, and to make these concepts useful tools for conservation and management, the proper selection of indicators and verifiers is crucial (CBD 1997).

To date, most existing C&I initiatives measure forest condition at either one of two levels: national or forest management unit (eg. Montreal Process, ITTO Helsinki Process; Forest Stewardship Council, CIFOR). In 1998, the WWF and the IUCN launched a C&I initiative to guide forest quality assessment at the landscape level. This initiative adopted forest quality as primary principle, and encompasses three criteria: forest authenticity, environmental benefits, and social and economic benefits (DUDLEY et al. 2006). For these criteria and indicators there are hints as to what can be measured in the field to assess forest quality. According to this initiative, forest quality is defined as the "significance and value of all ecological, social and economic components of the forest landscape" (WWF & IUCN 1999:5), considering the way in which people, forests and the biophysical environment interact in a region.

The forest authenticity criterion offers some advantages that may be useful in identifying and describing ecological quality of a given forest and its conservation value, and in developing of management strategies (DUDLEY 1996). Conceptually, forest authenticity is similar to the notions of ecological integrity (CAIRNS 1975), ecosystem health (COSTANZA et al. 1992; RAPPORT 1995), and naturalness-hemeroby (HORNSTEIN 1950; JALAS 1955; ANDERSON 1991; KOWARIK 1999), but its attractiveness lies on a relatively more precise definition and potential ease of use.

Seven major components are important in defining the relative authenticity of a forest ecosystem (WWF & IUCN 1999): the *composition* of species; the *pattern* of intra-specific variation; the *functioning* of plant and animal species in the forest; the *process* by which the forest changes and regenerates; the *resilience* of the forest in terms of tree health; the *area* of the forest; and all these components are in turn affected by *management* practices.

These indicators with their verifiers, provide in turn most of the basic information to fulfill the other two criteria in forest quality: environmental benefits and other social and economic benefits, which fit into the Millennium Assessment's concept of ecosystem services (MA 2005), here considered as an indicator.

Ecological integrity, ecosystem health, naturalness

Similar to forest authenticity, the concepts of ecological integrity (CAIRNS 1975), ecosystem health (COSTANZA et al. 1992; RAPPORT 1995) and naturalness-hemeroby (HORNSTEIN 1950; JALAS 1955; ANDERSON 1991; KOWARIK 1999), to assess disturbance or human influence degree in different ecosystems, have been used.

Ecological integrity has several definitions derived from ecosystem studies based in complex systems theories (WESTRA & LEMONS 1995). CAIRNS (1975) defines it as the way to maintain the structure and function in a community that are characteristic for a specific place or considered satisfactory to society. KARR & DUDLEY (1981) define ecological integrity as the capability of supporting and maintaining a balanced, integrated, adaptive, community of organisms having a composition, diversity and species functional organization comparable to the natural habitats in a certain region.

According to NOSS (1995), an ecosystem with integrity has several qualities on a high degree: ecosystem health, biodiversity, stability (in terms of resistance and resilience), sustainability, naturality and aesthetic beauty. In contrast, ROLSTON &

WESTRA (1994) affirmed that the idea of integrity is soft, visionary, rhetoric and politically and emotionally correct, but philosophically and biologically doubtful, because it cannot be made operational. Ecosystem health is a term used to describe the ideal or wished states of the environment. The objectives, aims and indicators of ecosystem health are valuable tools to guide ecosystem management, integrating social and natural sciences with human values (RAPPORT et al. 1998). Ecosystem health can be defined in terms of the capability of an ecosystem to resist adverse environmental impacts in the present (WESTRA & LEMONS 1995), closely related with the resilience concept. It could also be defined as the integration of the degree in which vegetation and disturbance conditions are similar to native patterns and to the levels of influence of human activities (HEMSTROM et al. 2001).

Naturalness has been used to represent the ecosystems that have not been influenced by man, or only indirectly (ERZ 1992; REIF & WALENTOWSKI 2008). It is often assessed by the similarity of an ecosystem to the expected natural state without human affectation (REIF & WALENTOWSKI 2008). So, in this sense, a strict natural forest would be one pristine, virgin, which nowadays is very difficult to find.

The notion of ecological integrity, ecosystem health, naturalness or hemeroby is so complex that its measure cannot be expressed through a single indicator and they cannot be absolute concepts. They all require a set of indicators at different spatial, temporal, and hierarchical levels of ecosystem organization (DE LEO & LEVIN 1997).

But, there is no simple way to define or measure the health, ecological integrity, naturalness, or authenticity of an ecosystem, and this has been a continuous critic on the validity of these concepts (DE LEO & LEVIN 1997; RAPPORT et al. 1998; DUDLEY et al. 2006). They are all mental constructs that represent useful tools for conservation and management. Their validity relies on the way they are conceptualized, described and assessed.

The purpose of this chapter was to design and implement a methodology for the assessment of "forest quality" in the southwest of Mexico City using multicriteria analysis and multivariate statistics. An integration of the information generated on previous chapters (vegetation and ecosystem services) combined with the analysis of the authenticity of the forests in the area is presented.

6.3 Methods

6.3.1 Definition and evaluation of forest quality indicators and verifiers

The map of vegetation units based on color air photogrammetry (Chapter 4) was used to select sampling units according to a stratified random procedure. A total of

116 25 × 25 m (625 m²) plots were inventoried from 2006 to 2008 (see Fig. 17 for spatial distribution and App. 5 for precise localization data). For each plot elevation, slope inclination and aspect were recorded. The information gathered in the field and the subsequent data processing in the lab allowed to evaluate three or more variables -or verifiers- for every indicator of the forest quality criteria. Indicators for these criteria and their verifiers are shown in Tab. 16.

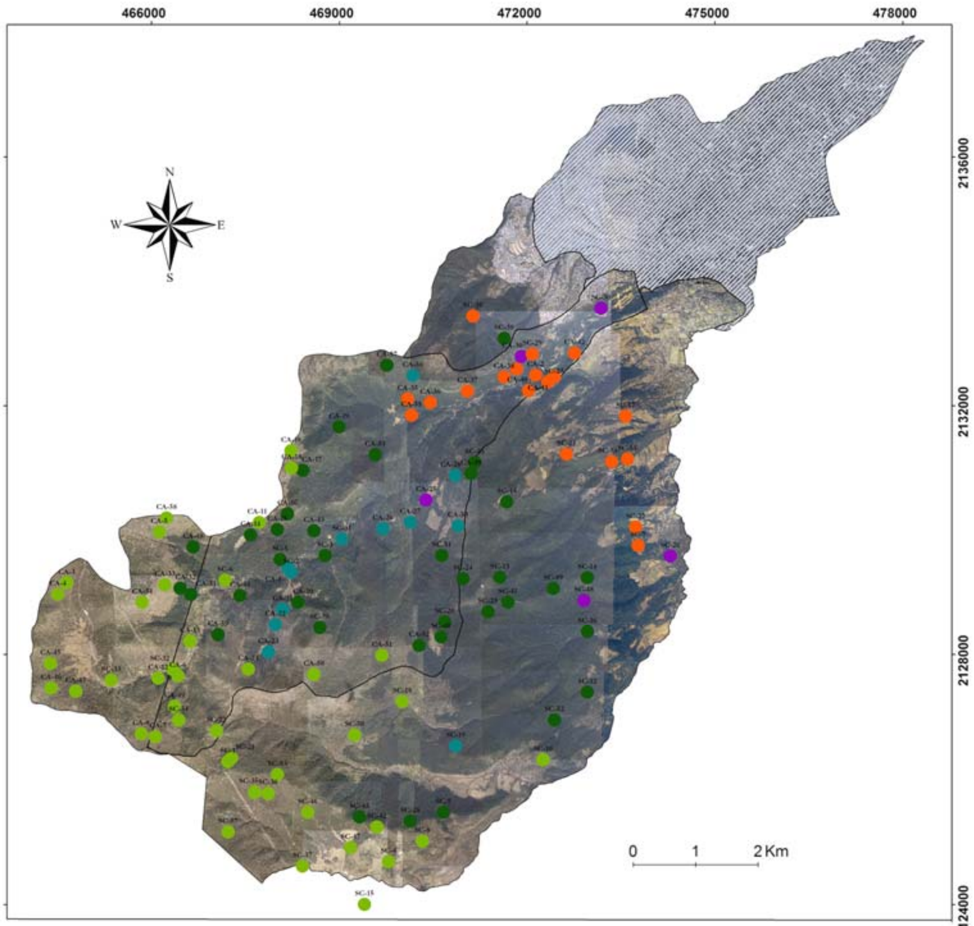

Fig. 17 Sample field plots in the upper Magdalena river watershed and the conservation area of Magdalena Contreras Municipality. Light green dots represent the sample plots within P. hartwegii forest; blue disturbed A. religiosa forest; dark green A. religiosa forest; purple forest plantations; orange Quercus forests

Assessment of the first indicator *-forest composition-* required the recording of each plant occurring in the study plots. Individual plants were determined to species or vouchers were collected for determination in the lab, when unrecognized in the field. For each species percent canopy cover was assessed relative to plot area (KENT & COKER 1992), and a search in specialized literature allowed the categorization of plant species by geographical origin (native vs. exotic species) and by ecological group (weedy vs. non-weedy species). Four verifiers were finally assessed for this indicator: plant species richness, Shannon diversity index, Simpson diversity index (both according to the formulas presented by MAGURRAN (2004)), and the alien (weedy+exotic) over native species ratio. The evaluation of the *forest pattern* indicator was based on quantitative variables measured in the field: individual DBH for every tree with a DBH ≥ 5 cm, individual tree height and percent total tree canopy cover; the five verifiers derived from these data were DBH frequency distribution in five categories (5-15, 15-25, 25-35, 35-45, and > 45 cm), tree height average, total basal area in the plot, tree density, and percent tree canopy cover. The three verifiers of the *forest function* indicator were appraised through soil and forest floor related variables: soil pH, soil percent organic matter, and percent litter cover; to this end, a compound soil sample (0-15 cm) was collected from each plot and analyzed in laboratory for pH (JACKSON 1982) and organic matter content (WALKLEY 1947; BLACK 1965). The *forest process* indicator comprised aspects of population dynamics and included three verifiers measured in the field: percent regeneration (percent cover of trees with DBH < 5 cm), number of standing dead trees, and percent dead wood cover. Assessment of the *tree health* indicator was achieved through observations on individual trees in every plot; the three corresponding verifiers were number of trees affected by bark beetles or defoliating insects, number of trees with mistletoe infestation, and number of trees with abnormal foliage color. For the evaluation of the *forest area and fragmentation* indicator a GIS was constructed on an ArcView 3.2 (ESRI 1998) platform; the three verifiers assessed in this way were area of each forest type, plot-to-road mean distance, and number of fragments by forest type. The last indicator, namely *forest management*, focused on variables that were informative of human activities in each plot; first, we noted which tree species had been used in previous reforestation actions, grading with a +1 those cases in which the proper species were used (species not only native to the study area but specific to the forest type), with a 0 when there had been no reforestation, and with a -1 when inadequate species had been used. Additionally, we used a four level scale (1 to 4) to make a visual estimate of human affluence and cattle grazing intensity (1 being the lowest level observed and 4 the highest). This indicator included five verifiers: adequacy of species for reforestation, percent cover of recharge tubs (holes dug in the soils to increase water infiltration rates), percent garbage cover, degree of cattle intensity, and degree of human affluence.

The environmental benefits and other social and economic benefits criterion, possessed one indicator, ecosystem services, comprised of four verifiers (Tab. 16). The evaluation of these verifiers was achieved through specific procedures described in Chapter 5.

The information gathered on field was then processed into index variables used for the assessment of forest quality (Tab. 16).

6.3.2 Multicriteria analysis

In addition to efforts aimed at gaining a better definition of C&I for measuring SFM, there have been calls for an increased inclusion of people's perceptions and values in the forest planning process (SHEPPARD & MEITNER 2005). Multicriteria analysis (MCA) is a decision-making tool developed to address complex problems, including qualitative and quantitative aspects, that gives special consideration to the opinions of people from various groups in order to rank or weight the involved variables. The application of MCA in forest and other natural resource management has been amply described in a number of studies (JANKOWSKI & RICHARD 1994; PETERSON et al. 1994; KANGAS et al. 2000; MENDOZA & PRABHU 2000b, 2003; SHEPPARD & MEITNER 2005; WOLFSLEHNER et al. 2005).

Relative weights were assigned to forest quality indicators and verifiers through pairwise comparison matrices, following the method proposed by SAATY (1977). Pairwise comparisons consist in a series of one to one expert judgments for assessing the relative importance of one indicator/verifier against another (MENDOZA et al. 1999). For ν components, the reciprocal matrix C = [cpr] is constructed, so that cpr = 1/crp for p, r = 1, 2, …, ν. The comparison of the relative importance w of element p against component r results in a value of cpr = wp/wr. The total number of comparisons is ν (ν -1)/2 as all values in the diagonal are equal to 1. The weights in the pairwise comparison procedure are determined through the normalization of the eigenvector associated with the highest eigenvalue of the reciprocal quotient of the matrix (MALCZEWSKI 1999).

A table questionnaire for the pairwise comparisons was handed to various experts representing as wide a range as possible of fields relevant to the forest quality concept. The aims of this project and the concepts of C&I, SFM and forest quality were presented to the interviewees, along with definitions of all verifiers. The questionnaire had eight matrices (seven corresponding to forest authenticity indicators and a last one to ecosystem services). For each indicator, experts were required to weight its verifiers. Subsequently, they were asked to complete a final matrix containing all indicators (taking ecosystem services as such), in order to assess their importance according to their contribution to forest quality assessment. The weighting scale spanned from 6 to 1/6 (6, 5, 4, 3, 2, 1, ½, 1/3, 1/4, 1/5, 1/6). Values > 1 give a higher importance to rows whilst values < 1 give a higher importance to columns. Values of 1 implied that both the row and the column variables had the same importance. Further details on this procedure are given in App. 7, along with a worked example.

6.3.3 Relation of environmental and forest quality variables with floristic composition variation

Multivariate analysis is the branch of mathematics that deals with the examination of multiple variables simultaneously. In community ecology, multivariate data are treated as a whole, summarizing the data and revealing their structure. Multivariate analysis falls mainly into two main groups: classification and ordination. Classification is the placement of species and/or sample units into groups, and ordination is the arrangement or ordering of species and/or sample units along gradients (GAUCH 1982). Canonical correspondence analysis (CCA), is a constrained ordination technique which output includes a set of vectors that visually represent the relative strength and directionality of gradients derived from environmental variables and species presence/cover data. The direction of a vector indicates how well an environmental variable correlates with the species composition axes and its length provides a relative measure of the variable's importance (JENKINS & PARKER 1998).

In order to examine the influence and relationships of selected forest quality verifiers and some environmental variables on floristic composition heterogeneity, a Canonical Correspondence Analysis (CCA) was performed with CANOCO 4.5 (TER BRAAK & SMILAUER 2002). Data were arranged in two matrices; the main one consisted of percent cover data for 360 plant species in 116 plots, and the secondary one included 19 verifiers representing all forest quality indicators (species richness, Simpson index, weed/native ratio; mean DBH, tree height average, basal area, percent canopy cover; percent regeneration; soil pH, soil organic matter content; mean distance to road; human affluence, grazers; carbon content, recreational value, water supply/infiltration and useful plants), besides altitude and slope inclination in the same 116 plots. The selected options were biplot escalation, without transformation and downweighting of rare species. The significance of eigenvalues, as well as the significance of the effect of the environmental variables and forest quality verifiers on floristic composition, were tested through 999 Monte Carlo permutations. The ordination graph was made in CANO DRAW 4.0, and the plots were classified by plant community types.

6.3.4 Forest quality index calculation and mapping

The information on all forest authenticity and ecosystem services verifiers was synthesized and standardized by computation of their means and standard deviations. Because subsequent calculations required all values to be positive, we added a constant value (+4) to them. Data so processed for each plot were then multiplied by their weights derived from the MCA. First, the values were multiplied by the weight given to the verifier (e.g. plant species richness). Then, the resulting products were added together (or subtracted) for each indicator, depending whether they were considered to be positive or negative contributors to forest quality (see Tab. 16, column 5), to obtain a single additive value by indicator. For example, for the forest composition indicator, we first summed the products for the three first verifiers (species richness, Shannon index and Simpson index), and from that total we subtracted the product corresponding to the alien/native species ratio; obviously, the sum value for the forest health indicator was always negative, as all verifiers contribute negatively to forest quality, whereas the management indicator could have positive or negative values, depending on the local situation. These new indicator totals were then multiplied by their weights derived from the MCA, and the new products were finally summed to obtain the forest quality index. Quality indices were calculated according to this procedure for individual plots, for 10 floristic associations and for three plant communities previously described for the area (Chapter 3).

Forest quality indicators and overall forest quality index values for individual plots were used to produce a spatial interpolation in ArcView 3.2 (ESRI 1998) using the Inverse Distance Weighted algorithm (LAM 1983), nearest neighbors, and a grid size of 10 units, classified in 8 equal interval classes. IDW is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell, weighting of nearby points is strictly a function of distance (ESRI 1998). This resulted in indicator maps and a general, integrative map of forest quality for the area.

6.4 Results

6.4.1 Multicriteria analysis

A total of 32 experts were interviewed regarding forest quality indicators and verifiers. These specialists came from a variety of backgrounds, ranging from ecology, natural resources management, and soil sciences, through agricultural engineering and forest engineering, to restoration ecology (see App. 4). No inconsistencies were found on the pairwise comparison matrices.

Overall, the highest weights were given by the experts to the forest composition and the forest process indicators (0.172 and 0.169, respectively), followed closely by the ecosystem services (0.128) and the forest pattern indicator (0.126). In the other end, the lowest weighted indicator was forest management (Fig. 18).

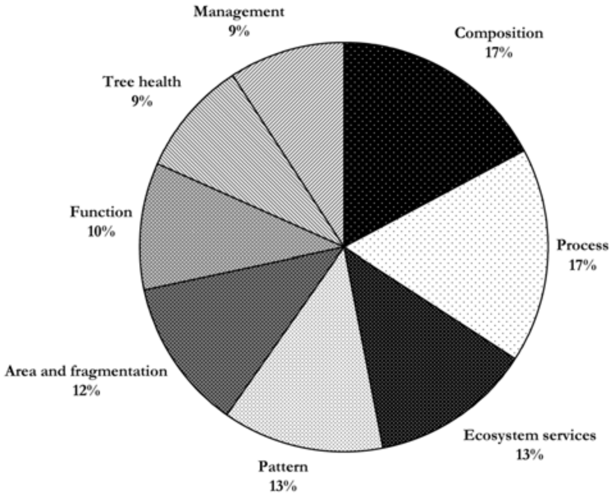

Fig. 18 Ponderation of forest quality indicators by specialists

Within *forest composition* the ratio between exotic and weed versus native plant species was considered the most important variable to assess forest quality, followed by the total number of plant species (Tab. 16). The Shannon diversity index was considered the least important variable. For the indicator of *forest process*, the verifier of regeneration was considerably more important than dead wood coverage and the number of standing dead trees, which had a similar weight. DBH size distribution was considered the most important verifier for the *forest pattern* indicator, having the other four verifiers a lower weight. In terms of forest function, specialists considered the content of organic matter in the soil as the most important variable and soil pH the least. Forest health, one of the lowest weighted indicators, had the number of trees with mistletoes as the most important verifier. When considering *forest area and fragmentation*, experts gave a much higher weight to the total area of a forest type, giving almost half the importance to the other two measured verifiers. For *forest management*, the way in which people mimic natural patterns, the used reforestation tree species got the highest weight, followed by the verifier of grazers presence. In terms of ecosystem services, experts gave more or less the same weight to the verifiers of water infiltration/supply, carbon sequestration, and biodiversity use. Recreational value was considered the least important verifier within ecosystem services.

Tab. 16 Criteria, indicators and verifiers used for the assessment of forest quality, and the weights given by specialists using pairwise comparison matrices. Bold typeface shows the highest and italics the lowest weighted values for the indicators of the forest authenticity and environmental and other social and economical benefits criteria.

Criteria	Indicators (weight)	Verifiers	Quantitative or qualitative	Positive (+) or negative (-)	Weight
Authenticity	Composition (0.172)	Plant species richness	Quant	+	0.295
		Simpson diversity index	Quant	+	0.235
		Shannon diversity index	Quant	+	0.160
		Weed+exotic/native plant species ratio	Quant	-	0.311
	Pattern (0.126)	DBH frequency distribution	Quant	+	0.306
		Tree height average	Quant	+	0.184
		Basal area	Quant	+	0.185
		Tree density	Quant	+	0.157
		Percent tree canopy cover	Quant	+	0.167
	Process (0.169)	Percent dead wood cover	Quant	+	0.278
		Number of standing dead trees	Quant	-	0.284
		Percent regeneration	Quant	+	0.438
	Function (0.100)	Soil pH	Quant	+	0.272
		Percent organic matter content	Quant	+	0.408
		Percent litter cover	Quant	+	0.319
	Forest health (0.093)	Number of trees with mistletoe	Quant	-	0.401
		Number of trees affected by bark beetles and leaf eating insects	Quant	-	0.323
		Number of trees with abnormal foliage color	Quali	-	0.276
	Area and fragmentation (0.119)	Area by forest type	Quant	+	0.467
		Plot-road distance	Quant	+	0.239
		Number of fragments by forest type	Quant	-	0.294
	Management (0.090)	Adequacy of species for reforestation	Quali	+	0.314
		Percent cover of recharge tubs	Quant	+	0.173
		Percent garbage cover	Quant	-	0.168
		Degree or cattle intensity	Quant	-	0.203
		Degree of human affluence	Quant	-	0.143
Environmental benefits and other social and economic benefits	Ecosystem services (0.127)	Water infiltration capacity/water supply	Quali/Quant	+	0.263
		CO_2 sequestration (carbon content in trees)	Quant	+	0.286
		Timber trees and useful non-timber plant species (useful plants)	Quant	+	0.272
		Recreational value	Quali/Quant	+	0.177

6.4.2 Canonical Correspondence Analysis

The obtained eigenvalues for the first three axes in the ordination (Tab. 17), suggest that there is a good separation between the forest communities, associated to environmental gradients along these variation axes (TER BRAAK 1987). There is a clear grouping of plots with the same plant community (Fig. 19). The CCA showed a strong relation between altitude, soil pH, soil organic matter content, tree average heights and human affluence variables against the plant composition data. The altitude clearly distinguished the vegetation units of *P. hartwegii* in the higher elevation areas and *Quercus sp.* vegetation types in the lowest ones. It could also be observed an inverse relation between altitude and human affluence. Regeneration is higher in higher altitudes and presented an inverse relation with canopy cover. The soil pH increases as altitude decreases. Carbon content tends to be higher in medium altitudes, mainly representing the *A. religiosa* and *Quercus* forests.

Soil organic matter had an inverse relation with slope, and it was higher in the plots of *A. religiosa* and *P. hartwegii* forests. Plant species richness did not show a strong influence, though it is directed towards *Quercus* and *A. religiosa* forests plots.

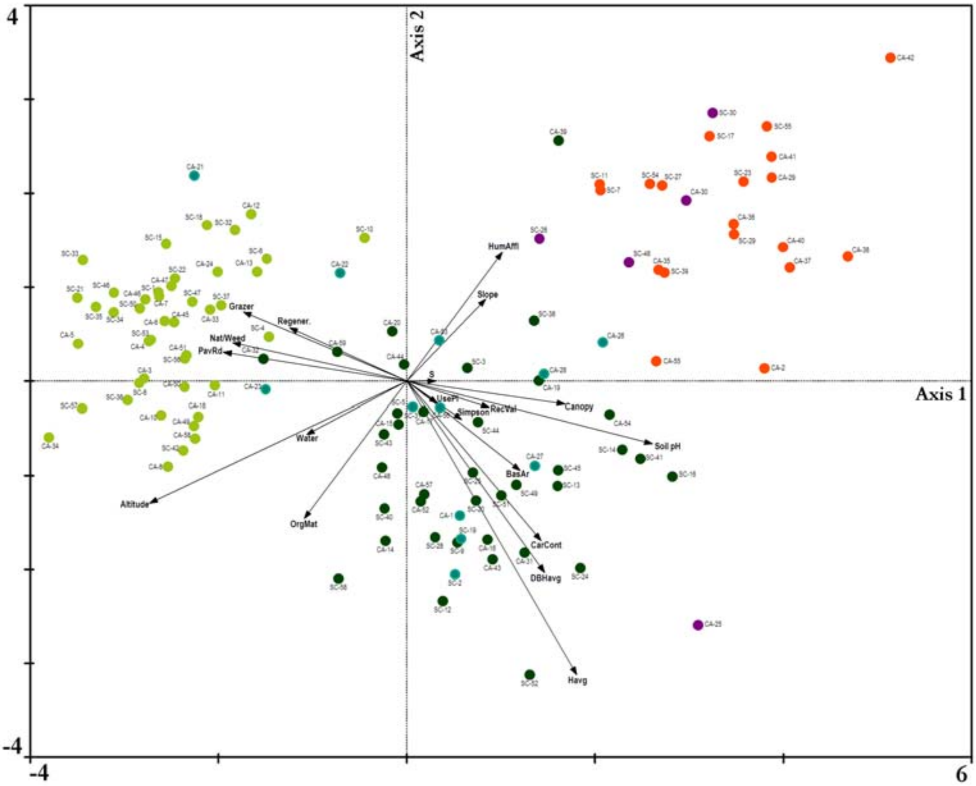

Fig. 19 Canonical correspondence analysis (CCA) biplot. Environmental variables vs. plant composition data in sample plots. Light green dots represent the sample plots of P. hartwegii forest; blue disturbed A. religiosa forest; dark green A. religiosa forest; purple forest plantations; orange Quercus forests

Tab. 17 Canonical correspondence analysis results. Eigenvalues, species-environment correlations and the accumulated variance of species and species-environment relations for the first three axes are shown.

	Axes		
	1	2	3
Eigenvalues	0.79	0.47	0.18
Species environment correlations	0.96	0.82	0.82
Accumulated variance (%)			
-Of species	9.3	14.8	17
-Of species-environment relations	33.8	53.4	61.1

The randomly generated data with the Monte Carlo permutation tests showed that the eigenvalues from the three axes as well as the correlations between species, environmental variables and the three ordination axes are significative ($P<0.02$), which suggest that the obtained CCA results are not due to chance.

6.4.3 Forest quality indicators

Some spatial patterns from the interpolated maps of the different forest quality indicators could be observed (Fig. 20 and Fig. 21). *Forest composition* showed the highest values in medium altitudes, towards the East and Southeast of the area. The ponderated *forest pattern* indicator got a spatial interpolation with the majority of the area having medium levels, with the lowest values towards the SW. In terms of the indicator of *forest function*, only a small area in the lower altitudes presented high values, while most exhibited medium to low levels. For the indicator of *forest process*, it was clear that only certain places present the highest levels, and most of the area under study has medium levels.

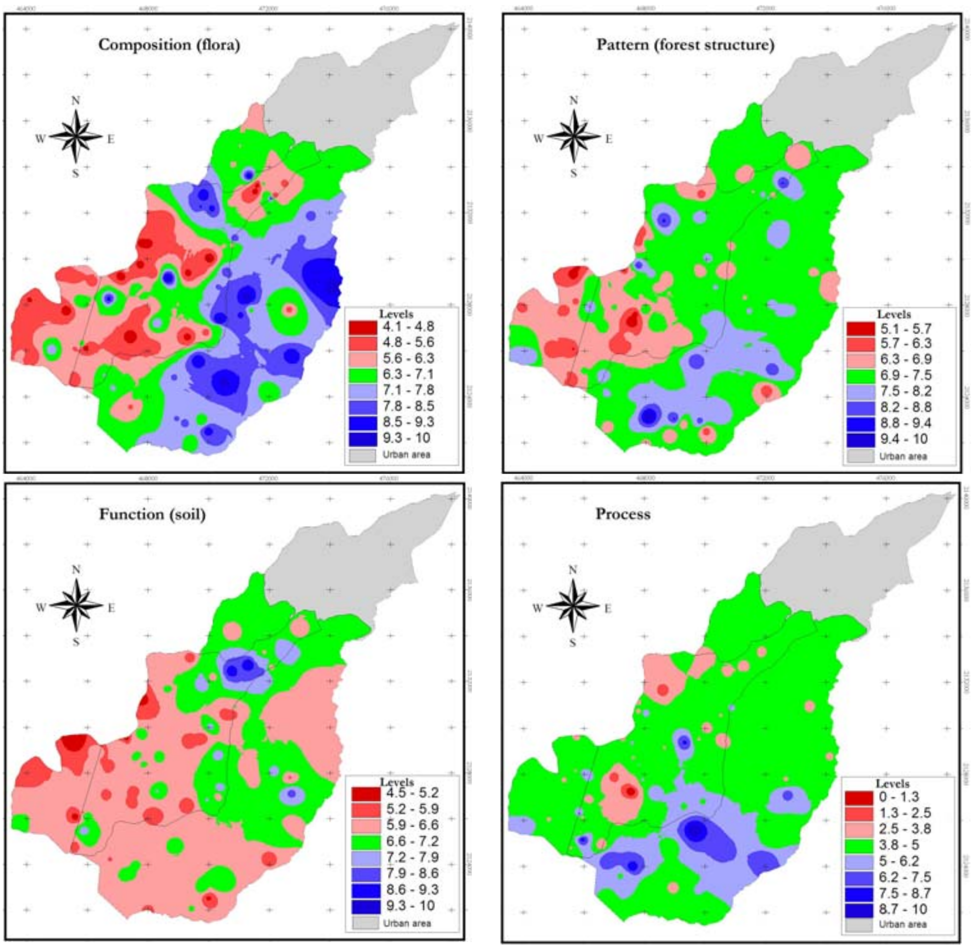

Fig. 20 Interpolated point maps showing the spatial distribution of four integrated forest quality indicators: Composition, Pattern, Function, and Process.

The indicator of *forest area and fragmentation* got medium to high values that are distributed all around the area, although there are some areas with considerably low values (Fig. 21). *Forest management* is an indicator that spatially showed medium to high values, having a big area of medium levels on the border with the urban area. The indicator of *tree health* showed high values spatially extending in most of the area. Though, some specific dots showed relatively low levels. The last indicator, *forest ecosystem services*, showed most of the area represented by medium to low values, and the highest levels being in the E and SE.

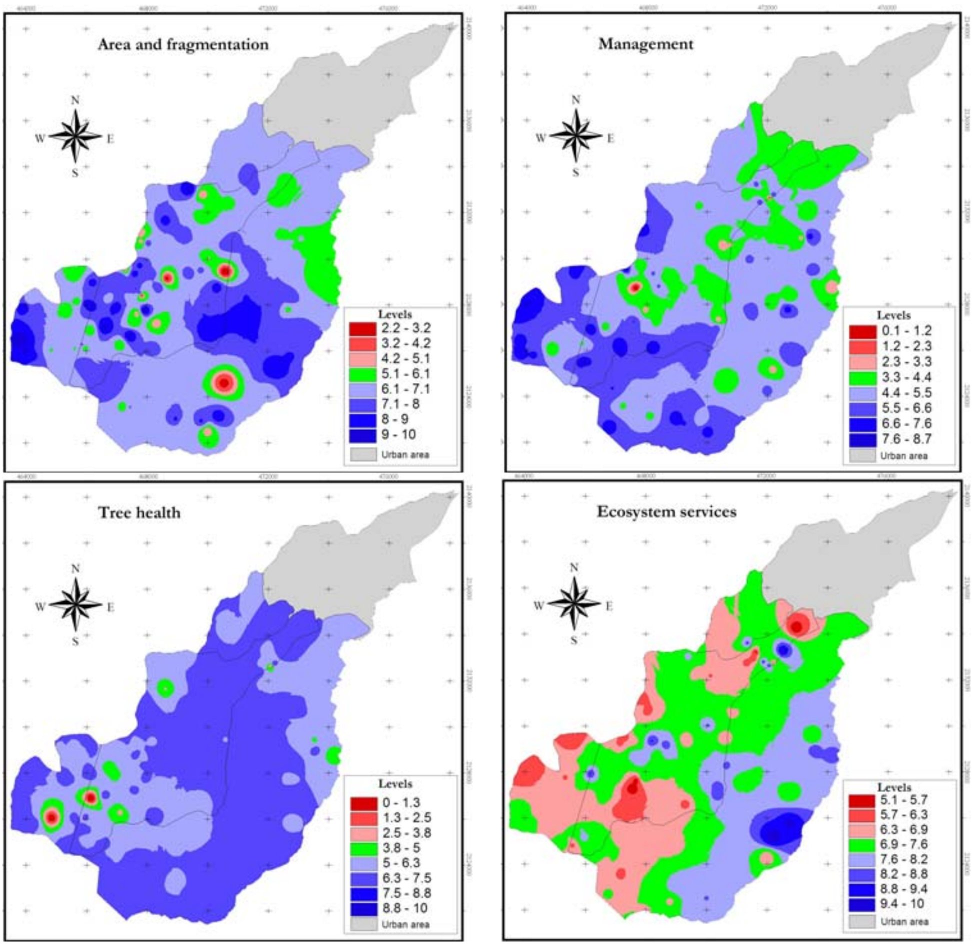

Fig. 21 Interpolated point maps showing the spatial distribution of four integrated forest quality indicators: Area and Fragmentation, Management, Tree Health and Ecosystem Services.

Tab. 18 Mean forest quality indicators (± SE) by forest community. C = composition, Pr = process, A&F = area and fragmentation, P = pattern, Fn = function, TH = tree health, Mg = management, ES = ecosystem services, and FQ = forest quality. Bold typeface shows the highest and italics the lowest values for each indicator.

Community	C	Pr	A&F	Pa	Fn	TH	Mg	ES	FQ
Pinus hartwegii	*6.2±1.1*	**4.8±1.3**	**6.6±1.0**	*6.8±0.6*	*6.1±0.6*	*6.2±1.4*	**6.0±1.1**	*6.8±0.5*	*6.4±0.6*
Abies religiosa	6.6±1.8	4.2±1.0	6.6±1.4	7.1±0.7	6.5±0.6	**6.4±0.8**	4.8±1.5	**7.3±1.1**	6.5±0.6
Quercus spp.	**6.9±1.2**	*3.9±0.2*	*6.2±0.6*	**7.3±0.5**	**7.2±1.1**	6.3±0.8	*4.7±1.2*	7.3±1.0	**6.6±0.4**
Total	6.6±1.5	4.5±1.3	6.9±1.5	7.1±0.8	6.5±0.9	6.4±1.2	5.2±1.4	7.2±0.9	6.6±0.8

Tab. 19 Mean weighed forest quality indicators (± SE) by plant association. C = composition, Pr = process, A&F = area and fragmentation, Pa = pattern, Fn = function, TH = tree health, Mg = management, ES = ecosystem services, and FQ = forest quality. Bold typeface shows the highest and italics the lowest values for each indicator.

Association	C	Pr	A&F	Pa	Fn	TH	Mg	ES	FQ
Pinus hartwegii – Calamagrostis tolucensis	6.9±1.0	**5.8±2.2**	7.1±0.8	**7.7±0.9**	6.4±0.5	6.5±0.5	5.9±0.9	7.2±0.4	7.3±0.6
Pinus hartwegii – Festuca tolucensis	6.5±1.5	4.6±1.1	6.6±1.3	6.7±0.5	6.3±0.8	6.3±1.4	5.9±1.2	7.0±0.8	6.5±0.5
Calamagrostis tolucensis – Pinus hartwegii	*5.6±0.8*	4.0±0.6	6.1±1.1	*6.1±0.5*	*5.6±0.7*	*5.8±2.3*	**6.4±1.3**	*6.3±0.4*	*5.5±0.6*
Abies religiosa – Roldana angulifolia	7.9±1.4	4.9±0.8	8.2±0.5	7.3±0.6	6.9±0.8	**6.9±0.4**	4.5±1.2	**7.8±0.5**	**7.5±0.3**
Abies religiosa – Thuidium delicatulum	5.7±1.2	4.4±1.2	**8.4±0.7**	7.5±0.7	6.4±0.5	6.2±1.0	4.8±1.2	7.5±1.1	6.7±0.7
Abies religiosa – Thuidium delicatulum – Acaena elongata	7.3±1.0	4.7±0.8	8.0±1.1	7.6±0.6	6.9±0.4	6.6±0.7	4.8±1.8	**7.8±0.9**	7.4±0.5
Disturbed *Abies religiosa*	6.7±2.0	4.1±2.0	*5.4±2.4*	6.6±0.7	6.2±0.5	6.5±0.6	4.6±1.1	7.0±1.1	6.1±0.9
Plantation – *Pinus* spp.	6.1±2.3	3.9±0.2	6.1±1.0	7.2±0.7	6.6±0.7	6.2±1.1	5.0±1.9	7.1±1.5	6.2±0.3
Quercus laurina – Q. rugosa	5.9±1.3	*3.8±0.1*	6.4±0.8	7.3±0.7	**7.5±1.3**	6.6±0.5	5.2±1.2	7.1±1.2	6.5±0.5
Q. rugosa – Q. laurina	**8.0±1.1**	4.0±0.4	6.1±0.4	7.4±0.4	6.9±1.0	6.0±1.2	*4.3±1.2*	7.5±0.8	6.8±0.3
Total	6.6±1.5	4.5±1.3	6.9±1.5	7.1±0.8	6.5±0.9	6.4±1.2	5.2±1.4	7.2±0.9	6.6±0.8

The plant communities and associations and their average ponderated forest quality indicators levels are shown in Tab. 18 and Tab. 19. At the community level, the *Quercus* spp. forests got the highest values in three of the forest quality indicators, and the *P. hartwegii* community got the least values for most of them. *P. hartwegii* forests got the highest scores for the indicator of *forest process*, suggesting a higher natural tree regeneration in this community. The *Quercus* spp. forest community, presented the highest values for the indicator of *forest function*, mainly due to the higher amount of organic matter content in the soil as well as the cover of leaf litter found in the sampled field plots.

When splitting the results of the forest quality indicators into forest associations, some things came up. There was a difference between the three associations of the *P. hartwegii* forest community, having the association of *C. tolucensis-P. hartwegii* as the one with the least scores for the used ponderated indicators. This association had the least canopy cover values and it represents an open forest, with abundant grass species. On average, the association of *A. religiosa-R. angulifolia*, presented the highest forest quality level, followed by *A. religiosa-T. delicatulum.-A. elongata* and *P. hartwegii-C. tolucensis.* For the forest composition indicator, the association of *Q. rugosa-Q. laurina* got the highest values, these meaning lower ratio values of native vs. weed plant species, and higher scores for plant richness and biodiversity indexes. Though, this association got the lowest values for the indicator of management, which suggests a non proper reforestation, higher human affluence and lower cover of recharge basins, among other verifiers.

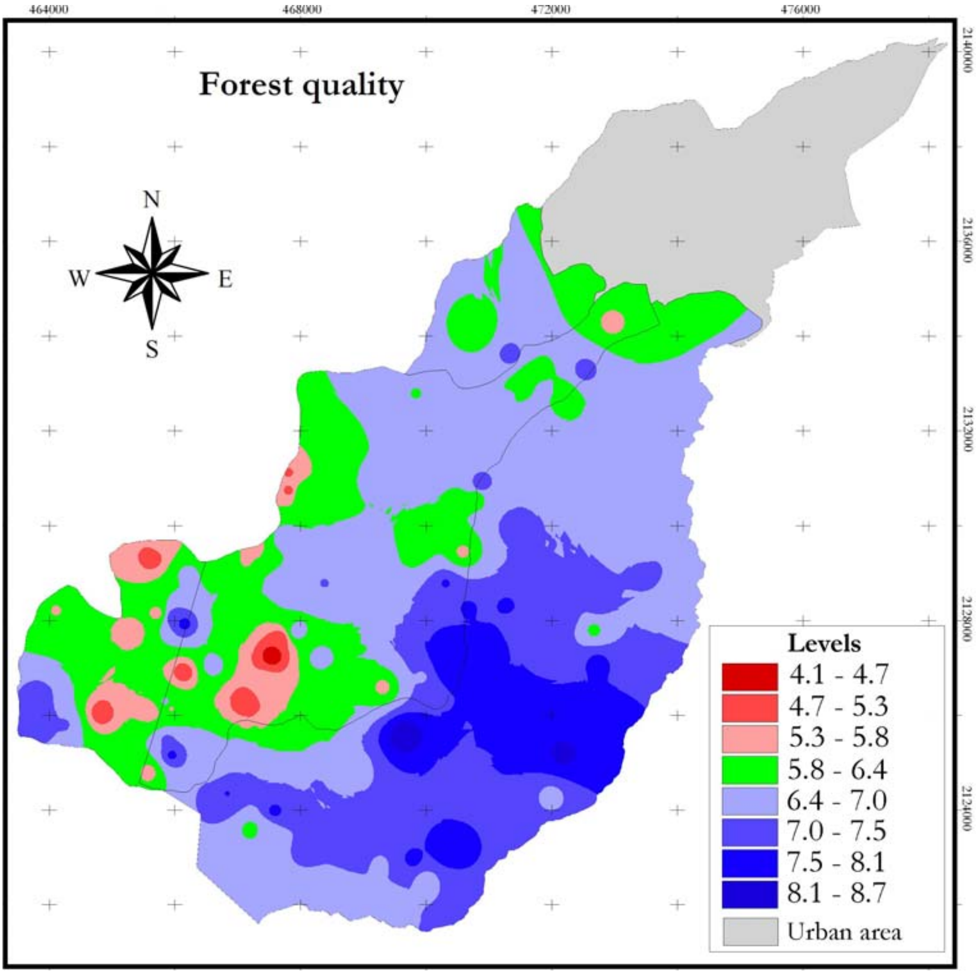

Fig. 22 Integrative ponderated forest quality map. It includes the information of all the eight forest quality weighted indicators: composition, pattern, process, function, area and fragmentation, forest health, management and ecosystem services.

When integrating all the weighted indicators into the forest quality index, 6.6±0.8 was the average level for the sampled field plots. The different levels of forest quality are spatially irregularly distributed, though, it could be seen that the highest values extend over the S and SW parts of the conservation area of Magdalena Contreras Municipality (Fig. 22). The lowest forest quality levels were found to be in the areas of *P. hartwegii* forest, but also in the contact between the urban and the conservation area.

6.5 Discussion

6.5.1 Multicriteria analysis

Problems and challenges from the real-world often involve multiple criteria and constraints. Criteria and alternatives have to be devised and problems are formulated to represent an optimal pattern of interaction between alternatives and criteria. This suggests a need for frameworks that will allow informed choices by providing opportunities for substantive participation in decision making supported by best available scientific data, incorporating uncertainty in an honest way (CHEE 2004). Multicriteria analysis (MCA) provides these mechanisms. MCA is a general approach that can be used to analyze complex problems considering multiple criteria, being able to deal with quantitative and qualitative data as well as expert opinions (MENDOZA & PRABHU 2003).

A proper application of MCA requires a good understanding of the aims and objectives, the number of criteria used, the procedure for the ponderation of the used variables, the choice of scale transformation, and how the criteria weights interact (HOWARD 1991). Pairwise comparisons, a technique based on the Analytic Hierarchy Process developed by SAATY (1977), is one of the mostly used MCA methods for the assessment of C&I (MENDOZA & PRABHU 2000a). It allowed the examination of the relative weights at the indicator and verifier levels. The MCA is a tool that has not been widely used in Mexico for biological resource assessments (CEBALLOS-SILVA & LÓPEZ-BLANCO 2003; ACEVES-QUESADA et al. 2006; BUSTILLOS-HERRERA et al. 2007). The use of pairwise comparisons on the interviews with the specialists, which were mainly academics, made some confusion due to its novelty. The one to one ponderations in matrixes were found to be complicate to fill out by some specialists. Other methods for weighting, like ranking and rating (MENDOZA et al. 1999), are more simple to understand, but do not allow to test for inconsistencies. This tool allowed the ponderation and integration of the different variables used, giving arguments that permitted forest quality assessment and that can be used for the priorization of management objectives.

As USHER (1986) found out, when it is intended to assess the level of disturbance in different ecosystems, there is a tendency on using "forest composition" verifiers, reflected on this study, by the highest given weight on this criterion. Assessing forest biodiversity is essential for effective conservation and sustainable management of forest resources (HUNTER 1999).

Within composition, diversity indices are commonly used to quantify the species diversity of ecosystems and occasionally ecosystem diversity of landscapes also. Among the most popular are Shannon's diversity index (believed to emphasize species richness) and Simpson's index (emphasizing evenness). Specialists considered

Shannon biodiversity index, one of the most widely used (NAGENDRA 2002), the least important verifier within forest composition indicator. A reason to explain this, might be that there was already another verifier covering species richness, so Simpson's index, more related to the abundance distribution of species, was then considered more important. Though, for the specialists, the most important verifier to assess forest quality in terms of composition was the ratio between native and non native plant species. Close after composition, the indicator of process was considered second in importance. Specialists found regeneration the most important verifier, which is fundamental due to the fact that future forest composition and stocking depends on existing regeneration and related factors (MCWILLIAMS et al. 2003).

Forest pattern (structural distribution of trees) was considered the third most important indicator, with DBH size distribution as the most important verifier. It was clear for specialists that, from the proposed verifiers (tree heights, basal area, tree density, canopy cover), the measurement of DBH would cover most of the information being addressed. DBH is one of the most important tree variables in forestry. It is used to describe stand structure, to estimate tree volume and to select inventory sample trees (AVERY & BURKHART 1994; OLIVER & LARSON 1996; CORRAL-RIVAS et al. 2007).

Forest function indicator was considered of low importance for the assessment of forest quality. It included measurements of soil, which can give an idea of nutrient cycling. Most existing inventory and monitoring efforts focus on living organisms as indicators and exclude indicators of forest function *per se*. The ecosystem, however, is a functional concept that focuses on the processes of organic matter accumulation via net primary productivity and the process of organic matter breakdown via consumption and decomposition (MARKEWITZ 2009). Some researchers consider *forest function* equal to ecosystem services (CAIRNS & PRATT 1995), which in this case got a higher ponderation. Within ecosystem services, the most "popular" forest functions got higher ponderations, having water infiltration/supply, carbon sequestration and biodiversity use and conservation similar weights. For the interviewed specialists, in terms of forest quality, the recreational value of an area would not be as relevant as the previously mentioned verifiers. Though, recreational activities represent one of the highest incomes for land-owners in the area under study. Science and education are two of the most important arenas for improving the well being of people (HUNTER 1999), and recreational activities should be directly linked to this.

6.5.2 Canonical correspondence analysis

Although individual indicators appear to be suitable, interactions may not be apparent if indicators are assessed without examining their interrelationships (MENDOZA & PRABHU 2003). Ordination allows the assessment of some of these relationships, and to distinguish the importance and direction of influence of different indicators or environmental variables on the spatial distribution of biodiversity, in this case plant composition.

Plant communities change gradually along environmental gradients (GLEASON 1926; WHITTAKER 1960; TER BRAAK & PRENTICE 1988; VAZQUEZ-GARCÍA & GIVNISH 1998; HUERTA-MARTÍNEZ et al. 2004). The distribution of plant species reflects the influence of several environmental variables at different scales. The canonical correspondence analysis organized the sample plots according to the different environmental variables and showed an agglomeration of same community forest types.

Even though the mountains of the Trans-Mexican Volcanic Belt represent one of the most biodiverse regions in Mexico, there have not been many studies to understand the relationship between environmental variables and the spatial distribution of species. The works of VELÁZQUEZ & CLEEF (1993), VELÁZQUEZ (1994), AVILA et al. (1994), SÁNCHEZ-GONZÁLEZ & GONZÁLEZ-MATA (2003) and SÁNCHEZ-GONZÁLEZ et al. (2005) represent some of these few examples. These authors used multivariate statistics (TWINSPAN, CCA, DCA) to study the plant communities in volcanoes near the study area (Tláloc and Pelado, Pico de Orizaba, Sierra Nevada and Trans-Mexican Volcanic Belt). They concluded that altitude, as found in this study, is one of the most important environmental variables determining the spatial distribution of plant composition. As it was also found by AVILA et al. (1994), altitude had a negative correlation with soil pH and a positive one with soil organic matter content in the A2 horizon.

The relationship between selected indicators should be analyzed using appropriate statistical approaches (HYMAN & LEIBOWITZ 2001). The importance of multivariate analysis techniques in community ecology and in SFM assessments, relies in the way they allow to detect the environmental variables or indicators responsible for structure and vegetation distribution changes. It should be considered an important tool to clarify and understand the relations between criteria, indicators, and verifiers.

6.5.3 Forest quality

Every measurable parameter has some value with regard to assessing environmental conditions. However, measuring every environmental variable or assimilating a large amount of information into the decision making process in an organized manner is impossible. Then, the most useful environmental parameters or indicators must be selected for assessing the degree to which specified environmental conditions have been achieved or maintained (CAIRNS et al. 1993). An indicator is a characteristic of the environment, that, when measured, quantifies the magnitude of stress and habitat characteristics (HUNSAKER & CARPENTER 1990). Individual metrics are scored based on the degree of similarity between values measured at a site of interest and that for some nominal state. For C&I to be effective and to gain acceptance, they need to be as clear as possible, easy to understand and simple to apply. They must provide information to forest managers and policy makers that is relevant, scientifically sound and cost-effective (STORK et al. 1997).

According to RAISON et al. (2001) key requirements of any indicator are the ability to detect important change in forest condition, and the capacity for cost-effective application at an operational scale. C&I are a new concept that has been developed to help provide greater clarity in defining SFM and tracking progress in achieving it over time. The criteria are used to describe the components of sustainability, and cover environmental (ecological), social and economic issues. Indicators measure various aspects of each criterion, and thus enable the effects of policy decisions and forest management practices on the state of forests to be monitored and reported.

Due to multi-faceted role of the resource, sustainable forest management necessitates decision-making which recognizes and incorporates diverse ecological, economic and social processes; a multitude of variables; and conflicting objectives and constraints (VARMA et al. 2000). A review by FAO of the several initiatives of C&I for the assessment of SFM developed so far (LANLY 1995) shows a consensus on the use of six criteria (forest quality indicators in parenthesis): (1) extent of forest resources (area and fragmentation), (2) conservation of biological diversity (composition), (3) forest health and vitality (tree health), (4) productive functions of the forest (pattern and process), (5) protective functions of the forest (function), and (6) forest-related economic and social needs (management and ecosystem services). It seems to be an agreement of which components to assess for SFM, though, methodologies and the specific considered verifiers will vary from case to case.

Different levels of forest quality were found in the area, which represent degrees of their present integrity, naturalness or conservation. In general, it was found that the *Quercus* spp. forests presented the highest forest quality indicator values at the community level. This shows that even that this community is the closest to the urban area, its forest quality is considerably good. At the association level, the *Abies religiosa-Roldana angulifolia* had the highest forest quality score, with high values for the ecosystem services and tree health indicator. The conservation of this plant association should be a priority. Due to the lowest values in the indicators of forest composition, forest pattern, forest function, tree health and ecosystem services, the *Calamagrostis tolucensis-Pinus hartwegii* association had the least forest quality. Sometimes these are all natural characteristics of this association (ALMEIDA-LEÑERO 1997), because it distributes in high altitudes, up to the timber line, where the weather conditions are less favorable. But, there are also the cases where this association present low values of forest quality indicators due to human influence, and there ecological restoration efforts should be directed. It was also found that the associations of disturbed *A. religiosa* forest and the Plantations-*Pinus* spp. forests got low values for most of the forest quality indicators. These associations are also a priority for ecological restoration, and the use of the information from this assessment should guide forest management more precisely.

The assessment of forest quality resulted from an integration of several indicators that allow a more precise way of planning and decision making, using the information integrated or separated by indicators or verifiers according to different specific objectives for sustainable forest management. The analysis suggested that there are different spatial patterns in the indicators of forest quality. Geographic information systems (GIS) and modeling are becoming powerful tools in natural resource management (HARTKAMP et al. 1999). Spatially distributed estimates of environmental variables are increasingly required for use in GIS and models (COLLINS & BOLSTAD 1996). Spatial interpolation is used to estimate the value of properties at not sampled sites within an area covered by sampled points, using the data from those points (BOUMAN et al. 1996). For the generation of the maps, a deterministic interpolation technique, called inverse distance weighting was used. It made possible the spatial visualization of the different forest quality indicators, separately and integrated. It is expected to be a useful geovisualization tool for decision making and better understanding of the spatial patterns. Improvements could be made testing other interpolation algorithms.

The method and database developed here allows further processing, being a flexible tool able to include some or all the variables in the principle of forest quality but also different specialists or stakeholders' opinions for the criteria and indicators ponderation. It can now be applied elsewhere and used as a management planning technique towards conservation and restoration of ecosystem services.

In practice, the results show the complexity of the analysis of the information gathered on field because of the differences between the variables used. They also show the difficulty of putting into practice the assessment of all the proposed theoretical concepts and the necessity to standardize the values from all the indicators and verifiers. The methodology developed here could still be modified, but the general idea of assessing at least an aspect of all the indicators in the forest quality principle together with the participation of specialists and stakeholders, and giving a spatial dimension should be maintained.

More information is needed on the biotic relations between different species that can complement the necessary information in the forest authenticity indicators. In further assessments of the quality of the forests in a certain area, it would be useful to make a pre selection of the criteria and indicators to be used. This could be done with literature review if there are previous studies in the area and also interviewing specialists about the best recommended variables to use. This would save time and make the assessment more cost effective.

Forest sustainability assessments should follow an holistic and systematic approach (MENDOZA & PRABHU 2003), where as many as possible elements are considered in a structured systems-oriented framework. CLARK et al. (1997) defined indicators that allow the establishment of restoration objectives and their further monitoring to assess the achieved results. These indicators are functional equivalence (habitats and organisms, the most complex to assess); structural equivalence (it supposes an equivalence in density, representation of the different trophic groups, an "adequate" proportion between native and exotic species, and an appropriate distribution and connectivity of the habitat elements); and elements equivalence (reflected in biodiversity indexes or the similarity in species composition between the target and the restored system). As defined by LINDENMAYER et al. (434: 2006), ecologically sustainable forestry is "perpetuating ecosystem integrity while contributing to provide wood and non-wood values" and "ecosystem integrity means the maintenance of forest structure, species composition, and the rate of ecological processes and functions within the bound of normal disturbance regimes". Forest quality contains these and other indicators that will allow the definition of ecological restoration and conservation priorities, as well as the monitoring and comparison of the management activities to assess the results achieved.

Forest quality indicators work as a guide that allows considering multiple elements, fundamental for integral assessments at the landscape scale. Landscapes are bigger than single sites and therefore almost always encompass a range of different management approaches (DUDLEY et al. 2005). The presented C&I system for SFM at the landscape level allows international sustainability evaluations in temperate forests and other kinds of forests using general SFM standards in the form of the generic C&I set while still considering specific local forest conditions and management concerns in the form of indicators, verifiers and norms. This concept is relatively new and had never been used in Mexico before. It is suggested to keep developing it in other parts of the World.

Scale has a fundamental role in ecology and conservation (NOSS 1992). When working at the landscape scale, it can provide a broad enough area to plan different restoration and conservation activities that can meet the needs from different stakeholders. Aims of forest landscape restoration have therefore always transcended conservation to embrace development as well (DUDLEY et al. 2005).

According to WWF and IUCN (2000), landscape restoration is "the planned process aimed to regain ecological integrity and enhance human well being in deforested or degraded landscapes". When using forest quality as the guide for the assessment towards ecological restoration at the landscape level, ecological integrity would be addressed by forest authenticity, and human well being by the environmental benefits and other social and economic benefits criteria.

The use of forest quality C&I is expected to vary in different landscape assessments, depending on the objectives, information, time and funds available. But it is important to remark, that an effort should be made to try to make forest quality assessments as sound and detailed as possible, considering at least some of the verifiers within all the C&I, weighted by experts or stakeholders. The framework for forest management towards ecological restoration and conservation of ecosystem services is set, and it would be intended to monitor positive or negative achievements in the near future.

7. Management proposal towards conservation and ecological restoration of ecosystem services in the southwest of Mexico City

7.1 Introduction

The concept of protected areas in Mexico has been known since prehispanic times. The ancient Mayan cultures used to include strictly protected zones and time periods in the exploited areas (SZÉKELY 1994). In the fifteenth century, Netzahualcóyotl, an Aztec ruler before Spain conquered Mexico, reforested large areas in the basin of Mexico City and during the following century, the emperor Moctezuma II founded several zoological parks and botanical gardens (CONABIO 2009).

The first Natural Protected Area founded in Mexico is the "Desierto de Los Leones", bordering the area under study, which was pronounced in 1876 for the importance of its springs. It gained the status of National Park in 1917, when its natural beauty and recreational potential was recognized (CONANP 2009).

Currently, the most important tool in nature and landscape protection in Mexico is the General Law of Ecological Equilibrium and Environment Protection (Ley General del Equilibrio Ecológico y la Protección al Ambiente - LGEEPA), which institutes the National Council of Nature Protected Areas (CONANP) as an advisory board to SEMARNAT (Ministry of Environment and Nature Resources) and enforces the process of decentralization and administration of protected areas management.

Protected areas represent in Mexico one of the most important conservation instruments of environmental policy from a juridical point of view. They are land or aquatic areas of the national territory representing the various ecosystems, in which the original environment has not been altered and which generate increasingly recognized and enhanced ecological benefits (CONANP 2009). They are established through a presidential decree and the activities that can be carried out within their territory are settled by their specific Management Plans. They are subject to special protection, conservation, recovery, and development regimes, according to the categories established by LGEEPA.

Protected areas need to be managed effectively and efficiently to achieve the objectives by which they were created, and it is essentially a social process. It takes place within communities formed by their histories, cultures, institutions, economic circumstances and politics. The meanings, purposes and management of protected areas are not static, but develop in conjunction with wider social, historical, economic and cultural influences (LOCKWOOD & KOTHARI 2006).

Due to the ecosystem services that the area provides to the inhabitants of Mexico City, in the recent years there have been some efforts to promote its conservation. Though, these efforts are still not enough for the proper conservation and ecological restoration of the area. The lack of operability as a protected area, together with an obsolete categorization, a lack of an specific zonification and the non inclusion of the local stakeholders in decision making, has caused several damages to the forests and the dynamic of the present rivers, so that the area is more propense for human settlements than for conservation (RAMOS RAMOS-ELORDUY 2008). Due to the importance of the area as a biodiversity refugee and ecosystem services provider, it is fundamental to reestablish its conservation status following an integrative management scheme, letting all the local stakeholders take part on the decision making and management.

Many of the research questions ecologists try to find an answer for are related to the conservation of nature. According to USHER (1986), the assessments for the decision making on nature conservation follow three steps. First, the attributes on the importance for conserving an area are identified. Second, the criteria to reflect the value of the attributes are developed; for example a species list could be used to find out the useful and/or endangered species. Finally, values are given to the different levels and particular state of criteria. The latter step is not scientific, and this given value must reflect the social given values to the area of study. In this study, the three steps were followed, the value for every forest quality indicator was given by specialists, and the stakeholders' perceptions about the environmental problematic were also gathered from interviews.

This chapter summarizes the results obtained in the previous chapters and gives general guidelines for management towards the ecological restoration of the main ecosystem services in the forests of the southwest of Mexico City.

7.2 Methods

7.2.1 Stakeholders survey on environmental problematic of the study area

A questionnaire was applied in presential interviews to 57 stakeholders from different groups (land owners, authorities, academics, visitors, etc; App. 3). Most of the interviews were sound recorded in order to complement the answers filled in the questionnaire and to remember important details on the perceptions and ideas expressed by the different stakeholders.

Before asking the questions a general explanation and the purpose of the project being carried out was explained. Personal names were asked but it was assured that the obtained results would be anonymous. The questionnaire consisted of six major sections. The first was for the identification of the interviewed (age, gender, scholarity, if member of a land owner community or ejido, etc.). The second section consisted to ask if people recognized the area as protected and if they knew its limits and total extension. It was then asked if several of the most common activities done in the area were allowed or not. Section three covered the relative importance of the different goods and services provided by the forests in the area and has been already addressed in Chapter 5. In section four people were asked about the environmental problematic of the area. They were asked: if they recognized differences in the landscape from before and now, what they could find before and does not exist anymore or is difficult to find, the period in years they have noticed differences, if they considered that the area was well protected and why, and the relative influence on the environmental problematic of the 12 factors considered more common (1=high importance, 2=medium importance, 3=low importance, 4=none importance). Blank spaces were left to let people tell, if considered, of other factors having and influence on the environmental problematic of the area. The last part of section four consisted of two open questions were it was asked what people thought about doing conservation, why to do conservation, who has to conserve and how could we achieve conservation?

Section number five covered the aspects related to environmental education. People were asked to tell what they felt when being in natural environments such as the forests in the area, if they considered that people in general had the knowledge of its importance, and what could be done to inform the people that visits and is related to the area. Last, it was asked if there was something in particular they would like to know about the forests in the area.

The interview finished thanking the time and perceptions given and asking if they had any comments or suggestions about all what is being done in the project.

7.2.2 Management proposal

For the proposal towards ecological restoration and conservation of ecosystem services, the official Management Program of Desierto de los Leones protected area (DOF 2006) was taken as a guide. The general guidelines for the management of the area here presented, represent an integration of the work that the author and the group from the "Laboratorio de Ecosistemas de Montaña" of the Sciences Faculty in the National Autonomous University of Mexico have carried out in the last eight years. This part is not intended to be strictly scientific, but it is based on all the scientific research and analysis done so far.

The maps of roads and spot places, and zonification were generated through the use of aerial photogrammetry and existing spatial information. A GIS was constructed on ILWIS 3.3 (ITC 2005) and ArcView 3.2 (ESRI 1998) platforms.

7.3 Results

7.3.1 Stakeholders' perceptions

Of the 57 interviewed people, being 41 male and 14 female with an average age of 44.6±13.4, 47% were members of a community or ejido from the area, 24% formed part of the academy group (researchers with experience in the area), 12% were persons from the authority group (working in the government at different levels: local, State and national), and the rest of the people were visitors, one member of an NGO, residents, a seller and a farmer. Their scholarity was represented by 47% with a university degree, 25% with primary school, 16% with secondary school, 7% with high school and 5% had never been to school.

Most of the interviewed people were familiar with the area being protected (45 knew, 12 did not know), but only 5 persons knew with precision its limits, conservation status and total extension. Even though the area is clearly perceived as protected, it was not clear at all which activities were allowed or not (Tab. 20).

The only clear allowed activity for the stakeholders was walking and exercise. Other activities where most of the people agreed to be allowed were horse riding, camping and mountain biking. The activities that are most confusing for their allowances were cattle management, plant and fruits recollection, paintball war and fishing. These activities happen within the area, but it was not clear for the interviewees. Most of the answers from the interviewed stakeholders included comments in the sense of: "it is (not) allowed, but…". The lack of clarity on the norms operating the area and a solid authority put together these ambiguities.

Tab. 20 Synthesis of the answers obtained from the stakeholders about the allowed activities in the Magdalena river watershed and the conservation area of Magdalena Contreras Municipality

Activity	**Yes**	**No**	**But…**	**Activity**	**Yes**	**No**	**But….**
Tree felling	3	54	No, only for cleaning ups when plagues No, but it happens	Animal recollection	6	51	Yes, with a permit No, but it happens
Bonfires	33	24	Yes, but only in specific places Yes, but with control	Walking and exercise	57	0	
Mushroom gathering	47	10	Yes, only local people Yes, without roots No, but it happens	Cattle management	32	25	Yes, but in certain areas No, but it happens
Horse riding	55	2	No, but it happens	Camping	55	2	No, its not safe
Motocross	15	42	No, but it happens Yes, in restricted degraded areas	Fuel wood recollection	46	11	No, only land owners Yes, only dead and dry wood
Plant and fruits recollection	33	24	No, but there's no control Yes, some, with a permit	Gotcha (paint ball war)	28	29	Yes, but it shouldn't be allowed No, there isn't
Mountain biking	52	5	Yes, on special trails	Fishing	26	31	Yes, in trout farms No, but it happens and its not controlled
Other, which?				Other, which?			
Controlled burns	X			Construction		X	
Pilgrimages	X			Spiritual cleanings		X	
Football	X			Pet abandonment		X	
Climbing	X			Littering		X	
Rappel	X			Car washing		X	
Research	X						

About the landscape differences between when people first experienced the area and now (in average 10 years of knowing the area; minimum 3 years; maximum 60 years), the majority said that there had been changes. They could perceive a diminish in the density of the forests, a clear increase in the number of irregular human settlements, less water in the river, weaker trees due to air pollution, decrease in water availability and plagues. On the contrary, some people answered that they had not noticed changes, and a few said that there had been some positive changes like a higher number of trees, and an increase on the provided services.

In general, interviewees agreed that before it was easier or more common to find or see the fauna of the area (reindeer, lynx, rabbits, eagles, coyotes, etc.), and also medicinal plants and edible mushrooms. People perceived a decrease in the abundance of natural resources, they agreed that the area is not well protected (45 said no; 12 said yes), because there is a lack of surveillance, there has been an indiscriminate use of resources, and there is a lack of clarity on the protection status and the prevailing norms, among other arguments.

From the main disturbance factors on the environmental problematic of the area (Tab. 21; Fig. 23), the interviewed stakeholders recognized irregular human settlements as the most important, followed by the groups on interest within ejidos and communities, littering and land tenure problems. Factors like visitors, lumberjacks, tree plagues, authorities, air pollution and cattle management were acknowledged to have a medium impact. Soccer fields and gotcha are considered to have a low importance on the environmental problematic of the area. Other mentioned factors, believed to have a high impact on the forest landscape, were forest fires and sewage discharge to the Magdalena river.

Tab. 21 Main disturbance factors and their relative importance on the environmental problematic of the area. Averages ± SE are shown. 1 represents a very high impact and 4 no impact.

Factor	**Impact**	**Factor**	**Impact**
Air pollution	1.62±0.84	Motocross	2.16±0.93
Garbage	1.46±0.68	Gotcha (paint ball war)	2.69±0.85
Tree plagues	1.71±0.73	Cattle management	1.86±0.80
Visitors	1.75±0.68	Hunting	2.39±0.82
Lumberjacks, loggers	1.79±0.90	Soccer fields	3.02±0.90
Authorities	1.92±0.85	Irregular human settlements	1.33±0.60
Groups of interest within “ejidos” and “comunidades”	1.41±0.65	Other: sewage discharge to the river (n=3) 1	
Land tenure problems	1.57±0.76	Other: Forest fires (n=3) 1	

When people were asked why to do or promote conservation, most answered with arguments related to the ecosystem services the area provides. Some of the most common answers were: we must conserve because “the area is the lung of Mexico City”, “it is a water source, provides many fundamental ecosystem services”, “of the intrinsic value of nature”, “to provide a better future for the next generations”, “for the socio-economic benefits to local communities”.

For the question on who should conserve the forests of the area, most of the interviewed stakeholders recognized differentiated responsibilities, starting with the land-owners, followed by the authorities at different levels (municipal, State, national), and people in general.

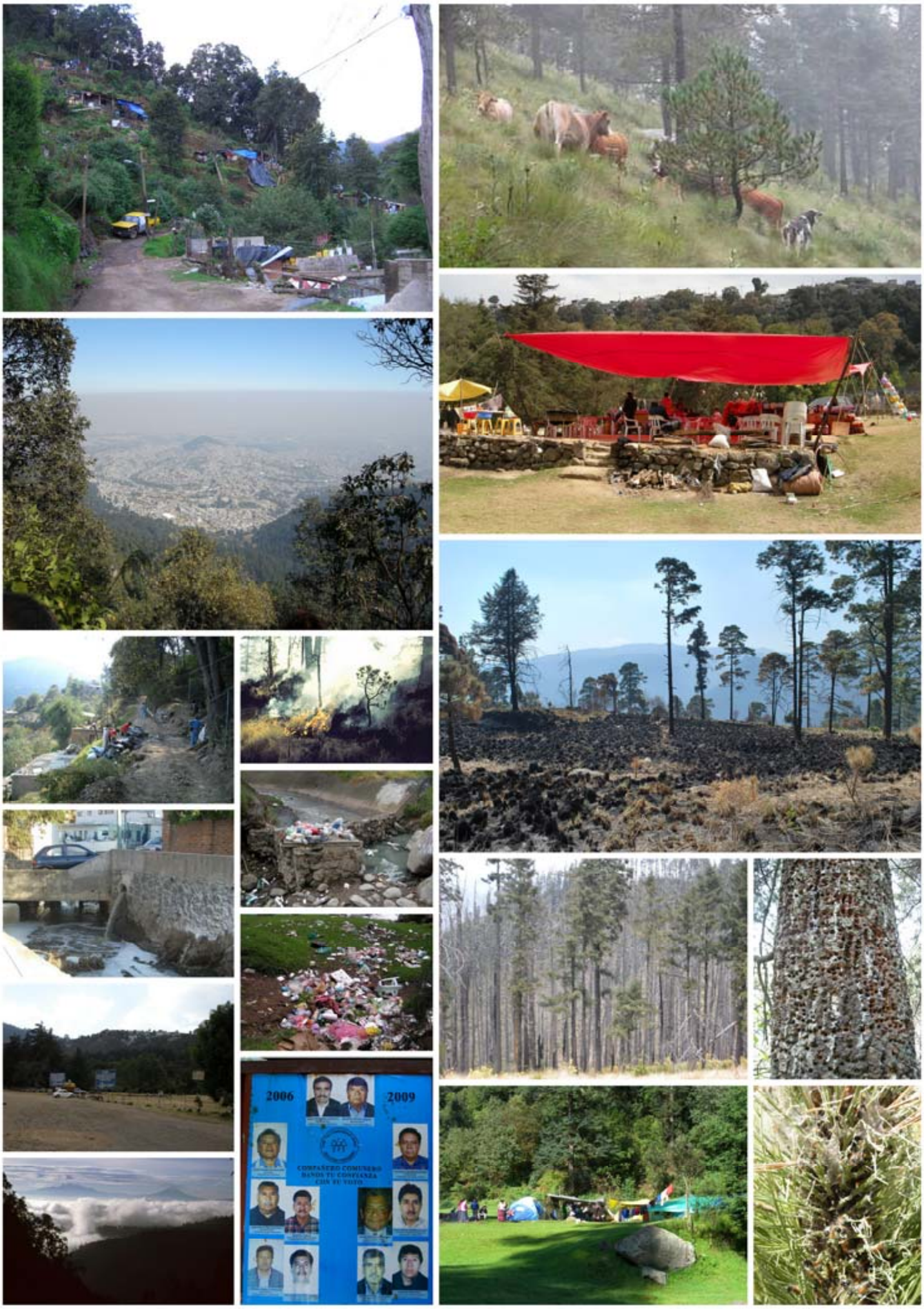

Fig. 23 Photos of main disturbance factors identified by stakeholders in the forests of the southwest of Mexico City.

And on "how can we achieve conservation?", most of the interviewees coincided on the need to inform and promote consciousness to the people involved in the area, to provide more security and surveillance, to rigorously enforce the available norms, to plan and establish a more proper forest management, etc.

For the environmental education section, the interviewees agreed on having a feeling of satisfaction when being in the forests of the area, they feel relaxed, without noise and pollution like in the urban zone. Only 15 of the interviewed stakeholders said that people knew about the importance of the forests in the area. There is a differentiated knowledge about this, being the local people, compared to the people living in the City, more aware. The 42 stakeholders that answered no to this question, said that people did not know about the importance of the area because there is a lack of environmental education and information, and because visitors are more aware of their particular needs rather than the ones from the society. They know that it is important to conserve the forests, but they do not assume their responsibility. On the ways for trying to inform the people about the importance of the forests of the area, stakeholders suggested that a combination of the use of different education and communication tools (workshops, books, pamphlets, signs, guided tours, conferences, courses, etc.), would be part of the solution for this problem. It was also suggested to build an environmental education center and to train field guides. In the last part of the questionnaire, 13 stakeholders answered that they would like to know about the flora and fauna present in the area (being specially useful to know the animals that are dangerous and the useful plant species), 10 said that they would be interested to know the quality and quantity of the water that is produced, and 9 said they would like to know more on how to take care of the forests. Other topics said to be of interest were: myths and legends of the forests, legal and land possession issues, soil carbon, etc.

7.4 Management proposal towards ecological restoration and conservation of the main ecosystem services

From the information developed and presented in previous chapters and the stakeholders' interviews, general guidelines for management towards conservation and ecological restoration of ecosystem services are presented. They are divided in three parts. The first is related to the legal issues of the area, to the importance of clarifying the protection status and the allowed activities with the respective surveillance. A second part consists on the environmental education, a fundamental issue. The last part is concerned with more technical aspects of management, how to polygonize the area for different uses and activities as well as specific issues on the sustainable forest management of the area. This proposal looks forward to be used as a divulgation tool for the importance and special characteristics of these forests and their ecosystem services. It is indispensable to make the information accessible for the stakeholders that have a direct or indirect influence to the area under study: land-owners, decision makers, visitors, residents, academics. Translated copies of this dissertation will be provided to authorities, land-owners and academics, and the rest of the people should be informed through the use of signs, pamphlets, and diverse divulgation material. A botanical guide with the most common useful plants is ready to be printed and a biological guide should be published in the near future.

7.4.1 Clarification of the status of the area as protected

As a first step, it is fundamental to redefine or clarify the status and the extent of the area as protected. As it was shown in Chapter 3 (3.3.4), there are different agreements and decrees for the type and extension of the Magdalena river watershed as a protected area. It is very important to make clear which of the different conservation categories is actual and to promote the development of the management plan, which is mandatory for every protected area in Mexico. This will serve as a legal support with which it would be clear which activities are allowed and the specific areas for them. It would also clarify the administrative responsibilities for the different governmental institutions related to the protection and management of the area. One of the interviewees said that there are around 135 institutions involved with the management of the area. This leads to an overlap and confusion of responsibilities.

There is already a fair amount of information for the development of the management plan (eg. NIETO DE PASCUAL 1995; FERNÁNDEZ 1997; ÁLVAREZ-ROMÁN 2000; ÁVILA-AKERBERG 2002; BOJORGE-GARCÍA 2002; FERNÁNDEZ et al. 2002; JUJNOVSKY-ORLANDINI 2003; NAVA-LÓPEZ 2003; ÁVILA-AKERBERG 2004; ESPINOSA-PÉREZ 2005; FLORES-RODRÍGUEZ 2006; JUJNOVSKY-ORLANDINI 2006; NAVA-LÓPEZ 2006; ALMEIDA-LEÑERO et al. 2007; ÁVILA-AKERBERG et al. 2008; RAMOS RAMOS-ELORDUY 2008; CANTORAL-URIZA et al. 2009), and it should all be considered.

The clear definition of the conservation status would also function as a legal instrument to stop the expansion of human irregular settlements, putting special attention to municipal elections, when it has been proved an increase of these settlements due to political clientelism (FERNÁNDEZ et al. 2002). It is a delicate and complicated task to relocate the established human settlements within the conservation area, but it is important to provide them with the basic services so that their negative influence towards the forests of the area diminishes. It must be clear that the sustainability of the area would be enormously threatened if new human irregular settlements within the area continue to appear.

Particular interests, together with the problems associated to legal issues on land possession, and the impact from certain visitor activities, represent a hindrance for the sustainable forest management. It is very important to solve the existing land tenure lawsuits to allow and assume management duties.

Some individual key points and perceptions from the interviews:

– "There is a lack of an effective policy to control the establishment of illegal human settlements."
– "The communities didn't agree with the establishment of the Conservation Area in Mexico City. People were offended, because they wanted to put fences to delimit the conservation area. The government didn't respect the agreed limits. Now there are a bunch of irregular settlements in this area, promoted by different governmental institutions."
– "The lack of a legitimate consolidation, specially in the Community of Magdalena Atlitic, is one of the main problems for the conservation of the area."
– "Because there are different interests inside the community, they are somehow antagonistic thus lowering the influence of groups inside the community against the forest. Disorganization is a defense!."
– "Problems in the land tenure: indefinition generates omission."
– "There is a lack of coordination between institutions. Sometimes there are replicated programs."
– "If we know what we are doing is wrong and threatens sustainability, why do we continue doing things wrong?."
– "Personal interests predominate, and they take advantage of the normativity limitations and their weak enforcement by the responsible authority. People have become very skilled to avoid laws and rules for their benefit, due to the fact that there is normally no punishment."
– "We are obedient, but without authority it is not possible to follow the rules."

7.4.2 Environmental education

One of the most important elements within conservation and ecological restoration is the communication of results. This allows making consciousness on the people and represents a crucial management tool. The process of environmental education seeks to recognize values and clarify concepts, with the aim of promoting qualities and attitudes of participation necessary to understand and appreciate the interrelations between man, culture and the biophysical environment. It increases public awareness and knowledge about environmental issues or problems and provides the capability and skills over time to analyze environmental issues, engage in problem solving, and take action to sustain and improve the environment. As a result, individuals are more capable of weighing various sides of an environmental issue to make informed and responsible decisions (EPA 2009). The process implies to achieve the voluntary participation of local people in the conservation and protection of the natural resources of the area, through the appropriation of knowledge about the forests, their elements and the biological processes.

UN General Assembly proclaimed the UN Decade of Education for Sustainable Development (DESD), 2005- 2014, emphasizing that education is a fundamental element for achieving sustainable development. It would be benefic to follow the proposed pillars of this program, being society, environment and economy**,** with culture as an essential additional dimension. Education should be embraced in a holistic and integrated manner, enabling all individuals to fully develop the knowledge, perspectives, values and skills necessary to take part in decisions to improve the quality of life both locally and globally (UNESCO 2009).

To communicate the developed and available information of the area, it is expected to generate a biological guide, with information about the area's history, biodiversity, provision of ecosystem services, and important information for visitors (what to do in case of, suggested trekking routes and elements to observe, general behavioral norms).

This would also be complemented with geovisualization tools to make information signs with maps in the places with most human affluence (see Fig. 25). These signs would have an aerial photo or drawing of the area, preferentially in 3D, showing the names and localization of important spots and places (hills, camping sites, security places), and the main dirt roads (Fig. 24). The general delineation of the different vegetation types should also be included, emphasizing common names without forgetting the scientific ones.

One of the perceived problems for the visitors of the area is the lack of security. There have been several cases of people that have been robbed. Some places, with dense forests and far from where most of the people are, represent optimal hiding places for smugglers. It is crucial to increment the security personnel of the area in order to assist people in case of an accident/incident and to discourage robberies.

Tourism, public use and recreation

The enormous growth of Mexico City has been promoted by wrong urban development policies, where the urban area extension has stolen place to the forested areas. The diminution of green areas has increased people's interest to maintain what is left. The forests in the southwest of Mexico City have been traditionally a spot for recreation.

Nowadays, the biggest concentration of visitors or tourists happen in the "Convento of Parque Nacional Desierto de los Leones", the "Cañada" and four "Dinamos" in the Magdalena river watershed, "Las Llantas" and "Rancho Viejo" in the Ecological Community Reserve of the "Ejido de San Nicolás Totolapan", and in "El Valle del Tezontle" (Fig. 25). In this sense, it is suggested that tourism keeps concentrated in these areas, where the negative impacts can be minimized having a good control of the different activities. Personnel from the "Secretaría de Medio Ambiente" (Ministry of Environment) of Mexico City, from the Magdalena Contreras Municipality, and from the surveillance commissions of the communities and ejidos, are responsible for this.

It is important to give maintenance to the different trekking paths, dirt roads, and visiting spot places, and to develop a common (same for the whole area) orientation program with clear and long lasting signs. An example map with the roads, and main spot places is shown in Fig. 25.

Some individual key points and perceptions from the interviews:

– "It is necessary to incorporate in the curricula of the basic education some of the most important topics about the ecological, social, and cultural importance of the area".
– "The people know that it is important to conserve the forests, but they do not assume their responsibility. The people do not modify their habits. 63% of the population in the Federal District thinks that the conservation area are the parks and sidewalks of the city."
– "The community has the intuition of the importance of conserving the forests in the area, but not the knowledge."
– "It is fundamental that the information becomes available to the land owners and people in general."
– "It is planned to buy and restore the "ex Hacienda de la Cañada" as a visitor and environmental education center."
– "Visitors don't respect the nature, they all want to take home something from the forest."

Fig. 24 Example of actual signs and the proposed idea for more useful ones. Geovisualization techniques should be applied to orient visitors and give them alternatives for different recreational activities.

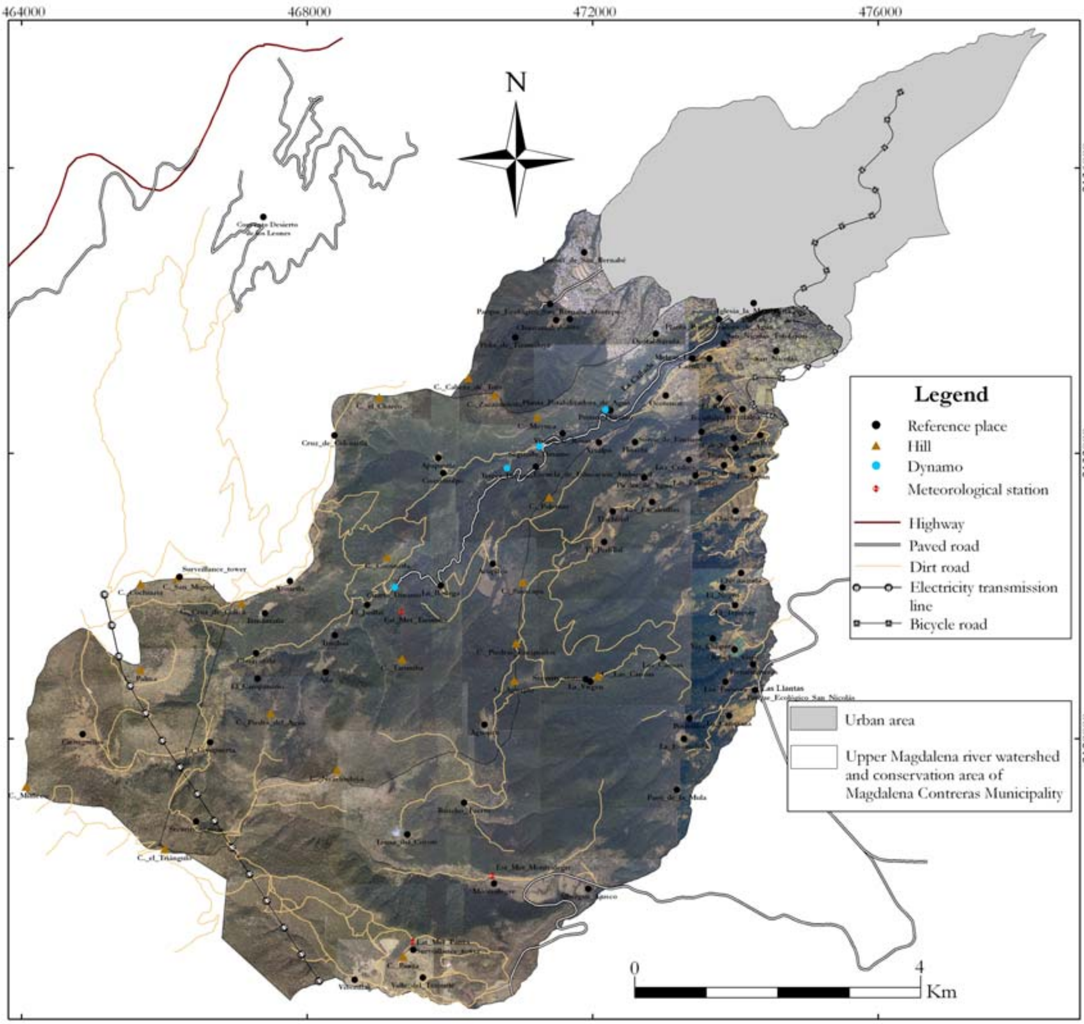

Fig. 25 Map of the roads and main reference places in the upper Magdalena river watershed and the conservation area of Magdalena Contreras Municipality.

7.4.3 Management actions according to forest quality levels

Ecological restoration should be a priority in the areas with less forest quality. These areas present different disturbance levels on which and, according to specific objectives, restoration efforts should be directed to promote and maintain biodiversity, water infiltration and supply, carbon sequestration and oxygen generation, and recreational activities.

Land owners are already getting paid for the provision of ecosystem services, by means of two governmental programs: one at the State level and the other at the national level. This seems to be a positive conservation instrument, though it needs to be better clarified and applied, but the given funds are not always properly distributed and used.

It is important to make clear the distinction between reforestation and ecological restoration for managers. It is time to do management beyond planting trees, avoiding the use of exotic species, to promote forests with higher quality. When doing ecological restoration, it is expected to use only native tree species, but also considering other important elements, like non tree species and soil.

There are zones with high biological diversity which must be protected. These are defined by higher quality values and should be decreed as core areas to restrict the activities that might create disturbance. The allowed activities for the areas with the highest forest quality levels would be related to preservation, ecological restoration and environmental education. These areas will serve as reference for management planning in lower forest quality or buffer areas.

It has been suggested that management techniques like proscribed burnings and shrub thinning, leads to maximum biodiversity levels in natural systems and the sustainable use of public areas (BAKER 1992; JOHNSON 1993).

In the fir (*Abies religiosa*) forests, there are high shrub covers, from a few species mainly. This limits natural regeneration and lowers plant species richness and evenness. In order to promote forest regeneration, it is suggested to cautiously reduce the high covers of shrubs, letting roots in the soil and using the plant material as erosion fencing control.

Proscribed burnings are useful in the highest parts, where *Pinus hartwegii* forests distribute. This promotes natural tree regeneration and the renewal of grasses, and reduces the excess of fuel materials. Special care has to be taken, considering slopes, wind currents, and the reaction capacity in case of an accident. A proscribed fire in 1998, burned more than half of the forests in the "Desierto de los Leones National Park" (MORA 2002, pers. comm.).

The oak forests (*Quercus rugosa* and *Q. laurina*) face the highest land use change pressure. They distribute on the limits with the urban area, having a direct influence from human activities. Fences or walls have not stopped irregular settlements influence. Environmental education campaigns and the provision of basic services (e.g. proper sewage and garbage management) is fundamental. Special attention should be put in these ecosystems, and it must not be allowed anymore to reforest with other species (e.g. *Cupressus lusitanica*) than the natives.

Some individual key points and perceptions from the interviews:

- "In the transition zone between the urban and ecological areas, it would be a good idea to manage tabulated cattle, this could work as a barrier for the expansion of the urban area."
- "Of the forest fires in the area, 6-7% are natural, the rest are induced (fireworks, people wanting to expand the urban area, cowboys trying to promote the regeneration of grasses, etc.)."
- "The soils in the area are made of volcanic ashes, when cows step on them they loose porosity and are degraded. They are easily erodible."
- "The forests are more disturbed now than before and this is mainly due to the lack of forest management."
- "When they do forest health management, they cut dead trees, but when cutting, they also kill or fall down live ones".
- "*Cupressus lusitanica* is a threat for the fir and oak forests. The *Cupressus* forest has a lower species richness. Reforestations are mainly done by CORENA. *Pinus ayacahuite* is also a common non native tree species that has been widely used."

Zonification criteria

The zonification of a protected area consists on identifying and delimiting portions of the territory, considering the actual and potential land use types, according to the conservation objectives. This refers to differentiated terms of use for management and allowed activities. It defines the density, intensity, limitations, and norms of the different activities.

It is suggested to define three main areas: a buffer zone where most of the recreational activities would take place, and a core zone, strictly for forest restoration, conservation and low impact activities (Fig. 26). A third zone category will include the zones where management and surveillance are fundamental and a priority.

In general, in the whole area it should only be allowed the activities related to the protection of the natural resources, the increase of its native flora and fauna, and non disturbing human activities: scientific research, tourism, recreation and environmental education.

Buffer or public use zones

Represent those areas with natural attractions for recreation and education activities. Historically, the public use of the area has had regulations according to the conditions and functions as a protected area, but these have not been respected and many of the recreational activities take place in a disorganized manner, with the consequent impacts. It is fundamental to make the norms clear for the visitors and to respect them.

This area should correspond with the traditional places where recreational activities have been taking place, concentrating visitors in specific areas where proper surveillance and management must exist. In this zone the following activities are allowed: picnics, camping, football soccer, trekking, flora and fauna observation, to have parking places, access paths and dirt roads. Environmental education and recreation should be promoted.

Tab. 22 Zonification matrix proposal, with the allowed and forbidden activities in the buffer or public use zones.

Zone	Allowed activity	Not allowed activity	Comments
Public use (buffer zone)	Environmental education	Native flora and fauna extraction	
	Scientific research	Fauna disturbance and hunting	
	Touristic infrastructure	Forest exploitation. Only dead wood for local use	
	Provision of visitor support services	Human settlements	
	Prevention and control of forest fires	Land use changes	
	Ecological restoration (reforestation and more)	Soil and water pollution	
	Major camping areas	Litter disposal	Very important to handle garbage
	Low impact tourism		
	Horse riding		
	Agriculture and tree nurseries		
	Soccer fields		
	Surveillance		
	Trekking and hiking		
	Surveillance and security		
	Cycling		

Priority attention zones

Represent the areas with the lowest forest quality levels, and the mapped vegetation types (Chapter 4) identified as disturbed, the irregular human settlements and the agricultural lands. It is fundamental to direct restoration efforts towards these areas, to promote a faster recovery of the forest, planting trees, removing excessive shrubs, promoting natural regeneration and succession, and managing the soil to slower and stop erosion. This zone requires immediate intervention where the soils and natural vegetation have been seriously damaged. In the other critical areas within this zone, the irregular human settlements, law enforcement must be emphasized, not allowing their expansion, trying to relocate them, and in cases where this is not possible anymore, providing them with the basic services in order to reduce the negative effects they might have on the forests.

Tab. 23 Zonification matrix proposal, with the allowed and forbidden activities for the priority attention zones.

Zone	Allowed activity	Not allowed activity	Comments
Priority focus zones	Ecological restoration (reforestation and more)	Native flora and fauna extraction	
	Conservation	Fauna disturbance and hunting	
	Prevention and control of forest fires	Forest exploitation. Only dead wood for local use.	
	Service provision	Irregular human settlements	Basic services should be provided to regularized human settlements
	Trekking and hiking	Cattle management	In regular human settlements only tabulated cattle management
	Scientific research	Soil and water pollution	
	Surveillance and security	Land use changes	

Ecological restoration and conservation zones (core zone):

These areas represent the highest levels of forest quality or any of its indicators or verifiers, oriented to preserve the natural environmental setting and the strict resource preservation. They are zones of difficult access that have not had much human influence and it is intended to keep them so. The aims and objectives for this zone are related to the conservation and ecological restoration of the forests and the ecosystem services provided.

Tab. 24 Zonification matrix proposal, with the allowed and forbidden activities for the ecological restoration and conservation zone

Zone	Allowed activity	Not allowed activity	Comments
Ecological restoration and conservation (core zone)	Ecological restoration	Native flora and fauna extraction	
	Conservation	Fauna disturbance and hunting	
	Scientific research	Forest exploitation. Only dead wood for local use	Scientifically justified forest exploitation could be planned.
	Prevention and control of forest fires	Cattle management	
	Reforestation (only native species)	Fences obstructing fauna displacement	
	Ecological restoration	Soil and water pollution	
	Surveillance and security	Paved roads construction	
	Environmental education	Motocross	
	Proscribed burnings	Not authorized motor vehicles	Only authorized and professional personnel
	Low impact tourism	Bonfires	Only in specific places
	Trekking and hiking		
	Plague control		
	Road maintenance		
	Native fauna reintroduction		
	Primitive camping areas		

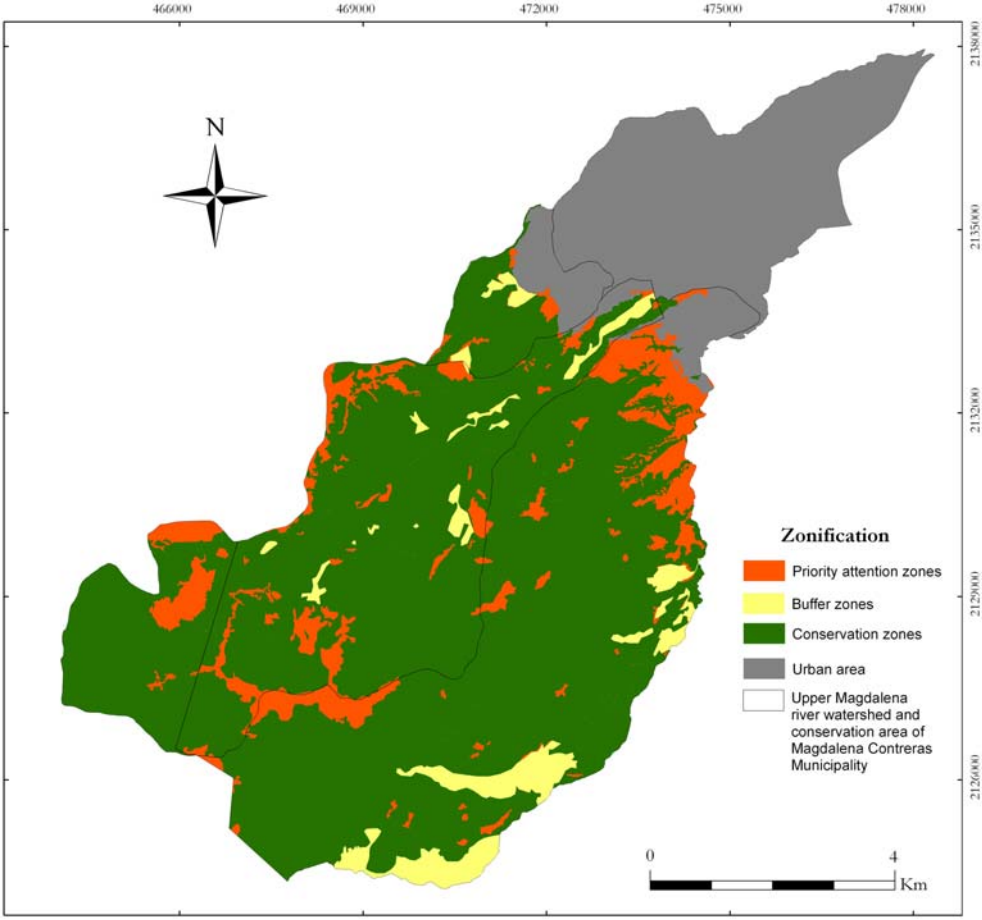

Fig. 26 Land zonification proposal for the upper Magdalena river watershed and the conservation area of Magdalena Contreras Municipality.

8. General summary

Most forests have already been modified by people: complete ecological integrity is already an historical concept in most parts of the world. The distinction between "natural" and "disturbed" forests is less important than the *degree* and *type* of disturbance.

Numerous attempts have been made to define criteria and indicators (C&I) for the assessment of sustainable forest management (SFM) at various levels (e.g. global, regional, national, forest management unit). In 1998, the WWF and the IUCN developed the forest quality C&I initiative for assessing SFM at the landscape level. The initiative relies on the forest quality principle and encompasses criteria from three categories: (1) forest authenticity, (2) environmental benefits, and (3) other social and economic benefits. These criteria, at the same time, contain indicators and verifiers of what can be evaluated in field to recognize the quality and present condition of a given forest ecosystem. It measures forest conditions at the landscape level, giving more space for considering the way in which people and forests interact in a region.

This project presents an evaluation of the forests in the southwest of Mexico City, one of the biggest and most populated metropolis of the world, following the concept of forest quality. The studied forests are located in the upper Magdalena river watershed, most of which lies within the conservation area of the Magdalena Contreras Municipality of the Federal District of Mexico, in the southern-central part of the country. In this largely forested area are located the headwaters of one of the last living rivers among many that in former times characterized much of the landscape where Mexico City grew. This is a high-elevation mountainous region (2470-3870 m asl) forming part of the extensive Transmexican Volcanic Belt that dissects the country in a E-W direction. The study area covers a surface of ca. 6,400 ha where the main temperate forest types of Mexico are present: pine (*Pinus hartwegii*), fir (*Abies religiosa*), mixed (*Pinus*, *Abies*, *Quercus*, and *Alnus*), cloud montane, and oak forests (*Quercus rugosa* and *Q. laurina*). They were given protection status primarily because they are a major source of drinking water, but also because of their crucial role in the maintenance of a sizable biodiversity, their ability to sequester carbon, and the provision of recreational opportunities for the inhabitants of Mexico City. The urban sprawl of the City poses a continuous threat to this area, but its protected status together with its complex topography, its high elevation, and the communal land tenure type have still succeeded in checking further encroachment of this enormous urban system. However, the area is not free from human influences, represented by isolated illegal settlements, presence of extensive cattle management, illegal logging, fires, air pollution and poorly organized local tourism.

For that purpose information on 116 field sample plots was gathered for the criteria, indicators and verifiers of forest quality during field work. Interviews (n=57) were hold with the main stakeholders (land owners, visitors, academics, authorities, etc.), in order to sense their perceptions about the relative importance of the ecosystem services and the environmental problematic of the area. To assess forest quality, field and laboratory verifiers of forest composition, pattern, function, process, tree health, area and fragmentation, and management, as well as ecosystem services indicators were integrated and weighted by a group of experts through a pairwise multicriteria analysis.

The dominant vegetation type of the area is the *Abies religiosa* forest (46%), followed by three classes of *Pinus hartwegii* forest (29%), the *Quercus* forest (8.3%), grassland (7.2%), mixed forest (1.3%), and the cloud montane forest (0.2%), among others. In an area equivalent to 0.0032% of the total extension of the country, it is possible to find all the temperate forests present in Mexico, with different levels of disturbance.

The stakeholders recognized the existence of ecosystem goods and services provided by the forests of the area and considered the ones related to soil erosion control, clean water and habitat for plants as the most important. The area is an important biodiversity refuge represented by 1175 species (including plants, mammals, birds, amphibians, reptiles, fungi, algae and butterflies), from which 209 are considered useful (*eg.* medicinal, edible, for construction, etc.) and 39 are listed in a category of risk. The forests of the area are storing in average 101 tC/ha, with the *Quercus* and mixed forests, followed by the *A. religiosa* forest having the highest carbon content values. The soil type and the forest stands promote the infiltration of rainwater recharging the aquifer of the basin of Mexico City (out of which ca. 70% of the City's water comes from), and 500 l/s of water from the Magdalena river are supplied directly to neighborhoods in the urban zone. Recreation is also one of the most important ecosystem services. Mexico City's inhabitants visit the area, mainly on the weekends, to fulfill the need for less crowded and green spaces where they can develop activities such as trekking, play football, bicycling, etc. The recreational activities occur mainly near the access roads. The understanding of the values and benefits provided by the forests should be of fundamental importance to their management. The information here presented will allow the implementation of a more precise and well oriented ecosystem services payment program, as an economic instrument for the conservation and ecological restoration of the forests in the area.

Overall, experts coincided in that forest composition and process verifiers are the most important indicators for forest quality assessment. Fir (*Abies religiosa*) forest has the highest values for the forest quality indicators, whereas the *Pinus hartwegii* forest, typical of very high elevations, had lower values in general. A forest quality map was produced through spatial interpolation and by integrating information for all indicators; this tool is expected to provide a solid yet flexible framework for decision making and monitoring of the sustainable forest management in the area.

Stakeholders recognized irregular human settlements as one of the most important disturbance factors on the environmental problematic of the area, followed by the groups of interest within landowners, littering and land tenure problems. Factors like visitors, lumberjacks, tree plagues, authorities, air pollution and cattle management were acknowledged to have a medium impact. People in general are aware of the importance of the forests in the area, though there is a lack of environmental education and information, and the management and conservation responsibilities are not clear.

General guidelines for a more sound management towards ecological restoration and conservation of the main ecosystem services are presented, together with a proposal for an environmental education program, and a zonification of the area.

9. Zusammenfassung

Die meisten Wälder sind bereits vom Menschen modifiziert worden: vollständige ökologische Integrität ist in den meisten Teilen der Welt allenfalls ein historisches Konzept. Die Unterscheidung zwischen "natürlichen" und "gestörten" Wäldern ist von weit geringerer Bedeutung als etwa der Grad respektive die Art der Störung.

Es hat entsprechend zahlreiche Versuche gegeben, Kriterien und Indikatoren (C + I) nachhaltigen Waldmanagements auf diversen Ebenen (globaler, regionaler, nationaler und Waldeinheit) zu erstellen. Im Jahr 1998 haben WWF und IUCN eine auf C + I basierende Initiative zur Evaluierung von Waldqualität auf Landschaftsniveau entwickelt, die der Beurteilung nachhaltigen Forstmanagements dient. Das vorgeschlagene Konzept bedient sich des Prinzips der Waldqualität und umfasst Kriterien aus drei Kategorien: *(1) forest authenticity, (2) environmental benefits* und *(3) social and economic benefits*. Diese Kriterien liefern Indikatoren und Prüfgrößen anhand derer die Qualität und der gegenwärtige Zustand eines gegebenen Wald-Ökosystems noch im Feld beurteilen werden kann. Sie messen den Zustand des Waldes auf Landschaftsniveau, wobei mehr Freiraum bleibt, um die Art und Weise zu beleuchten, in der Menschen und Wald miteinander interagieren.

Das vorliegende Projekt präsentiert eine solche dem Konzept der Waldqualität folgende Bewertung der Wälder im Südwesten von Mexiko-Stadt, einer der größten und bevölkerungsreichsten Metropolen der Welt. Die untersuchten Wälder sind im oberen Wassereinzugsgebiet des Flusses Magdalena situiert, das größtenteils vom Schutzgebiet der Magdalena Contreras Gemeinde im Bundesbezirk Mexiko umschlossen wird, welche sich in der südlichen Mitte des Landes befindet. Der Fluss, der zu den wenigen verbliebenen und für die Landschaft, in der sich Mexiko-Stadt herausbildete, so charakteristischen Strömen zählt, entspringt in diesem dicht bewaldeten Gebiet. Es handelt sich ferner um eine Hochgebirgsregion (2470-3870 m ü.M.), welche dem Transmexikanischen Vulkangürtel zugehört, der das Land in Ost-West Richtung zergliedert. Das untersuchte Gebiet umfasst ca. 6.400 ha, auf denen die Haupttypen des temperaten Waldes von Mexiko vorzufinden sind: Kiefern- (*Pinus hartwegii*), Tannen- (*Abies religiosa*), Mischwald (*Pinus*, *Abies*, *Quercus* und *Alnus*), Gebirgsnebel- und Eichenwald (*Quercus rugosa* and *Q. laurina*). Diesen ist der Schutzstatus vor allem deshalb verliehen worden, weil sie als Haupttrinkwasserquelle fungieren, aber ebenso aufgrund ihrer entscheidenden Rolle für den Erhalt erheblicher Biodiversität, ihrer Fähigkeiten Kohlenstoff zu speichern sowie ihres Angebotes diverser Erholungsmöglichkeiten für die Bewohner von Mexiko-Stadt. Die Zersiedelung des Umlandes der Stadt stellt eine kontinuierliche Bedrohung für dieses Gebiet dar. Bislang konnte der Schutzstatus in Kombination mit der komplexen Topographie, der beträchtlichen Höhe und dem kommunalen Landbesitztyp einem weiteren Vordringen dieses enormen urbanen Systems erfolgreich Einhalt gebieten. Dennoch ist das Gebiet nicht frei von menschlichen Einflüssen, wie etwa einzelnen illegalen Siedlungen, extensiver Rinderhaltung, illegalem Holzeinschlag, Feuer, Luftverschmutzung oder mangelhaft organisiertem Lokaltourismus.

Die Region wird flächenmäßig dominiert von *Abies religiosa* Wald (46%), gefolgt von, unter anderen, 3 Klassen von *Pinus hartwegii* Wald (29%), *Quercus* Wald (8.3%), Graslandschaft (7.2%) und Mischwald (1.3%), sowie menschlichen Siedlungen (0.8%) und Gebirgsnebelwald (0.2%). Damit lassen sich in einem Gebiet, das 0,0032% des gesamten Landes umfasst alle in Mexiko vorkommenden temperaten Wälder mit unterschiedlichem Beeinträchtigungsgrad vorfinden.

Entsprechend wurden im Zuge des Feldzuganges auf 116 Auswahlflächen die nötigen Informationen für eine auf C + I basierenden Bewertung der Waldqualität gesammelt. Ferner sind Interviews mit den Hauptinteressenvertretern (Landbesitzer, Besucher, Wissenschaftler, Behörden, etc.) durchgeführt sowie Fragebögen an diese verteilt worden (n=57), um einen Eindruck von deren Wahrnehmung der Bedeutung von ökosystemaren Leistungen sowie den Umweltproblematiken des Gebietes zu erhalten. Um die Waldqualität einzuschätzen wurden als Prüfgrößen in Feld und Labor Waldkomposition, -struktur, -funktion, -prozess, Baumgesundheit, Gebiet und Fragmentierung, sowie Management als auch Indikatoren Ökosystem Leistungen integriert und im Zuge einer paarweisen Multikriterienanalyse durch eine Gruppe von Experten gewichtet.

Interessenvertreter erkennen die Existenz von Ökosystem Gütern und Leistungen an, welche die Wälder des Gebietes bieten, wobei der Bodenerosionsschutz, sauberes Wasser oder aber das Habitat für Pflanzen als die wohl bedeutsamsten aufgefasst werden. Das Gebiet ist außerdem ein wichtiger Hort für Biodiversität, belegt durch die 1175 Arten, welche die Region beherbergt (einschließlich Pflanzen, Säugetieren, Vögeln, Amphibien, Reptilien, Pilzen, Algen oder Schmetterlingen). Von diesen werden wiederum 209 als von Nutzen (z.B. für medizinische Zwecke, Ernährung oder Bau) angesehen und 39 gelten außerdem als bedroht. Im Durchschnitt speichern die Wälder der Region 101tC/ha, wobei *Quercus* und Mischwälder gefolgt von *A. religiosa* Wald die höchsten Werte für den Kohlenstoffgehalt haben. Die Bodenart und der Waldbestand befördern die Infiltration und Aufstockung des Grundwasserreservoirs von Mexiko-Stadt mit Regenwasser. Aus diesem werden 70% der Stadt mit Wasser vesorgt. Weitere 500 l/s gehen direkt aus dem Magdalena Fluss an benachbarte städtische Gebiete. Außerdem stellt Erholung eine der wichtigsten ökosystemaren Leistungen dar. Die Einwohner von Mexiko-Stadt besuchen die Gegend, hauptsächlich an den Wochenenden, um ihren Wunsch nach weniger überfüllten sowie nach grünen Orten zu erfüllen. Zu den gängigen Erholungsaktivitäten,, denen vornehmlich nahe den Zugangsstrassen nachgegangen wird, gehören zum Beispiel Trekking, Fußball, Radfahren. Den Wert und die Vorzüge, welche der Wald darstellt und bietet, zu verstehen erscheint von fundamentaler Bedeutung für dessen Management zu sein. Entsprechend sollen die hier präsentierten Informationen die Implementierung eines daran entsprechend ausgerichteten und präziseren PES (*payment for ecosystem services*) Programms ermöglichen, welches als ökonomisches Instrument zum Schutz und zur ökologischen Sanierung des Waldes in dem Gebiet dienen kann.

Insgesamt stimmen Experten darin überein, dass die Prüfgrößen Waldkomposition und –prozess die wichtigsten Indikatoren zur Beurteilung der Waldqualität darstellen. Tannenwald (*Abies religiosa*) erhält bei den Indikatoren für Waldqualität dabei die höchsten Werte, während *Pinus hartwegii* Wald, der typisch für die oberen Höhenlagen ist, generell niedrigere Werte hat. Eine Waldqualitätskarte wurde mittels räumlicher Interpolation sowie durch die Integration der Informationen aller Indikatoren erstellt; von diesem Hilfsmittel wird erwartet, dass es einen soliden und dennoch flexiblen Rahmen für den Entscheidungsprozess und das Monitoring nachhaltigen Forstmanagements in dem Gebiet bieten kann.

Interessenvertreter haben außerdem die regelwidrigen Siedlungen als einen der für die Umweltprobleme bedeutsamsten Störfaktoren benannt, gefolgt von den Interessenkonflikten zwischen Landbesitzern, Müll sowie Problemen des Landbesitzes. Anderen Faktoren wie Besucher, Waldarbeiter, Baumkrankheiten, Behörden, Umweltverschmutzung oder die Rinderhaltung wurde ein nur mittelstarker Einfluss beigemessen. Die Menschen sind sich im Allgemeinen der Bedeutung der Wälder dieser Region gewahr; dennoch besteht ein Mangel an Umweltbildung und -information und auch die Zuständigkeiten für Management und Schutz sind unklar.

Es werden entsprechend allgemeine Richtlinien für ein vernünftigeres Managements zum Schutz und zur ökologischen Wiederherstellung der wichtigsten ökosystemaren Leistungen vorgestellt und ein Vorschlag für ein Umweltbildungsprogramm sowie für eine Zonierung des Gebietes unterbreitet.

10. Appendixes

*App. 1 Floristic list of the southwest of Mexico City. After the species name and its author — life form (tree, herb, shrub, low growing, climber, epiphyte); growth form sensu Raunkiaer (Ph:phanerophyte, He:hemicryptophyte, Ch:chamephyte, Cr:cryptophyte, Th:therophyte, Pa:parasite); in parenthesis the phytogeographical affinity of the genus (NT:neotropical, WTr:wide tropical, NA:nearctic, HA:holarctic, WTe:wide temperate, NT:neotropical, MX:Mexico, AA:austral antarctic); if it has a use: Med=medicinal, Or=ornamental, Edi=edible, Fod=fodder, Con=construction, Ind=industrial, Mag/Tox=magical/toxic, Woo=fuel wood, Ins=instrumental, Handi=Handicrafts; Col:collected as part of this research; said to be found in the area by: a=*REICHE *and* SÁNCHEZ *(1923; 1969), b=*MADRIGAL *(1967), c=*LUIS-MARTÍNEZ *(1985), d=*DE RZEDOWSKI & RZEDOWSKI *(2001), e=*NIETO DE PASCUAL *(1995) and f=*VELÁZQUEZ & ROMERO *(1999). End=species endemic to Mexico.*

Taxon	Col	a	b	c	d	e	f	End
NON VASCULAR PLANTS								
Bryophyta								
Brachytheciaceae								
Brachythecium corbierei Card. — low growing Cr (HA)	*		*					
Bryaceae								
Bryum procerum Schimp — low growing Cr (HA)	*		*				*	
Fissidentaceae								
Fissidens repandus Wils. — low growing Cr (WTe)	*		*					
Geocalycaceae								
Lophocolea bidentata (L.) Dum. — low growing Cr (HA)			*					
Grimmiaceae								
Grimmia tolucensis Card. — low growing Cr (CO)	*		*					
Pottiaceae								
Trichostomum cylindricum (Bruch.) C. M. — low growing Cr (HA)	*		*				*	
Thuidiaceae								
Thuidium delicatulum (Herdw) Mitt. — low growing Cr (NA)	*		*				*	
VASCULAR PLANTS								
Equisetophyta								
Equisetaceae								
Equisetum hyemale ssp. *affine* L. (Engelm.) Calder & Roy L.Taylor — herb Cr (CO) Med	*							
Lycopodiophyta								
Selaginella pallescens (C. Presl) Spring — fernlike Ch (CO) Med	*							
Pteridophyta								
Aspleniaceae								
Asplenium monanthes L. — herb He (HA)	*		*				*	
Dryopteridaceae								
Cystopteris fragilis (L.) Bernh. — herb He (CO)	*							
Dryopteris cinnamomea (Cav.) C. Chr. — herb He (CO)								
Dryopteris parallelogramma (Kunze) Alston — herb He (CO)	*							
Plecosorus speciossisimus (A. Braun ex Kunze) T. Moore — herb He (CO)	*							
Polystichum rachichlaena Fée — herb He (CO)	*							*
Hymenophyllaceae								
Hymenophyllum abruptum Hook. — herb Cr (NT)	*							
Polypodiaceae								
Polypodium plesiosorum Kunze — herb He (NA)	*							
Pteridaceae								
Adiantum ampillus-veneris L. — herb He (NT)	*		*					
Adiantum andicola Liebm. — herb He (NT)	*							
Adiantum marginatum Bory — herb He (NT)	*							
Cheilanthes farinosa (Forssk.) Kaulf. — herb He (NT)	*							

Cheilanthes hirsuta Link. — herb He (NT)	*						*	
Cheilanthes marginata Kunth. — herb He (NT)	*							
Cheilanthes sinuata (Lag. ex Sw.) Domin — herb He (NT)	*							
Pteridium aquilinum (L.) Kuhn — herb Cr (NT)	*							
Coniferophyta								
Cupressaceae								
Cupressus lusitanica Mill. — tree Ph (HA)	*		*	*	*	*	*	
Juniperus monticola var. *monticola* Martínez — tree Ph (HA)	*							
Juniperus monticola fo. *compacta* Martínez — shrub Ph (HA)	*							
Pinaceae								
Abies religiosa (Kunth) Schltdl. & Cham. — tree Ph (HA) Woo	*		*		*	*	*	
Pinus ayacahuite var. *veitchii* C. Ehrenb. ex Schltdl. (Roezl) Shaw — tree Ph (HA) Woo	*			*	*		*	
Pinus hartwegii Lindl. — tree Ph (HA) Woo	*	*			*		*	
Pinus leiophylla Schiede ex Schltdl. — tree Ph (HA) Woo	*	*			*		*	*
Pinus montezumae Lamb. — tree Ph (HA) Woo	*			*	*		*	
Pinus patula Schltdl. & Cham. — tree Ph (HA) Woo	*				*		*	
Pinus pseudostrobus Lindl. — tree Ph (HA) Woo	*			*	*		*	
Pinus rudis Endl. — tree Ph (HA) Woo	*	*			*		*	
Pinus teocote Schltdl. & Cham. — tree Ph (HA) Woo	*			*	*		*	
Magnoliophyta								
Aceraceae								
Acer negundo var. *mexicanum* L. (DC.) Standl. & Roy L.Taylor — tree Ph (NT) Or	*			*	*		*	
Amaranthaceae								
Iresine ajuscana Suessenguth & Beyerle — herb He (WTr)	*			*	*		*	*
Iresine diffusa Humb. & Bompl — herb Th (WTr)	*			*	*		*	
Iresine elongata Humb. & Bompl. ex Willd. — herb He (WTr)	*							
Apiaceae								
Angelica nelsonii J. C. Coult. & Rose — herb Cr (HA)					*		*	
Arracacia atropurpurea (Lehm.) Benth. & Hook ex Hemsl. — herb Cr (NT)	*			*	*		*	*
Arracacia rigida J. C. Coult. & Rose — herb Cr (NT)					*		*	
Daucus montanus Humb. & Bonpl. ex Spreng. — herb He (HA)	*				*			
Donnellsmithia juncea (Humb. & Bonpl.) Mathias & Constance — herb Ch (NT)	*				*			
Eryngium alternatum J. C. Coult. & Rose — herb He (HA)					*		*	
Eryngium carlinae F. Delaroche — herb He (HA) Med	*	*			*	*	*	
Eryngium proteaeflorum F. Delaroche — herb He (HA) Or, Med	*				*		*	
Eryngium serratum Cav. — herb He (HA)	*				*	*		
Eryngium subacaule Cav. — herb He (HA)	*				*		*	
Osmorhiza mexicana Griseb. — herb He (WTe)	*	*	*		*		*	
Rhodosciadium purpureum Mathias & Constance — herb He (NT)								
Tauschia alpina (J. C. Coult. & Rose) Mathias — herb He (NA)	*							
Aquifoliaceae								
Ilex tolucana Hemsl. — shrub Ph (WTe)	*							
Asclepiadaceae								
Asclepias notha W.D. Stevens — herb Ph (WTr) weed				*	*		*	
Asclepias otarioides F. Fourn. — herb Cr (WTr)					*			
Asclepias ovata M. Martens & Galeotti — herb Ph (WTr) Med	*			*	*		*	
Matelea chrysantha (Greenm.) Woodson — climber He (NT)		*			*		*	*
Matelea pedunculata (Decasine) Woodson — herb He (NT)	*	*			*		*	*
Metastelma angustifolium Turcz. — climber Ch (CO)				*	*		*	
Metastelma pubescens (Greenm.) W.D. Stevens — climber Ch (CO)					*			
Asteraceae								
Achillea millefolium L. — herb He (HA) Med weed	*				*		*	
Acourtia humboldtii (Less.) B. L. Turner — herb Ch (NA) Med				*				
Acourtia turbinata (Lex.) Reveal & R. M. King. — herb Ch (NA) Med					*		*	
Ageratina calaminthifolia (Kunth) R. M. King & H. Rob. — herb Ph		*			*		*	

(WTe) Med, Mag								
Ageratina deltoidea (Jacq.) R. M. King & H. Rob. — shrub Ph (WTe)		*			*		*	
Ageratina enixa (Rob.) R. M. King & H. Rob. — herb Ph (WTe)	*				*			
Ageratina glabrata (Kunth) R. M. King & H. Rob. — shrub Ph (WTe) Med, Or	*	*	*	*	*		*	*
Ageratina mairetiana (DC.)R. M. King & H. Rob. — shrub Ph (WTe)	*	*	*	*	*		*	
Ageratina oligocephala (DC.)R. M. King & H. Rob. — herb Ph (WTe)	*			*	*		*	*
Ageratina pazcuarensis (Kunth) R. M. King & H. Rob. — herb Ph (WTe) Med	*			*	*		*	*
Ageratina petiolaris King. & H. Rob. — shrub Ph (WTe) Med	*							
Ageratina prunellifolia (Kunth) R. M. King & H. Rob. — herb Ph (WTe)	*							
Ageratina rhomboidea (Kunth) R. M. King & H. Rob. — shrub Ph (WTe)	*				*			
Ageratina rivalis (Greenm.)R. M. King & H. Rob. — shrub Ph (WTe)	*							
Ageratina vernicosa (Sch. Bip. ex Greenm.) R. M. King & H. Rob. — shrub Ph (WTe)	*				*			
Ageratum corymbosum Zuccagni — shrub He (NT) Med, Or	*	*		*	*		*	
Alloispermum integrifolium (DC.) H. Rob. — shrub He (MX)								
Archibaccharis asperifolia (Benth.) S. F. Blake — shrub Ch (NT)	*	*			*		*	
Archibaccharis auriculata (Hemsl.) G. L. Nesom — herb Ch (NT)					*		*	
Archibaccharis hieracioides (S. F. Blake) S. F. Blake — herb Ch (NT)	*		*		*		*	*
Archibaccharis hirtella (DC.) Heering — climber Ch (NT)	*	*			*		*	
Archibaccharis schiedeana (Benth. in Oerst.) J. D. Jackson. — herb Ch (NT)	*							
Archibaccharis serratifolia (Kunth) Blake — herb Ch (NT)	*							
Artemisia ludoviciana ssp. *mexicana* Nutt (Willd.exSpreng.) D.D. Keck — herb Cr (HA) Med weed	*	*		*	*	*	*	
Aster moranensis Kunth — herb Cr (CO)		*		*	*			
Aster subulatus Michx. — herb Th (CO) Med, Or weed	*			*	*		*	
Baccharis conferta Kunth — shrub Ph (NT) Med	*	*		*	*		*	*
Baccharis multiflora Kunth — herb Ph (NT)	*		*		*		*	*
Baccharis pteronioides DC. — shrub Ph (NT)		*			*			
Baccharis salicifolia (Ruiz & Pav.) Pers. — shrub Ph (NT)					*			
Baccharis serraefolia DC. — shrub Ph (NT)					*			
Bidens anthemoides (DC.) Sherff — herb Th (CO) weed	*				*			
Bidens aurea (Aiton) Sherff — herb Th (CO)	*							
Bidens laevis (L.) Britton, Sterns & Poggenb. — herb Th (CO)		*					*	
Bidens odorata Cav. — herb Th (CO) Med weed	*	*		*	*		*	
Bidens ostruthioides (DC.) Sch. Bip. — herb Ch (CO)	*	*		*	*		*	
Bidens serrulata (Poir.) Desf. — herb Th (CO) weed	*	*			*		*	
Bidens triplinervia Kunth — herb Ch (CO) Or	*				*	*	*	
Brickellia nutanticeps S. F. Blake — herb Ch (NT)	*				*			
Brickellia pendula (Schrad.) A. Gray — herb Ch (NT) Med	*				*		*	
Brickellia scoparia (DC.) A. Gray — herb Ch (NT)	*				*		*	
Cirsium ehrenbergii Sch. Bip. — herb He (HA) Med	*			*	*	*	*	*
Cirsium jorullense ssp. *jorullense* (Kunth) Spreng. (Kunth) Spreng. — herb He (HA)	*				*		*	*
Cirsium nivale (Kunth) Sch. Bip. — herb He (HA)	*				*		*	*
Conyza canadensis (L.) Cronquist — herb Th (CO) weed		*			*		*	
Conyza schiedeana (Less.) Cronquist — herb Th (CO)	*	*			*		*	
Coreopsis mutica DC. — shrub Ph (NT) weed	*							
Cosmos bipinnatus Cav. — herb Th (NT) weed	*	*		*	*		*	
Cosmos scabiosoides Kunth — herb Th (NT) Med		*		*	*		*	*
Cotula mexicana (DC.) Cabrera — low growing Cr (CO)		*			*		*	
Dahlia coccinea Cav. — herb Cr (NT) Med, Or, Edib	*	*		*	*		*	
Dahlia pinnata Cav. — herb Cr (NT) Med, Or, Edib					*			
Dahlia scapigera (A. Dietr.) Knowles & Westc. — herb Cr (NT)	*							*
Erigeron galeottii (A. Gray) Greene — herb He (CO) Med weed	*	*			*	*	*	*

Erigeron karvinskianus DC. — herb Ch (CO) Med	*							
Erigeron pubescens Kunth — herb He (CO) Med	*							
Eupatorium isolepis B. L Rob. — herb He (WTe)	*			*	*		*	
Eupatorium lucida (Ortega) R. M. King & H. Rob. — shrub He (WTe)	*			*	*		*	*
Eupatorium oreithales (Greenm.) B. L. Turner. — herb He (WTe)	*			*	*		*	
Eupatorium schaffneri Sch. Bip. ex Robinson — shrub Ph (WTe)	*							*
Fleischmannia pycnocephala (Less.) R. M. King & H. Rob. — herb He (NA)	*							
Florestina pedata (Cav.) Cass. — herb Th (MX) weed	*							*
Galinsoga parviflora Cav. — herb Th (NT) Or weed	*			*	*		*	
Gamochaeta americana (Mill.) Wedd. — herb He (CO) Med weed	*				*	*	*	
Gnaphalium chartaceum Greenm. — herb Th (CO)	*							
Gnaphalium inornatum DC. — herb He (CO) Med weed	*	*	*		*		*	
Gnaphalium liebmanii var. *monticola* Sch. Bip. ex Klat. (McVaugh) D.L.Nash. — herb He (CO)	*							
Gnaphalium salicifolium (Bertol.) Sch. Bip. — herb He (CO)	*							
Gnaphalium semiamplexicaule DC. — herb He (CO) Med weed	*		*		*			
Haplopappus stoloniferus DC. — herb Ph (NA)	*							
Helenium scorzoneraefolium (DC.) A. Gray — herb He (NT)	*	*			*		*	
Hieracium dysonymum S. F. Blake — herb He (WTe)	*				*			*
Hieracium mexicanum Less. — herb He (WTe)	*							
Hymenostephium microcephalum (Lees.) S. F. Blake — low growing Cr (NA)	*							
Melampodium repens Sessé & Moc. — herb Th (NT)	*	*			*		*	
Mexerion sarmentosum (Klatt.) G. L. Nesom. — herb He (MX)	*							*
Montanoa frutescens (Mairet. ex DC.) Hemsl. — shrub Ph (NT)	*			*	*		*	
Oxylobus adscendens (Sch. Bip. ex Hemsl) B.L. Rob & Greenm. — herb He (MX)	*				*		*	
Oxylobus arbutifolius (Kunth) A. Gray — herb He (MX)	*				*			
Packera bellidifollia (Kunth) W. A. Weber & Á. Löve — herb He (CO) Med	*							*
Packera sanguisorbae (DC.) C. Jeffrey — herb He (CO)	*							*
Packera toluccana (DC.) W. A. Weber & Á. Löve — herb He (CO)	*							*
Parthenium hysterophorus L. — herb He (CO)	*							
Perymenium berlandieri DC. — shrub He (NT)	*							
Picris echioides L. — herb Th (CO) weed	*				*	*		
Pinaropappus roseus var. *roseus* (Less.) Less. (Less.) Less. — herb He (NT) Med weed	*	*			*			
Piqueria pilosa Kunth — herb Cr (NT) Med	*							*
Piqueria trinervia Cav. — herb He (NT) Med, Or, Mag	*	*			*		*	
Porophyllum tagetoides (Kunth) DC. — herb Th (NT) Edib, Med		*			*		*	*
Pseudognaphalium arizonicum (A. Gray) Anderb. — herb He (NA)	*							
Pseudognaphalium oxyphyllum (DC.) Kirp. — herb He (NA)	*							
Pseudognaphalium oxyphyllum var. *nataliae* DC. F.J. Espinosa — herb He (NA) Med	*							
Pseudognaphalium purpurascens (DC.) Anderb. — herb He (NA)	*							
Roldana albonervia (Greenm.) H. Rob. & Brettell — shrub Ph (CO)	*	*			*		*	*
Roldana angulifolia (DC.) H. Rob. & Brettell — shrub Ph (CO)	*		*	*	*		*	
Roldana barba-johannis (DC.) H. Rob. & Brettell — shrub Ph (CO) Edib, Med	*		*	*	*	*	*	
Roldana platanifolia (Benth.) H. Rob. & Brettell — herb Ph (CO) Or, Med	*							
Roldana reticulata (DC.) H. Rob. & Brettell — herb Cr (CO)	*							
Roldana sinuata B. L. Turner — herb Ph (CO)	*							
Sabazia humilis (Kunth) Cass. — herb He (MX) weed	*				*			*
Sanvitalia procumbens Lam. — low growing Th (NT) Med weed	*			*	*		*	
Senecio callosus Sch. Bip. — herb He (CO) Med, Or	*	*	*	*	*	*	*	
Senecio cinerarioides Kunth — shrub Ph (CO) Med Dist. indicator	*		*		*		*	*
Senecio jacalensis Greenm. — herb He (CO)	*							

Senecio mulgediifolius S. Schauer — herb Ph (CO)	*						
Senecio multidentatus Sch. Bip. ex Hemls. — herb He (CO)	*						
Senecio roseus Sch. Bip. — herb He (CO)	*						
Senecio salignus DC. — shrub Ph (CO) Med	*						*
Sigesbeckia jorullensis Kunth — herb He (WTe) Med, Fod weed	*	*	*	*	*	*	
Sigesbeckia orientalis L. — herb He (WTe)	*						
Simsia amplexicaulis (Cav.) Pers. — herb He (NT) Med weed	*			*			
Sonchus oleraceus L. — herb Th (CO) Med, Or	*						
Stevia eupatoria (Spreng.) Willd. — herb He (WTr)	*		*	*		*	
Stevia glandulosa Hook. & Arn. — herb He (WTr)	*						
Stevia incognita Grashoff — herb He (WTr)	*			*			
Stevia jorullensis Kunth — herb Th (WTr)							*
Stevia micrantha Lag. — herb Th (WTr)							
Stevia monardifolia Kunth — herb Cr (WTr)	*	*		*		*	
Stevia myricoides McVaugh — herb He (WTr)	*						
Stevia ovata var. *ovata* Willd. Willd. — herb He (WTr)	*			*		*	
Stevia purpusii B. L. Rob. — herb He (WTr)	*			*			
Stevia subpubescens var. *subpubescens* Lag. Lag. — shrub Ph (WTr)	*			*		*	*
Stevia viscida Kunth — herb He (WTr)	*			*			
Tagetes erecta L. — herb Th (NT)	*						
Tagetes lucida Cav. — herb Th (NT) Med, Edib		*	*	*		*	
Tagetes micrantha Cav. — low growing Th (NT) Med weed	*	*	*	*		*	
Tagetes triradiata Greenm. — herb Th (NT)	*						
Taraxacum officinale L. — herb He (NT) Med, Edib weed	*		*	*		*	
Tridax coronopifolia (Kunth) Hemsl. — herb He (WTe)	*						*
Telanthophora andrieuxii (DC.) H. Rob. & Brettell — shrub He (NT)							*
Verbesina oncophora B. L. Rob. & Seaton — shrub Ph (WTr) Med	*			*		*	*
Verbesina virgata Cav. — shrub Ph (WTr)			*	*		*	
Vernonia alamanii DC. — shrub Ph (WTr)	*	*		*			
Villanova achillaeoides (Less.) Less. — herb He (MX)	*						*
Zinnia peruviana (L.) L. — herb Th (NT) Med weed	*	*	*	*			
Begoniaceae							
Begonia gracilis Kunth — herb Cr (WTe) Med, Or	*						
Berberidaceae							
Berberis moranensis Schult & Schult. f. — tree Ph (CO) Med, Or	*	*		*		*	*
Berberis schiedeana Schltdl. — shrub Ph (CO)	*	*		*		*	
Betulaceae							
Alnus acuminata ssp. *arguta* Kunth (Schltdl.) Furlow — tree Ph (HA) Med	*	*		*		*	
Alnus acuminata ssp. *glabrata* Kunth (Fernald) Furlow — tree Ph (HA)	*		*	*		*	
Alnus jorullensis ssp. *jorullensis* Kunth Kunth — tree Ph (HA) Med, Cons	*		*	*		*	
Alnus jorullensis ssp. *lutea* Kunth Furlow — tree Ph (HA) Cons	*		*	*		*	
Boraginaceae							
Hackelia mexicana (Schltdl. & Cham.) I. M. Johnst. — shrub Ph (HA)	*		*	*		*	
Lasiarrhenum trinervium (Lehm.) B. L. Turner — herb He (MX)	*	*		*		*	
Lithospermum distichum Ortega — herb He (HA) Med, Fod	*			*		*	
Lithospermum strictum Lehm. — herb He (HA) Med weed	*			*		*	*
Myosotis sylvatica Ehrh. ex Hoffm. — herb He (WTe) weed	*						
Brassicaceae							
Barbarea orthoceras Ledeb. — herb He (HA)	*						
Brassica campestris L. — herb Th (CO)	*						
Brassica rapa L. — herb Th (CO) Fod	*		*	*	*	*	
Capsella bursa-pastoris L. Medic — herb Th (WTe)	*						
Cardamine flaccida Cham. & Schltdl. — herb Th (HA) Med, Edib	*		*	*		*	
Cardamine hirsuta L. — herb Th (HA)	*						
Cardamine obliqua Hochst. — herb He (HA)	*		*	*		*	
Descurainia impatiens (Cham. & Schltdl.) O. E. Schultz — herb He (WTe) weed	*		*	*		*	

Draba jorullensis Kunth — herb Cr (WTe)	*	*			*		*	
Draba nivicola Rose — herb Cr (WTe)	*				*			
Eruca sativa Mill. — herb Th (HA) Med, Edib weed	*			*	*		*	
Erysimum capitatum (Douglas ex Hook.) Greene — herb He (HA)	*	*			*		*	
Halimolobos hispidula var. *acutifolia* (DC.) O. E. Schulz (Schulz) Rollins — herb He (NT)	*	*			*		*	
Lepidium schaffneri Thell. — herb Th (CO) weed	*			*	*		*	
Lepidium virginicum var. *pubescens* L. (Greene) C.L.Hitchc. — herb Th (CO) Med, Edib, Mag weed	*			*	*		*	
Pennellia longifolia (Benth.) Rollins — herb Th (NT)	*				*		*	
Raphanus raphanistrum L. — herb Th (HA) Med, Edib weed	*	*			*		*	
Romanschulzia arabiformis (DC.) Rollins — herb He (NT)	*				*		*	
Rorippa nasturtium-aquaticum (L.) Hayek — low growing He (CO) Med, Edib	*	*			*		*	
Rorippa mexicana (Moc. & Sessé) Standl. & Steyermark — herb He (CO)	*							
Sisymbrium officinalis (L.) Scop — low growing Th (CO)	*							
Cactaceae								
Opuntia ficus-indica (L.) Mill. — shrub Ph (NT) Med, Edib	*			*	*		*	
Campanulaceae								
Diastatea micrantha (Kunth) McVaugh — herb Th (NT) weed	*				*			
Diastatea tenera (A. Gray) McVaugh — herb Th (NT) weed	*							
Lobelia fenestrallis Cav. — herb He (CO) Med weed	*	*			*		*	
Lobelia gruina var. *gruina* Cav. Cav. — herb He (CO) Or weed	*				*		*	*
Lobelia laxiflora var. *angustifolia* Kunth A. DC. — herb He (CO) Med weed	*	*			*		*	
Lobelia schmitzii E. Wimmer — herb He (CO)	*							
Caprifoliaceae								
Lonicera pilosa Willd. ex Kunth — shrub Ph (HA)	*	*			*		*	
Sambucus nigra var. *canadensis* L. (L.) B.L.Turner — tree Ph (CO)	*			*	*		*	
Symphoricarpos microphyllus Kunth — shrub Ph (HA) Or, Inst	*		*	*	*	*	*	
Viburnum elatum Benth. — tree Ph (HA)	*	*			*		*	
Viburnum stenocalyx (Oerst.) Hemsl. — tree Ph (HA)	*	*			*		*	
Caryophyllaceae								
Arenaria bourgaei Hemsl. — low growing He (WTe)	*	*			*		*	
Arenaria lanuginosa (Michx.) Rohrb. — herb He (WTe)	*	*	*		*		*	
Arenaria lycopodioides Willd. ex Schltdl. — herb He (WTe)	*				*		*	
Arenaria oresbia Greenm. — herb He (WTe)	*							
Arenaria paludicola B.L. Rob. — herb He (WTe)	*							
Arenaria reptans Hemsl. — low growing He (WTe)	*	*			*		*	
Cerastium glomeratum Thuill. — herb Th (HA)	*	*			*		*	
Cerastium molle Bartl. — herb He (HA)	*	*			*		*	*
Cerastium nutans Raf. — herb He (HA) weed	*				*			*
Cerastium orithales Schltdl. — herb He (HA)	*							
Cerastium purpusii Greenm. — herb He (HA)	*							
Cerastium tolucense D. A. Good — herb He (HA)	*				*			
Cerastium vulcanicum Schltdl. — herb He (HA) weed	*	*			*		*	
Drymaria effusa A. Gray — herb Th (CO)	*							
Drymaria laxiflora Benth. — herb He (CO) Med	*				*			
Drymaria leptophylla (Cham. & Schltdl.) Fenzl ex Rohrb. — low growing Th (CO)	*							
Drymaria molluginea (Ser.) Didr. — herb Th (CO)	*							
Drymaria tenuis S. Watson — herb Th (CO)	*							
Drymaria villosa Schltdl. & Cham. — herb Th (CO) weed	*				*		*	
Sagina procumbens L. — herb Ch (HA)	*	*			*		*	
Stellaria cuspidata Willd. ex Schltdl. — herb He (WTe)	*			*	*		*	
Stellaria media L. — herb He (WTe)	*							
Stellaria umbellata Turcz. — herb He (WTe)	*							
Casuarinaceae								

Casuarina equisetifolia L. — tree Ph (AA) exotic	*							
Cistaceae								
Helianthemum glomeratum (Lag.) Lag. ex DC. — herb Ch (WTe) Med	*			*	*		*	
Clethraceae								
Clethra mexicana DC. — tree Ph (WTr)	*			*	*		*	
Cornaceae								
Cornus disciflora DC. — tree Ph (HA)	*			*	*		*	
Cornus excelsa Kunth — tree Ph (HA)	*			*	*		*	
Crassulaceae								
Altamiranoa mexicana (Schltdl.) Rose — herb Ch (NT) Or	*	*			*		*	
Echeveria gibbiflora Moc. & Sessé ex DC. — herb Ch (NT) Med, Or	*			*	*		*	
Echeveria mucronata Schltdl. — herb Ch (NT)	*							
Echeveria secunda Booth ex Lindl. — herb Ch (NT) Med, Or	*			*	*		*	*
Sedum batallae Barocio — herb Ch (HA)	*							
Sedum bourgaei Hemsl. — herb Ch (HA)	*	*			*		*	
Sedum jaliscanum S. Watson — herb Ch (HA)	*							
Sedum minimum Rose — herb Ch (HA)		*			*		*	*
Sedum moranense Kunth — herb Ch (HA) Med		*			*		*	
Sedum oxypetalum Kunth — shrub Ph (HA)	*	*			*		*	*
Sedum praealtum ssp. *parviflorum* A. DC. (R.T.Clausen) R.T.Clausen — herb Ch (HA) Med, Or		*			*		*	
Tillaea connata Ruiz & Pavón — herb Th (CO)	*	*			*		*	
Villadia batessii Baehni & Macbride — herb Ch (HA)	*							
Cucurbitaceae								
Cucurbita ficifolia Bouché — herb Th (CO) weed	*							
Cucurbita radicans Naudin — herb Th (CO) weed	*							*
Sicyos deppei G. Don — herb Th (WTr) weed				*	*			*
Sicyos parviflorus Willd. — herb Th (WTr) weed	*						*	*
Ericaceae								
Arbutus tessellata P. D. Sorensen — tree Ph (WTe)	*				*			
Arbutus xalapensis Kunth — tree Ph (WTe) Med	*	*		*	*	*		
Comarostaphylis discolor var. *discolor* (Hook.) Diggs Soó — tree Ph (NT)	*			*	*			
Gaultheria lancifolia Small — shrub Ph (CO)	*				*			
Orthilia secunda (L.) House — herb He (WTe)								
Pernettya prostrata (Cav.) DC. — shrub Ph (AA) Med	*				*		*	
Vaccinium caespitosum Michx. — shrub He (HA)	*				*		*	
Euphorbiaceae								
Euphorbia furcillata var. *furcillata* Kunth Douin — herb Ch (CO)	*			*	*	*	*	
Euphorbia indivisa (Engelm.) Tidestr. — herb Th (CO)	*				*			
Euphorbia peplus Linn. — herb Th (CO)	*				*			
Euphorbia prostrata Ait. — herb Th (CO) Med	*				*		*	
Fagaceae								
Quercus candicans Neé — tree Ph (HA)	*			*	*		*	
Quercus castanea Neé — tree Ph (HA) Woo, Edib	*			*	*		*	*
Quercus crassipes Humb. & Bonpl. — tree Ph (HA) Woo, Tox	*			*	*		*	*
Quercus dysophylla Benth. — tree Ph (HA)					*			
Quercus frutex Trel. — tree Ph (HA) Med				*	*		*	*
Quercus laeta Liebm. — tree Ph (HA)	*			*	*		*	
Quercus laurina Bonpl. — tree Ph (HA) Woo, Tox	*			*	*		*	
Quercus mexicana Bonpl. — tree Ph (HA) Woo			*	*	*		*	
Quercus obtusata (Willd.) Pursh — tree Ph (HA) Woo, Inst	*	*			*		*	*
Quercus rugosa Neé — tree Ph (HA) Med, Woo, Inst	*			*	*	*	*	
Garryaceae								
Garrya laurifolia ssp. *laurifolia* Hartw. ex Benth. Hartw. ex Benth. — tree Ph (HA) Med	*		*	*	*		*	
Gentianaceae								
Centaurium brachycalyx Standl. & L.O. — herb He (HA)					*			
Centaurium laurifolia Standl. & L.O. — herb He (HA)	*							
Gentiana ovatiloba (G. Don) Briq. — herb He (WTe)	*							

Gentianella amarella ssp. *hartwegii* (L.) Börner (Benth.) J.M. Gillet — herb He (WTe)		*			*			*
Gentianella amarella ssp. *mexicana* (L.) Börner (Griseb.) J.M. Gillett — herb He (WTe)	*				*			*
Gentianella quitense (Benth.) Gillett. — herb He (HA)	*				*			
Halenia brevicornis (Kunth) G. Don — herb Th (HA)	*	*			*		*	
Halenia plantaginea (Kunth) G. Don — herb Th (HA)	*				*		*	*
Halenia pringlei B. L. Rob & Seaton — herb Th (HA)	*	*			*			*
Geraniaceae								
Erodium cicutarium (L.) L´Hér. ex Aiton — herb He (CO) Med weed	*			*	*		*	
Geranium latum Small — herb He (WTe)	*							*
Geranium lilacinum Knuth — herb He (WTe)	*							*
Geranium potentillaefolium DC. — herb He (WTe) Or, Fod weed	*			*	*		*	*
Geranium seemanii Peyr. — low growing He (WTe) weed	*			*	*	*	*	
Guttiferae								
Hypericum philonotis Schltdl. & Cham. — herb He (WTe)	*				*		*	*
Hypericum silenoides var. *mexicanum* Juss. (Keller) Rodr. — herb He (WTe)	*				*		*	*
Hydrangeaceae								
Philadelphus mexicanus Schltdl. — shrub Ph (HA)		*		*	*			
Hydrophyllaceae								
Nama dichotomum var. *dichotomum* (Ruiz & Pav.) Choisy Choisy — herb Ch (NT) weed					*			
Phacelia platycarpa (Cav.) Spreng. — herb He (NT) Fod weed	*	*			*		*	
Wigandia urens (Ruiz & Pav.) Kunth — shrub Ph (NT) Med weed	*			*	*			
Lamiaceae								
Agastache mexicana (Kunth) Linton & Epling — herb Ph (HA) Med	*				*		*	*
Cunila lythrifolia Benth. — herb Ph (NT) Med	*				*		*	
Hedeoma piperita Benth. — herb Ph (NT) Med	*				*		*	
Lamium purpureum L. — herb He (HA)	*							
Lepechinia caulescens (Ortega) Epling — herb He (NT) Med weed	*	*			*		*	
Marrubium vulgare L. — herb He (HA) Med weed		*			*		*	
Prunella vulgaris L. — herb He (HA) Med	*	*			*		*	
Salvia amarissima Ortega — herb Ph (WTe)	*			*	*		*	
Salvia concolor Lamb. — herb Ph (WTe)	*			*	*		*	*
Salvia elegans Vahl ex Benth. — herb Ch (WTe)	*		*	*	*	*	*	*
Salvia fulgens Cav. — herb Ph (WTe)		*			*		*	*
Salvia gesneraeflora Lindl. & Paxton — herb Ph (WTe)	*				*		*	
Salvia lavanduloides Kunth — herb Ph (WTe)	*			*	*		*	
Salvia mexicana L. — herb He (WTe)	*							*
Salvia mexicana var. *minor* L. (L.) Benth. — herb He (WTe) Or	*	*			*		*	*
Salvia microphylla var. *microphylla* L. Rolfe — herb Ph (WTe) Med, Mag	*							
Salvia microphylla var. *neurepia* L. (Fernald) Epling — herb Ph (WTe)	*			*	*		*	
Salvia patens Cav. — herb Ph (WTe)	*							*
Salvia polystachia Cav. — herb He (WTe) Med, Edib	*			*	*		*	
Salvia prunelloides Kunth. — herb He (WTe)	*	*			*		*	*
Salvia reptans Jacq. — herb He (WTe)	*	*			*			
Salvia stricta Sessé & Moc. — herb He (WTe)	*				*		*	*
Satureja macrostema (Moc. & Sessé ex Benth.) Briq. — herb Ph (CO) Med	*			*	*		*	
Scutellaria coerulea Moc. & Sessé ex Benth. — herb He (HA)		*			*		*	
Stachys agraria Schltdl. & Cham. — herb Th (WTr) weed	*	*			*		*	
Stachys coccinea Ortega — herb Ch (WTr) Or	*	*			*		*	
Stachys eriantha Benth. — herb Ch (WTr)	*							
Stachys repens M. Martens & Galeotti — herb Ch (WTr)	*				*			
Stachys sanchezii Rzed. & A. García — herb Ch (WTr)	*				*			*
Lauraceae								
Litsea glaucescens Kunth — tree Ph (WTr) Med, Edib, Mag	*			*	*		*	
Leguminosae								

Astragalus guatemalensis var. *brevidentatus* Hemsl. (Hemsl.) Barneby — herb He (WTe)	*	*		*	*	
Astragalus micranthus var. *micranthus* Desv. Barneby — herb He (WTe)		*		*	*	*
Calliandra grandiflora (L´ Hér.) Benth. — shrub Ch (NT) Med				*		
Cologania broussonetii (Balb.) DC. — herb He (NT)		*		*	*	
Dalea leporina (Ait.) Bullock — herb Ph (NT)	*					
Dalea minutifolia (Rydb.) Harms — herb Ph (NT)			*	*	*	
Dalea obovatifolia var. *uncifera* Ortega (Schltdl.&Cham.) Barneby — herb Ph (NT)		*		*	*	
Dalea zimapanica S. Schauer — herb Ph (NT)		*		*	*	
Desmodium aparines (Link) DC. — herb He (WTr)	*	*		*		
Desmodium molliculum (Kunth) DC. — herb Th (WTr)	*	*		*		
Desmodium neomexicanum A. Gray — herb Th (WTr)	*					
Erythrina coralloides DC. — tree Ph (WTr) Med, Edib, Woo	*	*			*	
Eysenhardtia polystachya (Ortega) Sarg. — tree Ph (MX) Med, Inst	*		*	*	*	*
Lathyrus odoratus L. — herb Ph (Wte)	*					
Lupinus elegans Kunth — herb Ph (HA) Or	*	*			*	
Lupinus glabratus J. Agardh — herb Ph (HA)	*	*		*	*	*
Lupinus montanus Kunth — herb He (HA)	*					
Lupinus prostratus J. Agardh — herb Ph (HA)						
Lupinus versicolor Lindl. — herb Ph (HA)			*	*	*	*
Phaseolus pedicellatus Benth. — herb He (NT)		*		*	*	*
Senna multiglandulosa (Jacq.) H. S. Irwin & Barneby — shrub Ph (WTr)	*		*	*	*	
Trifolium amabile Kunth — herb Cr (HA) Fod	*		*	*	*	
Trifolium mexicanum Hemsl. — herb Cr (HA) weed			*	*	*	
Trifolium repens L. — herb Cr (HA)	*					
Trifolium wormskioldii var. *ortegae* Lehm. (Greene) Barneby — herb Cr (HA)		*		*	*	
Vicia faba L. — herb Th (HA)	*					
Vicia pulchella ssp. *mexicana* Kunth (Hemsl.) C.R.Gunn — climber Th (HA)	*		*	*	*	
Vicia sativa L. — climber He (HA)	*					
Lentibulariaceae						
Utricularia livida (DC.) E. Mey. — low growing Cr (CO)	*	*		*	*	
Linaceae						
Linum orizabae Planch. — herb He (CO)	*			*		*
Linum usitatissinum L. — herb He (CO)	*			*		
Loganiaceae						
Buddleia cordata ssp. *cordata* Kunth Kunth — tree Ph (WTe) Med, Inst	*					
Buddleia parviflora Kunth — tree Ph (WTe) Med	*					*
Loranthaceae						
Arceuthobium abietis-religiosae Heil — epiphyte Pa (NT)			*	*	*	
Arceuthobium globosum Hawksw. & Wiens — epiphyte Pa (NT)	*			*	*	
Arceuthobium vaginatum (Humbd. & Bonpl. ex Willd.) J. Presl — epiphyte Pa (NT) Med	*			*	*	
Phoradendron velutinum (DC.) Oliv. — epiphyte Pa (NT)	*		*	*	*	
Lythraceae						
Cuphea aequipetala Cav. — herb He (NT) Med weed	*	*		*	*	
Malvaceae						
Kearnemalvastrum subtriflorum (Lag.) D. M. Bates — herb He (NT)	*			*		
Malva parviflora L. — herb He (HA) Med weed				*		
Myrtaceae						
Eucalyptus globulus Labill. — tree Ph (AA) Med exotic	*					
Nyctaginaceae						
Mirabilis jalapa L. — herb He (NT) Med weed			*	*	*	
Oleaceae						
Fraxinus uhdei (Wenz.) Lingelsh. — tree Ph (HA) Med	*		*	*	*	*
Ligustrum japonicum Thunb. — tree Ph (CO) Or	*		*	*	*	
Onagraceae						

Epilobium ciliatum ssp. *ciliatum* Raf. Elmer — herb He (WTe)		*			*		*	
Fuchsia microphylla ssp. *microphylla* Kunth Andersson — shrub Ph (AA) Or	*		*	*	*	*	*	
Fuchsia thymifolia ssp. *thymifolia* Kunth Danser — shrub Ph (AA)	*			*	*		*	
Gaura coccinea Pursh — herb Ph (NT) Med weed	*	*			*		*	
Gaura mutabilis Cav. — herb Ph (NT)	*				*			
Lopezia racemosa ssp. *racemosa* Cav. Hassk. — herb Th (NT) Med weed	*				*		*	
Ludwigia palustris (L.) Elliott — herb Ph (CO)					*		*	
Oenothera deserticola (Loes.) Munz — herb He (HA)	*							*
Oenothera pubescens Willd. ex Spreng. — herb He (HA) weed	*	*			*		*	
Oenothera purpusii Munz — herb He (HA)	*				*		*	*
Oenothera rosea L´Hér. ex Aiton — herb Th (NT) Med, Or weed	*	*		*	*		*	
Orobanchaceae								
Conopholis alpina Liebm. — herb Cr (NT)	*				*		*	
Oxalidaceae								
Oxalis alpina (Rose) R. Knuth — low growing Cr (CO)	*			*	*	*	*	
Oxalis corniculata L. — low growing He (CO) Med, Or weed	*			*	*		*	
Oxalis nelsonii (Small) R. Knuth — low growing Cr (CO)	*			*	*		*	
Oxalis tetraphylla Cav. — low growing Cr (CO)				*	*		*	
Papaveraceae								
Argemone ochroleuca Sweet — herb Th (NT) Med	*							
Argemone platyceras Link & Otto — herb Th (NT) Med, Ind weed	*	*			*		*	
Passifloraceae								
Passiflora exsudans Zucc. — climber He (WTr) Med	*			*	*			
Phytolaccaceae								
Phytolacca icosandra L. — herb He (WTr) Med, Edib weed	*			*	*		*	
Piperaceae								
Peperomia campylotropa A. W. Hill. — herb Cr (NT) Or	*	*			*		*	*
Peperomia galioides Kunth — epiphyte Cr (NT)				*	*		*	
Peperomia hintonii Yunck. — herb Cr (NT)	*	*			*		*	
Peperomia hispidula (Sw.) A. Dietr. — herb Cr (NT)		*			*		*	
Peperomia quadrifolia (L.) Kunth — epiphyte Cr (NT)				*	*		*	
Plantaginaceae								
Plantago alismatifolia Pilg. — herb He (CO) weed					*			
Plantago australis ssp. *hirtella* Lam. (Kunth) Rahn — herb He (CO) Med weed	*				*		*	
Plantago linearis Kunth — herb He (CO)	*							
Plantago major L. — herb He (CO) Med	*							
Plantago nivea Kunth — herb Cr (CO) weed	*				*			
Polemoniaceae								
Loeselia glandulosa (Cav.) G. Don — herb Ch (NT)					*			*
Loeselia mexicana (Lam.) Brand — herb Ch (NT) Med weed				*	*		*	
Polemonium mexicanum Sessé & Moc. ex DC. — herb Ch (HA) Or weed		*			*		*	*
Polygalaceae								
Eriogonum jamesii Benth. — shrub He (NT)	*	*			*		*	
Monnina ciliolata Sessé & Moc. ex DC. — shrub Ph (NT)	*			*	*		*	*
Polygonum aviculare L. — herb Th (CO) Fod weed	*	*			*		*	
Polygonum hydropiperoides Michx. — herb Cr (CO) Med, Fod	*	*					*	
Polygonum punctatum var. *eciliatum* Elliot Small — herb Cr (CO) Fod weed	*			*	*		*	
Rumex acetosella L. — herb He (CO) weed		*			*		*	
Rumex crispus L. — herb He (CO) Edib weed	*				*		*	
Rumex flexicaulis Rech. f. — herb He (CO)	*				*			*
Rumex obtusifolius ssp. *agrestis* L. (Fr.) Danser — herb He (CO) Med, Fod weed		*			*		*	
Portulacaceae								
Calandrinia megarhiza Hemsl. — herb Th (NT)	*	*			*		*	
Claytonia perfoliata ssp. *mexicana* (Rydb.) John M. Miller & K.L.	*	*			*		*	

Chambers — herb Cr (HA) Med								
Montia chamissoi (Ledeb. ex Spreng.) Greene — herb Cr (HA)	*	*			*		*	
Talinum lineare Kunth — herb He (WTr)		*			*		*	
Primulaceae								
Anagallis arvensis L. — herb Th (CO) weed, exotic	*	*			*		*	
Centunculus minimus L. — herb Th (WTe)					*			
Pyrolaceae								
Chimaphila umbellata L. — shrub Ph (HA)	*							
Monotropa hypopitys (Scop.) Linn. — herb He (HA)		*					*	
Monotropa uniflora Linn. — herb He (HA)	*	*			*		*	
Ranunculaceae								
Clematis dioica L. — climber Ph (CO) Or	*			*	*		*	
Ranunculus dichotomus Moc. & Sessé ex DC. — herb Cr (WTe)					*		*	
Ranunculus donianus Pritz. — herb Cr (WTe)	*	*			*		*	
Ranunculus multicaulis var. *multicaulis* D. Don ex G. Don — herb Cr (WTe)	*							
Ranunculus peruvianus Pers. — herb Cr (WTe)		*			*		*	
Ranunculus petiolaris var. *arsenei* Kunth ex DC. (L.D. Benson) T. Duncan — herb Cr (WTe) weed		*			*		*	
Ranunculus petiolaris var. *sierrae-orientalis* Kunth ex DC. L.D. Benson — herb Cr (WTe)		*			*		*	
Ranunculus petiolaris var. *trahens* Kunth ex DC. T. Duncan — herb Cr (WTe) weed		*			*		*	
Ranunculus praemorsus var. *amellus* Kunth ex DC. (Briq.) T. Duncan — herb Cr (WTe)	*				*			
Thalictrum pubigerum Benth. — herb He (HA)	*	*			*		*	*
Thalictrum strigillosum Hemsl. — herb He (HA)		*			*		*	
Resedaceae								
Reseda luteola L. — herb Th (CO) Med, Ind weed, exotic	*			*	*		*	
Rhamnaceae								
Ceanothus coeruleus Lag. — tree Ph (NT) Med, Or	*			*	*	*	*	
Rosaceae								
Acaena elongata L. — shrub He (AA)	*		*	*	*	*	*	
Alchemilla aphanoides L. — herb Ch (NT) Fod	*				*		*	
Alchemilla pectinata Kunth — herb Ch (NT)	*							
Alchemilla pringlei (Rydb.) Fedde — low growing Ch (NT)				*	*		*	
Alchemilla procumbens Rose — low growing Ch (NT) Med, Fod	*	*	*		*		*	
Alchemilla sibbaldiifolia var. *bourgeaui* Kunth (Rydb.) Perry — low growing Ch (NT)	*	*			*		*	
Alchemilla vulcanica Schltdl. & Cham. — low growing Ch (NT)	*				*			
Amelanchier denticulata (Kunth) K. Koch — tree Ph (HA) Med, Or, Edib, Inst	*	*			*		*	
Crataegus mexicana Moc. & Sessé ex DC. — tree Ph (HA) Med, Edib	*			*	*		*	
Duchesnea indica (Andrews) Focke — herb Ch (WTe)	*	*			*		*	
Fragaria mexicana Schltdl. — herb Ch (WTe) Med, Edib	*		*	*	*		*	*
Potentilla candicans Humb. & Bonpl. ex Nestl. — herb Cr (HA) Med	*			*	*		*	*
Potentilla laxiflora Drew — herb Cr (HA)	*							
Potentilla ranunculoides Kunth — herb Cr (HA)	*							
Potentilla rubra Willd. ex Schltdl. — herb Cr (HA)	*				*		*	*
Potentilla staminea Rydb. — herb Cr (HA)								
Prunus serotina ssp. *capuli* Ehrh. (Cav.) McVaugh — tree Ph (WTe) Edib, Or, Ind	*			*	*		*	
Rosa canina L. — shrub He (WTe)	*			*	*		*	
Rubus liebmannii Focke — shrub Cr (CO)	*	*			*		*	*
Rubus pumilus Focke — herb Cr (CO)	*	*			*		*	*
Rubiaceae								
Bouvardia multiflora (Cav.) Schult. & Schult. f. — shrub Ch (NT)	*							
Bouvardia obovata Kunth — herb Ch (NT)	*				*			
Bouvardia ternifolia (Cav.) Schltdl. — herb Ch (NT) Med, Or	*			*	*		*	

Didymaea alsinoides (Cham. & Schltdl.) Standl. — herb He (NT)	*	*			*		*	*
Didymaea floribunda Rzed. — herb He (NT)					*			
Galium aschembornii Nees & S. Schauer — herb He (WTe)			*		*	*	*	
Galium mexicanum ssp. *mexicanum* Kunth De Wit — herb He (WTe)	*							
Galium praetermissum Greenm. — herb He (WTe)	*			*			*	
Hedyotis cervantesii Kunth — herb He (WTr)	*							
Sherardia arvensis L. — herb He (CO)	*							
Sabiaceae								
Meliosma dentata (Liebm.) Urb. — tree Ph (WTr)	*	*			*		*	
Salicaceae								
Salix oxylepis C. K. Schneid. — shrub Ph (HA)	*							
Salix paradoxa Kunth — tree Ph (HA) Handi.	*			*	*		*	*
Saxifragaceae								
Heuchera orizabensis Hemsl. — herb He (NT)	*	*			*		*	*
Ribes affine Kunth — shrub Ph (HA)	*	*			*		*	*
Ribes ciliatum Humb. & Bonpl. ex Schult. — shrub Ph (HA) Med	*	*	*		*		*	
Ribes ciliosum Howell — shrub Ph (HA)	*							
Scrophulariaceae								
Castilleja arvensis Schltdl. & Cham. — herb He (CO) Med, Or weed	*			*	*		*	
Castilleja lithospermoides Kunth — herb He (CO)					*			*
Castilleja moranensis Kunth — herb He (CO)	*				*		*	*
Castilleja tenuiflora Benth. — herb He (CO) Med weed	*				*	*	*	
Lamourouxia dasyantha (Cham. & Schltdl.) W. R. Ernst — herb He (NT)		*			*			*
Lamourouxia multifida Kunth — herb He (NT)		*			*		*	
Lamourouxia rhinanthifolia Kunth — herb He (NT)		*			*		*	*
Lamourouxia xalapensis Kunth — herb He (NT)	*	*			*		*	
Mimulus glabratus Kunth — herb He (WTe) Med	*	*			*		*	
Pedicularis mexicana Zucc. ex Bunge — herb He (HA)	*	*			*		*	*
Penstemon barbatus (Cav.) Roth — herb Ch (HA)		*			*		*	
Penstemon campanulatus (Cav.) Willd. — herb Ch (HA) Or weed	*	*		*	*	*	*	
Penstemon gentianoides (Kunth) Poir. — herb Ch (HA) Or Dist. indicator	*	*			*	*	*	
Penstemon roseus (Cerv. ex Sweet) G. Don — herb Ch (HA)	*				*		*	*
Sibthorpia repens (L.) Kuntze — low growing Cr (HA)	*		*		*	*	*	
Veronica americana Schwein. ex Benth. — low growing He (HA)				*	*		*	
Veronica serpyllifolia L. — herb He (HA)	*							
Solanaceae								
Cestrum anagyris var. *anagyris* Dunal E. Murr. — tree Ph (NT)	*			*	*		*	
Cestrum nitidium M. Martens & Galeotti — shrub Ph (NT)					*			*
Cestrum thyrsoideum Kunth — shrub Ph (NT)	*		*	*	*		*	*
Datura stramonium L. — herb Th (NT) weed				*	*		*	
Lycianthes moziniana (Dunal) Bitter — herb He (WTr) weed	*							*
Lycianthes peduncularis (Schlecht.) Bitter — herb He (WTr)	*							*
Nicotiana glauca Graham — herb Ph (NT) exotic	*							
Nectouxia formosa Kunth — herb He (MX) weed	*	*			*		*	*
Physalis chenopodifolia Lam. — herb He (CO)	*							
Physalis coztomatl Dunal — herb Ph (CO) Med, Fod	*	*			*		*	*
Physalis orizabae Dunal — herb He (CO) weed	*				*		*	
Physalis pringlei Greenm. — herb He (CO)	*							
Physalis sordida Fernald — herb He (CO)	*							*
Physalis stapelioides (Regel) Bitter — herb He (CO)	*							
Solanum americanum Mill. — herb Cr (CO)	*							
Solanum appendiculatum Dunal — herb Cr (CO)		*			*		*	
Solanum bulbocastanum var. *bulbocastanum* Dunal Standl. — herb Cr (CO)	*				*	*		*
Solanum cervantesii Lag. — shrub Ph (CO) Med	*				*	*	*	
Solanum demissum Lindl. — herb Ph (CO)	*	*			*		*	
Solanum marginatum L.f. — shrub Cr (CO) Med weed		*			*		*	
Solanum nigrescens M. Martens & Galeotti — herb Th (CO) weed	*			*	*		*	

Solanum stoloniferum Scchltdl. — herb Cr (CO)		*			*	*	*
Solanum verrucosum Scchltdl. — herb Cr (CO)					*	*	
Symplocaceae							
Symplocos citrea Lex. ex La Llave & Lex. — tree Ph (NT)	*			*	*	*	*
Theaceae							
Ternstroemia sylvatica Schltdl. & Cham. — tree Ph (WTr)				*		*	
Urticaceae							
Parietaria pensylvanica Muhl. ex Willd — herb Th (CO)				*	*		
Urtica chamaedryoides Pursh — herb Th (WTe) weed	*	*			*	*	
Urtica mexicana Liebm. — herb Th (WTe)				*	*	*	
Urtica subincisa Benth. — herb Th (WTe)		*			*	*	
Urtica urens L. — herb Ch (WTe) weed	*			*	*	*	
Valerianaceae							
Valeriana clematitis Kunth — herb Th (HA) Med	*		*	*	*	*	
Valeriana sorbifolia Kunth — herb Th (HA)	*						
Verbenaceae							
Bouchea prismatica var. *brevirostra* (L.) Kuntze Grenzeb. — herb Th (NT)		*			*	*	
Lippia mexicana Grieve — herb He (WTr)				*	*	*	
Verbena bipinnatifida Nutt. — herb He (CO) Med	*			*	*		
Verbena carolina L. — herb Th (CO) Med weed				*	*	*	
Violaceae							
Viola guatemalensis W. Becker — herb Cr (WTe)	*				*		
Viola hemsleyana Calderón — herb Cr (WTe)	*				*		
Viola hookeriana Kunth — herb Cr (WTe)	*				*	*	
Viola humilis Kunth — herb Cr (WTe)	*						
Viola painteri Rose & House — herb He (WTe)	*			*	*	*	*
Liliophyta							
Agavaceae							
Agave atrovirens Karw. ex Salm-Dyck — herb Ph (NT)	*						
Agave macroculmis Tod. — herb Ph (NT) Med	*				*		
Agave salmiana Otto ex Salm-Dyck — herb Ph (NT) Med	*						
Furcraea bedinghausii K. Koch — tree Ph (NT) Or	*	*			*	*	*
Manfreda pringlei Rose — herb He (NT)	*						
Amaryllidaceae							
Zephyranthes carinata (Lindl.) Benth. — herb Cr (NT) Or	*						*
Zephyranthes fosteri Traub. — herb Cr (NT)	*	*			*	*	*
Commelinaceae							
Commelina coelestis Willd. — herb He (WTr) Med, Or weed	*			*	*	*	
Commelina dianthifolia L. — herb He (WTr)	*			*	*	*	
Commelina diffusa Burm. — herb He (WTr)	*						
Commelina orchioides Booth. — herb He (WTr)	*				*	*	
Commelina tuberosa L. — herb He (WTr)	*				*	*	
Gibasis pulchella (Kunth) Raf. — herb He (NT)	*			*	*	*	
Tinantia erecta (Jacq.) Schltdl. — herb Cr (NT)	*						
Tradescantia crassifolia var. *crassifolia* Cav. Cav. — herb Cr (NT) weed	*				*	*	*
Tripogandra pupurascens (S. Schauer) Handlos — herb Cr (NT)	*						
Bromeliaceae							
Tillandsia andrieuxii (Mez) L. B. Smith — epiphyte Ph (NT)	*				*		*
Tillandsia recurvata (L.) L. — epiphyte Ph (NT) Med, Or, Ind	*				*		
Tillandsia usneoides (L.) L. — epiphyte Ph (NT) Or	*				*		
Tillandsia violacea Baker — epiphyte Ph (NT)	*				*		
Cyperaceae							
Carex anisostachys Liebm. — herb Ch (CO)					*		
Carex boliviensis Van Heurck & Müell. Arg. — herb Ch (CO)	*				*		
Carex brunnipes Reznicek — herb Ch (CO)					*		
Carex chordalis Liebm. — herb Ch (CO)	*				*		
Carex tuberculata Liebm. — herb Ch (CO)	*				*		
Cyperus aggregatus (Willd.) Endl. — herb Cr (CO)					*		
Cyperus esculentus L. — herb Cr (CO) weed					*		

Cyperus hermaphroditus (Jacq.) Standl. — herb Cr (CO) weed	*	*	*	*	*	
Cyperus manimae var. *manimae* Kunth Kunth — herb Cr (CO)	*					*
Cyperus niger Ruiz & Pav. — herb Cr (CO)	*			*	*	
Cyperus semiochraceus Boeck. — herb Cr (CO)	*	*	*			
Cyperus seslerioides Kunth — herb Cr (CO)	*	*	*	*	*	
Eleocharis acicularis (L.) Roem. & Schult. — herb He (CO)				*	*	
Eleocharis dombeyana Kunth — herb He (CO)	*			*	*	
Eleocharis montevidensis var. *montevidensis* Kunth Kunth — herb He (CO)	*			*	*	
Kyllinga odorata Vahl — herb He (CO)				*		
Rhynchospora kunthii Nees ex Kunth — herb He (CO)	*			*		
Hypoxidaceae						
Hypoxis mexicana Schult — herb Cr (Wte)	*			*		
Iridaceae						
Orthrosanthus exsertus (Foster) Ravenna — herb Cr (WTr)	*			*	*	
Sisyrinchium angustissimum (B. L. Rob. & Greenm.) Greenm. & C. H. Thomps. — herb Cr (NT)				*	*	*
Sisyrinchium bracteatum Greenm. — herb Cr (NT)	*					
Sisyrinchium cernuum (Bicknell) Kearney — herb Cr (NT)				*		
Sisyrinchium convolutum (Nocca) Herb. — herb Cr (NT)	*			*		
Sisyrinchium conzatii Calderón & Rzedowski — herb Cr (NT)				*		*
Sisyrinchium scabrum Schltdl. & Cham. — herb Cr (NT)	*			*		
Sisyrinchium schaffneri S. Watson — herb Cr (NT)	*			*		*
Sisyrinchium tenuifolium Humb. & Bonpl. ex Willd. — herb Cr (NT)	*			*	*	
Sisyrinchium tolucense Peyr. — herb Cr (NT)	*			*	*	
Juncaceae						
Juncus ebracteatus E. Mey. — herb Hy (CO)				*	*	
Juncus liebmanii var. *liebmanii* J. F. Macbr. Takht. — herb Hy (CO)				*	*	
Luzula denticulata Liebm. — herb He (CO)	*			*		
Luzula racemosa Desv. — herb He (CO)	*			*	*	
Liliaceae						
Echeandia mexicana Cruden — herb Cr (MX)	*			*		*
Echeandia nana (Baker) Cruden — herb Cr (MX)				*		
Stenanthium frigidum (Schltdl. & Cham.) Kunth — herb Cr (NA)	*			*		
Nolinaceae						
Nolina parviflora (Kunth) Hemsl. — tree Ph (MX)	*			*		*
Orchidaceae						
Bletia reflexa Lindl. — herb Cr (NT)				*	*	
Corallorhiza macrantha Schltr. — herb Cr (HA)				*		
Corallorhiza maculata (Raf.) Raf. — herb Cr (HA)		*		*	*	
Corallorhiza wisteriana Conrad — herb Cr (HA)	*			*		
Domingoa kienastii (Rchb. f.) Dressler — epiphyte Cr (NT)				*		
Habenaria guadalajarana S. Watson — herb Cr (WTr)	*			*		
Laelia autumnalis (La Llave ex Lex.) Lindl. — epiphyte Cr (NT)	*			*		
Malaxis myurus (Rchb. f.) Kuntze — herb Cr (WTr)	*			*		
Malaxis soulei L. O. Williams — herb Cr (CO)	*			*	*	
Platanthera sparsiflora var. *brevifolia* (S. Watson) Schltr. (Greene) Luer — herb Cr (WTr)				*		
Spiranthes hyemalis A. Rich. & Galeotti — herb Cr (CO)	*		*	*		
Spiranthes minutiflora A. Rich. & Galeotti — herb Cr (CO)	*			*		
Poaceae						
Aegopogon cenchroides Humb. & Bonpl. ex Willd. — herb Th (NT) Fod weed		*		*	*	
Aegopogon tenellus (DC.) Trin. — herb Th (NT) weed				*		
Agrostis bourgaei E. Fourn. — herb He (CO)				*	*	*
Agrostis perennans (Walter) Tuck. — herb He (CO)				*	*	
Agrostis schaffneri E. Fourn. — herb He (CO) weed				*	*	
Agrostis tolucensis Kunth — herb He (CO) weed	*			*	*	
Agrostis vinosa Swallen — herb He (CO)	*			*		
Aristida divaricata Humb. & Bonpl. ex Willd. — herb Ph (WTr)		*		*		

Avena sativa L. — herb Th (WTe)	*							
Blepharoneuron tricholepis (Torr.) Nash — herb He (NA) Fod	*						*	
Brachypodium mexicanum (Roem. & Schult.) Link — herb He (WTr) Fod			*		*		*	
Brachypodium pringlei Scribn. ex Beal — herb He (WTr)	*				*			
Bromus carinatus Hook. & Arn. — herb He (WTe) weed					*	*	*	
Bromus dolichocarpus Wagnon — herb He (WTe)	*	*			*		*	
Bromus exaltatus Bernh. — herb He (WTe)		*			*		*	
Calamagrostis tolucensis (Kunth) Trin. ex Steud. — herb He (WTe) Fod	*				*		*	
Chloris rufescens Lag. — herb He (WTr)		*			*			
Cinna poiformis (Kunth) Scribn. & Merr. — herb He (WTe) Fod	*				*		*	
Cynodon dactylon (L.) Pers. — herb He (WTr) Fod				*	*		*	
Deschampsia elongata (Hook.) Munro — herb He (HA)					*			
Festuca amplissima Rupr. — herb Ch (WTe) Fod	*		*		*		*	
Festuca arundinacea Schreb. — herb Ch (WTe)	*							
Festuca orizabensis E. B. Alexeev — herb Ch (WTe)					*		*	
Festuca tolucensis Kunth — herb Ch (WTe) Fod	*				*			
Hilaria cenchroides Kunth — herb Ch (MX) weed		*			*		*	*
Lycurus phleoides Kunth — herb He (NT)					*			
Muhlenbergia alamosae Vasey — herb Ch (WTe)		*		*			*	
Muhlenbergia ciliata Kunth — herb Ch (WTe)	*							
Muhlenbergia macroura (Kunth) Hitchc. — herb Ch (WTe) Fod, Ind weed	*	*			*	*	*	
Muhlenbergia montana (Nutt.) Hitchc. — herb Ch (WTe)								
Muhlenbergia nigra Hitchc. — herb Ch (WTe) Fod	*	*		*	*		*	
Muhlenbergia quadridentata (Kunth) Trin. — herb Ch (WTe) Fod	*	*			*		*	
Muhlenbergia ramulosa (Kunth) Swallen — herb Ch (WTe)					*		*	
Muhlenbergia robusta (E. Fourn.) Hitchc. — herb Ch (WTe)		*					*	
Muhlenbergia vaginata Swallen — herb Ch (WTe)					*			
Muhlenbergia virlettii (E. Fourn.) Soderstr. — herb Ch (WTe)					*			
Pennisetum villosum R. Br. ex Fresen. — herb He (WTr) weed, exotic					*			
Piptochaetium fimbriatum (Kunth) Hitchc. — herb He (AA)	*							
Piptochaetium seleri (Pilg.) Henrard — herb He (AA)	*						*	
Piptochaetium virescens (Kunth) Parodi — herb He (AA)							*	
Poa annua L. — herb Th (WTe) Fod weed, exotic				*	*		*	
Poa pratensis L. — herb Th (WTe)					*			
Sporobolus indicus (L.) R. Br. — herb He (CO) weed	*	*			*		*	
Stipa ichu (Ruiz & Pav.) Kunth — herb Ch (CO)	*			*	*		*	
Stipa mexicana Hitchc. — herb He (CO)	*				*			
Trisetum altijugum (E. Fourn.) Scribn. — herb He (WTe)					*		*	
Trisetum irazuense (Kuntze) Hitchc. — herb He (WTe)					*		*	
Trisetum kochianum Hern. Torres — herb He (WTe)	*				*		*	
Trisetum spicatum (L.) K. Richt. — herb He (WTe)	*				*		*	
Trisetum virlettii E. Fourn. — herb He (WTe) Fod	*	*	*		*		*	*
Vulpia bromoides (L.) Gray — herb Ch (CO) exotic	*							
Smilacaceae								
Smilax moranensis M. Martens & Galeotti — climber Ph (WTr)	*		*		*		*	*

App. 2 Synthetic phytosociological table. The most frequent and abundant species per plant community are shown. Frequencies: V=the species appears in more than 60% of the relevés, IV=between 40 and 60%, III=20-40%, II=10-20%, I=<10%. In parenthesis the minimum and maximum cover values.

***Pinus hartwegii* community**	**Freq. (cover)**	***Abies religiosa* community**	**Freq. (cover)**	***Quercus* and mixed**	**Freq. (cover)**
Pinus hartwegii	V(10-95)	*Abies religiosa*	V(30-90)	*Quercus rugosa*	V(1-90)
Calamagrostis tolucensis	V(2-80)	*Acaena elongata*	V(0.5-80)	*Quercus laurina*	IV(5-60)
Alchemilla vulcanica	V(0.5-70)	*Roldana angulifolia*	V(0.5-80)	*Ageratina rivalis*	IV(0.5-60)
Penstemon campanulatus	V(0.5-20)	*Thuidium delicatulum*	V(0.5-90)	*Buddleia cordata*	III(0.5-10)
Muhlenbergia quadridentata	IV(0.5-60)	*Roldana barba-johannis*	IV(0.5-50)	*Smilax moranensis*	III(0.5-5)
Eryngium carlinae	IV(0.5-5)	*Symphoricarpos microphyllus*	IV(0.5-25)	*Salvia concolor*	III(0.5-10)
Vaccinium caespitosum	IV(0.5-2)	*Salix paradoxa*	IV(0.5-15)	*Stachys coccinea*	II(0.5-20)
Festuca tolucensis	III(0.5-70)	*Sibthorpia repens*	IV(0.5-15)	*Prunus serotina var. capulli*	II(0.5-5)
Baccharis conferta	III(0.5-1)	*Solanum cervantesii*	III(0.5-60)	*Alnus jorullensis ssp. jorullensis*	II(0.5-20)
Geranium potentillaefolium	III(0.5-20)	*Alchemilla procumbens*	III(0.5-60)	*Ceanothus coeruleus*	II(0.5-1)
Oxalis alpina	III(0.5-15)	*Cestrum thyrsoideum*	III(0.5-70)	*Conopholis alpina*	II(0.5-0.5)
Oxalis corniculata	III(0.5-0.5)	*Salvia elegans*	III(0.5-60)	*Adiantum andicola*	II(0.5-3)
Erigeron galeottii	III(0.5-1)	*Ageratina glabrata*	III(0.5-30)	*Clethra mexicana*	II(0.5-5)
Gnaphalium liebmanii var. monticola	III(0.5-2)	*Senecio toluccanus*	III(0.5-50)	*Salvia amarissima*	II(0.5-15)
Stevia incognita	III(0.5-10)	*Buddleia parviflora*	III(0.5-10)	*Salvia gesneriflora*	I(0.5-30)
Commelina orchioides	III(0.5-0.5)	*Physalis coztomatl*	III(0.5-15)	*Rubus pumilus*	II(0.5-15)
Phacelia platycarpa	III(0.5-1)	*Ribes ciliatum*	III(0.5-10)	*Trepadora mediana*	II(0.5-15)
Potentilla candicans	III(0.5-5)	*Fragaria mexicana*	III(0.5-5)	*Montanoa frutescens*	I(0.5-15)
Arenaria lycopodioides	III(0.5-2)	*Fuchsia microphylla var microphylla*	III(0.5-15)	*Valeriana clematitis*	I(0.5-20)
Cirsium jorullense ssp. jorullense	III(0.5-5)	*Asplenium monanthes*	III(0.5-1)	*Phytolacca icosandra*	I(0.5-5)
Potentilla rubra	III(0.5-5)	*Cinna poiformis*	II(0.5-30)	*Cupressus lusitanica*	I(1-15)
Lupinus glabratus	III(0.5-1)	*Ageratina pazcuarensis*	II(0.5-3)	*Arbutus xalapensis*	I(1-10)
Eryngium proteiflorum	II(0.5-20)	*Senecio cinerarioides*	II(0.5-5)	*Tagetes lucida*	I(0.5-10)
Helenium scorzonerifolium	II(0.5-50)	*Comarostaphylis discolor var. discolor*	II(0.5-1)	*Moss*	I(0.5-5)
Lupinus montanus	II(0.5-5)	*Cirsium ehrenbergii*	II(0.5-1)	*Cystopteris fragilis*	I(0.5-0.5)
Senecio roseus	II(0.5-5)	*Packera sanguisorbae*	II(0.5-15)	*Quercus crassipes*	I(0.5-5)
Plantago nivea	II(0.5-20)	*Sambucus nigra var. canadensis*	II(0.5-10)	*Trisetum virlettii*	I(0.5-5)
Eupatorium schaffneri	II(0.5-0.5)	*Stellaria cuspidata*	II(0.5-3)	*Helecho sp3*	I(0.5-0.5)
Trisetum altijugum	II(0.5-5)	*Geranium seemanni*	II(0.5-5)	*Archibaccharis hirtella*	I(0.5-2)
Stachys repens	II(0.5-1)	*Cerastium nutans*	II(0.5-0.5)	*Agave atrovirens*	I(0.5-0.5)
Bidens odorata	II(0.5-10)	*Drymaria laxiflora*	II(0.5-1)	*Phoradendron velutinum*	I(0.5-0.5)
Ranunculus donianus	II(0.5-0.5)	*Sigesbeckia jorullensis*	II(0.5-30)	*Viburnum stenocalyx*	I(0.5-1)
Bryum procerum	II(0.5-30)	*Senecio callosus*	II(0.5-10)		
Viola hookeriana	II(0.5-0.5)	*Pteridium aquilinium*	II(0.5-1)		
Achillea millefolium	II(0.5-10)	*Monotropa uniflora*	II(0.5-0.5)		

Gamochaeta americana	II(0.5-0.5)	*Salvia mexicana var. minor*	I(0.5-10)	
Trisetum spicatum	II(0.5-1)	*Monnina ciliolata*	I(0.5-5)	
Astragalus micranthus	II(0.5-1)	*Salvia microphylla var. neurepia*	I(0.5-1)	
Taraxacum officinale	II(0.5-0.5)	*Erodium cicutarium*	I(0.5-1)	
Gnaphalium semiamplexicaule	II(0.5-0.5)	*Stevia ovata var. ovata*	I(0.5-0.5)	
Muhlenbergia macroura	I(0.5-3)	*Plantago major*	I(0.5-0.5)	
Penstemon gentianoides	I(0.5-0.5)	*Piqueria pilosa*	I(1-1)	
Conyza schiedeana	I(0.5-0.5)	*Salvia fulgens*	I(0.5-10)	
Potentilla ranunculoides	I(0.5-0.5)	*Festuca amplissima*	I(0.5-0.5)	
Arenaria reptans	I(0.5-0.5)	*Pinus ayacahuite*	I(0.5-15)	
Prunella vulgaris	I(0.5-40)	*Brickelia scoparia*	I(0.5-1)	
Arceuthobium vaginatum	I(0.5-1)			

App. 3 Interviewed stakeholders for the perceptions on the environmental problematic and the relative importance of ecosystem services in the area.

Quest.	Date	Stakeholder group	Age	Gender	Profession
1	22/09/2006	Community	38	F	Domestic work, waitress
2	22/09/2006	Community	21	F	Waitress
3	22/09/2006	Community	46	M	Farmer, Ejido President
4	29/09/2006	Community	33	M	Worker and farmer
5	11/10/2006	Visitor	24	F	Domestic work
6	11/10/2006	Visitor	33	M	Plumber
7	11/10/2006	Seller	22	F	Domestic work, waitress
8	11/10/2006	Community	39	M	Bussinessman, Community guard
9	18/10/2006	Community	50	M	Federal government employee
10	15/01/2007	Community	38	F	Bussinessman
11	30/01/2007	Community	71	M	Local government employee
12	30/01/2007	Community	63	F	Bussinessman
13	30/01/2007	Community	35	M	Worker
14	30/01/2007	Visitor	40	M	Carpenter
15	31/01/2007	Authority	36	M	Local government employee
16	07/02/2007	Academy	35	M	Proffessor and researcher
17	07/02/2007	Academy	39	M	Proffessor and researcher
18	07/02/2007	Academy	29	F	Proffessor and researcher
19	08/02/2007	Authority	44	M	Local government employee
20	08/02/2007	Academy	40	M	Proffessor and researcher
21	08/02/2007	Academy	29	F	Proffessor and researcher
22	08/02/2007	Academy	43	M	Proffessor and researcher
23	09/02/2007	Authority	43	F	Local government employee
24	12/02/2007	Academy	53	M	Proffessor and researcher
25	12/09/2007	Ejido	26	M	Farmer
26	12/09/2007	Ejido	45	M	Industrial mechanic
27	26/10/2007	Farmer	75	M	Farmer, Ejido guard
28	30/10/2007	Community	78	M	Farmer
29	30/10/2007	Community	57	M	Community guard
30	30/10/2007	Resident	36	F	Bussinessman
31	23/11/2007	Community	57	M	Proffessor and researcher
32	28/11/2007	Community	38	M	Community guard
33	28/11/2007	Community	51	M	Community guard
34	04/12/2007	Community	49	F	Bussinessman
35	04/12/2007	Academy	48	M	Proffessor and researcher
36	10/03/2008	Authority	50	M	Farmer, local Government employee
37	12/03/2008	Community	34	F	Bussinessman
38	14/03/2008	Ejido	47	M	Farmer
39	25/03/2008	Community	78	M	Farmer

39A	25/03/2008	Community	34	M	Bussinessman
40	25/03/2008	Authority	50	M	Local Government employee
41	25/04/2008	Ejido	32	M	Farmer
42	29/04/2008	Resident	42	F	Bussinessman
43	29/04/2008	Community	55	M	Community guard
44	29/04/2008	Academy	46	F	Biologist
45	29/04/2008	Ejido	58	M	Guide
46	29/04/2008	Resident	52	M	Lawyer and teacher
47	30/04/2008	Community	68	M	Retired
48	07/05/2008	Ejido	50	M	Ejido guard
49	09/05/2008	Academy	51	M	Biologist, researcher
50	29/10/2008	NGO	37	M	Ecologist, consultant
51	11/02/2009	Academy	50	F	Proffessor and researcher
52	11/02/2009	Academy	49	M	Proffessor and researcher
53	11/02/2009	Academy	49	M	Proffessor and researcher
54	11/02/2009	Authority	53	M	Economist
55	20/02/2009	Authority	25	F	Architect
56	20/02/2009	Academy	30	M	Researcher

App. 4 Interviewed experts for the ponderation of the used forest quality variables

Expert	Profession	Field of expertise
1	Biologist	Ecology
2	Forest engineer	Ecological restoration of temperate forests
3	Biologist	Vegetation ecology
4	Biologist	Edaphology
5	Biologist	Ecosystem ecology
6	Edaphologist	Soil geography
7	Biologist	Natural resources and GIS
8	Biologist	Vegetation biogeography
9	Biologist	Edaphology
10	Biologist	Natural resources conservation
11	Forest engineer	Economy and forest management
12	Biologist	Ethnobiology, ecology
13	Biologist	Carbon, ecology, climate change
14	Biologist	Plant phisiology
15	Biologist	Forest ecology
16	Biologist	Biogeography and ecology
17	Biologist	Tropical ecology
18	Biologist	Ecology
19	Biologist	Temperate forests restoration
20	Forest engineer	Forest ecology
21	Agricultural engineer	Silviculture, forest ecology
22	Ecologist	Tropical ecology
23	Biologist	Ecological restoration and regeneration of forests
24	Forest engineer	Silviculture and forest economics
25	Forest ecologist	Forest restoration
26	Forest engineer	Forest governance and resource access
27	Biologist	Landscape ecology
28	Biologist	Forest ecology
29	Forest engineer	GIS+RS in forest management
30	Biologist	Landscape ecology, biodiversity research
31	Biologist	Urban and community forestry-ecosystem services
32	Biologist	Dendrochronology, carbon in forests

App. 5 Localization, vegetation type, slope and altitude of the field sample plots

#	Plot	Veg type	Association	Slope (%)	Coord. (N,W)	Altitude
1	CA-1	*A. religiosa*	Disturbed *A. religiosa*	45	2129389,468179	3260
2	CA-2	*Quercus*	*Q. rugosa-Q. laurina*	40	2132494,472136	2725
3	CA-3	*P. hartwegii*	*C. tolucensis-P. hartwegii*	20	2129151,464644	3610
4	CA-4	*P. hartwegii*	*C. tolucensis-P. hartwegii*	30	2128962,464504	3640
5	CA-5	*P. hartwegii*	*C. tolucensis-P. hartwegii*	35	2129970,466122	3620
6	CA-6	*P. hartwegii*	*P. hartwegii-F. tolucensis*	10	2127657,466422	3470
7	CA-7	*P. hartwegii*	*C. tolucensis-P. hartwegii*	45	2126680,466059	3655
8	CA-8	*P. hartwegii*	*C. tolucensis-P. hartwegii*	15	2126727,465834	3645
9	CA-10	*P. hartwegii*	*C. tolucensis-P. hartwegii*	5	2131275,468226	3510
10	CA-11	*P. hartwegii*	*C. tolucensis-P. hartwegii*	55	2130121,467720	3565
11	CA-12	*P. hartwegii*	*C. tolucensis-P. hartwegii*	75	2127617,466103	3465
12	CA-13	*P. hartwegii*	*C. tolucensis-P. hartwegii*	35	2128214,466610	3425
13	CA-14	*A. religiosa*	*A. religiosa-T. delicatulum*	25	2129921,467581	3405
14	CA-15	*A. religiosa*	*A. religiosa-T. delicatulum*	65	2130006,468004	3455
15	CA-16	*A. religiosa*	*A. religiosa-T. delicatulum*	50	2130258,468170	3500
16	CA-17	*A. religiosa*	*A. religiosa-T. delicatulum*	60	2130960,468418	3490
17	CA-18	*P. hartwegii*	*C. tolucensis-P. hartwegii*	5	2131000,468236	3500
18	CA-19	*A. religiosa*	*A. religiosa-T. delicatulum*	40	2131662,468991	3295
19	CA-20	*A. religiosa*	*A. religiosa-T. delicatulum*	20	2128835,468337	3275
20	CA-21	*A. religiosa*	Disturbed A. religiosa	35	2128723,468092	3310
21	CA-22	*A. religiosa*	Disturbed A. religiosa	45	2128475,467974	3370
22	CA-23	*A. religiosa*	Disturbed A. religiosa	20	2128037,467865	3435
23	CA-24	*P. hartwegii*	*C. tolucensis-P. hartwegii*	40	2127763,467546	3540
24	CA-25	*Mixed*	Plantation-*Pinus* spp. forest	10	2130483,470382	3090
25	CA-26	*A. religiosa*	Disturbed A. religiosa	50	2130019,469692	3145
26	CA-27	*A. religiosa*	Disturbed A. religiosa	5	2130126,470133	3140
27	CA-28	*A. religiosa*	Disturbed A. religiosa	20	2130879,470850	3120
28	CA-29	*Quercus*	*Q. laurina-Q. rugosa*	70	2132589,471831	2835
29	CA-30	*Mixed*	Plantation-*Pinus* spp. forest	70	2132793,471907	2880
30	CA-31	*A. religiosa*	*A. religiosa-T. delicatulum*	60	2128961,466622	3455
31	CA-32	*A. religiosa*	*A. religiosa-T. delicatulum*	40	2129063,466456	3505
32	CA-33	*P. hartwegii*	*C. tolucensis-P. hartwegii*	40	2129121,466210	3560
33	CA-34	*P. hartwegii*	*P. hartwegii-F. tolucensis*	17	2128835,465849	3804
34	CA-35	*Mixed*	*Q. rugosa-Q. laurina*	65	2132112,470091	2955
35	CA-36	*Mixed*	*Q. rugosa-Q. laurina*	75	2132053,470452	2910
36	CA-37	*Quercus*	*Q. rugosa-Q. laurina*	50	2132235,471046	2870
37	CA-38	*Quercus*	*Q. laurina-Q. rugosa*	55	2132465,471629	2780
38	CA-39	*A. religiosa*	*A. religiosa-T. delicatulum*	33	2130912,471105	2802
39	CA-40	*Quercus*	*Q. laurina-Q. rugosa*	55	2132243,472022	2812
40	CA-41	*Quercus*	*Q. laurina-Q. rugosa*	35	2132467,472437	2700
41	CA-42	*Quercus*	*Q. laurina-Q. rugosa*	50	2132851,472759	2685
42	CA-43	*A. religiosa*	*A. religiosa-T. delicatulum*	5	2129990,468594	3273
43	CA-44	*A. religiosa*	*A. religiosa-T. delicatulum*	55	2128946,467412	3370
44	CA-45	*P. hartwegii*	*P. hartwegii-F. tolucensis*	20	2127856,464383	3598
45	CA-46	*P. hartwegii*	*P. hartwegii-C. tolucensis*	30	2127463,464394	3600
46	CA-47	*P. hartwegii*	*P. hartwegii-C. tolucensis*	15	2127410,464787	3558
47	CA-48	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	65	2129724,466659	3500
48	CA-49	*P. hartwegii*	*P. hartwegii-F. tolucensis*	35	2127168,466364	3610
49	CA-50	*P. hartwegii*	*C. tolucensis-P. hartwegii*	45	2127679,468591	3667
50	CA-51	*P. hartwegii*	*P. hartwegii-F. tolucensis*	7	2127984,469679	3538
51	CA-52	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	30	2128145,470274	3430
52	CA-53	*A. religiosa*	Disturbed *A. religiosa*	60	2130067,470895	3133
53	CA-54	*A. religiosa*	*A. religiosa-T. delicatulum*	30	2131213,469573	3101
54	CA-55	*Mixed*	*Q. rugosa-Q. laurina*	40	2131849,470151	2996
55	CA-56	*A. religiosa*	*Disturbed A. religiosa*	50	2132487,470173	3220
56	CA-57	*A. religiosa*	*A. religiosa*-R. *angulifolia*	30	2132651,469760	3310
57	CA-58	*P. hartwegii*	*C. tolucensis-P. hartwegii*	55	2130193,466236	3750
58	CA-59	*A. religiosa*	*A. religiosa-T. delicatulum*	45	2128314,467060	3430
59	SC-1	*P. hartwegii*	*P. hartwegii-C. tolucensis*	32	2126280,467219	3650
60	SC-2	*A. religiosa*	Disturbed *A. religiosa*	15	2129321,468232	3218

61	SC-3	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	15	2129589,468772	3127
62	SC-4	*P. hartwegii*	*P. hartwegii-F. tolucensis*	40	2124688,469786	3465
63	SC-5	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	5	2129526,468051	3200
64	SC-6	*P. hartwegii*	*P. hartwegii-F. tolucensis*	30	2129192,467176	3340
65	SC-7	*Mixed*	*Q. rugosa-Q. laurina*	19	2129747,473775	2780
66	SC-8	*P. hartwegii*	*P. hartwegii-F. tolucensis*	2	2125015,470327	3480
67	SC-9	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	5	2125481,470660	3356
68	SC-10	*P. hartwegii*	*P. hartwegii-F. tolucensis*	3	2126311,472256	3121
69	SC-11	*Mixed*	*Q. rugosa-Q. laurina*	15	2131223,472628	2830
70	SC-12	*A. religiosa*	*A. religiosa-T. delicatulum*	25	2127392,472962	3000
71	SC-13	*A. religiosa*	*A. religiosa-R. angulifolia*	35	2129239,471563	3045
72	SC-14	*A. religiosa*	*A. religiosa-R. angulifolia*	18	2129234,472964	2965
73	SC-15	*P. hartwegii*	*P. hartwegii-F. tolucensis*	8	2124001,469400	3402
74	SC-16	*A. religiosa*	*A. religiosa-R. angulifolia*	30	2128364,472963	2900
75	SC-17	*Quercus*	*Q. laurina-Q. rugosa*	33	2131831,473574	2650
76	SC-18	*P. hartwegii*	*P. hartwegii-C. tolucensis*	19	2127244,470006	3360
77	SC-19	*A. religiosa*	Disturbed *A. religiosa*	35	2126534,470859	3370
78	SC-20	*A. religiosa*	*A. religiosa-R. angulifolia*	45	2128521,470684	3220
79	SC-21	*P. hartwegii*	*P. hartwegii-C. tolucensis*	20	2126343,467277	3585
80	SC-22	*P. hartwegii*	*P. hartwegii-C. tolucensis*	32	2126776,467034	3575
81	SC-23	*Quercus*	*Q. rugosa-Q. laurina*	45	2132384,472329	2685
82	SC-24	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	37	2129216,470976	3170
83	SC-25	*A. religiosa*	*A. religiosa-R. angulifolia*	20	2128683,471374	3230
84	SC-26	*P. hartwegii*	Plantation-Pinus forest	2	2129582,474290	2841
85	SC-27	Mixed	*Q. rugosa-Q. laurina*	38	2130044,473734	2820
86	SC-28	*A. religiosa*	*A. religiosa-R. angulifolia*	22	2125336,470132	3509
87	SC-29	*Quercus*	*Q. rugosa-Q. laurina*	36	2132836,472084	2700
88	SC-30	Mixed	Plantation-*Pinus* spp. forest	2	2133571,473180	2540
89	SC-31	*A. religiosa*	Disturbed *A. religiosa*	2	2129854,469039	3115
90	SC-32	*P. hartwegii*	*P. hartwegii-F. tolucensis*	35	2127760,466336	3430
91	SC-33	*P. hartwegii*	*C. tolucensis-P. hartwegii*	5	2127587,465353	3540
92	SC-34	*P. hartwegii*	*P. hartwegii-C. tolucensis*	30	2126947,466433	3621
93	SC-35	*P. hartwegii*	*P. hartwegii-F. tolucensis*	30	2125797,467649	3690
94	SC-36	*P. hartwegii*	*C. tolucensis-P. hartwegii*	4	2125776,467862	3679
95	SC-37	*P. hartwegii*	*P. hartwegii-F. tolucensis*	15	2124617,468411	3455
96	SC-38	*A. religiosa*	*A. religiosa-R. angulifolia*	60	2133085,471635	2975
97	SC-39	*Quercus*	*Q. laurina-Q. rugosa*	55	2133443,471134	2960
98	SC-40	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	5	2128280,470625	3355
99	SC-41	*A. religiosa*	*A. religiosa-R. angulifolia*	85	2128836,471693	3195
100	SC-42	*P. hartwegii*	*P. hartwegii-C. tolucensis*	30	2125246,469598	3580
101	SC-43	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	30	2125404,469321	3520
102	SC-44	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	3	2130453,471676	3110
103	SC-45	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	20	2131091,471165	3070
104	SC-46	*P. hartwegii*	*P. hartwegii-C. tolucensis*	15	2125476,468494	3580
105	SC-47	*P. hartwegii*	*P. hartwegii-F. tolucensis*	60	2124912,469178	3520
106	SC-48	*P. hartwegii*	*Plantation-Pinus forest*	10	2128863,472908	2960
107	SC-49	*A. religiosa*	*A. religiosa-R. angulifolia*	6	2129059,472419	3130
108	SC-50	*P. hartwegii*	*P. hartwegii-C. tolucensis*	40	2126707,469245	3570
109	SC-51	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	40	2129587,470635	3190
110	SC-52	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	15	2126948,472438	3165
111	SC-53	*P. hartwegii*	*P. hartwegii-C. tolucensis*	30	2126076,468008	3710
112	SC-54	*Quercus*	*Q. rugosa-Q. laurina*	25	2131101,473351	2750
113	SC-55	*Quercus*	*Q. laurina-Q. rugosa*	45	2131144,473602	2630
114	SC-56	*P. hartwegii*	*P. hartwegii-C. tolucensis*	3	2122928,470675	3535
115	SC-57	*P. hartwegii*	*P. hartwegii-C. tolucensis*	15	2125165,467222	3760
116	SC-58	*A. religiosa*	*A. religiosa-T. delicatulum-A. elongata*	35	2128428,468687	3615

App. 6 Experts table questionnaire for the ponderation of forest quality indicator and verifiers.

Profession:____

Area of research:____

Forest quality

Forest quality is a criteria and indicators initiative for the assessment of sustainable forest management. The criteria and indicators fall in three overlapping categories: *forest authenticity, environmental benefits and social and economic benefits*. Forest quality is defined as the "significance and value of all ecological, social and economic components of the forest landscape". It measures forest conditions at the **landscape level**, giving more space to consider the way in which people, forests and ecology interact in a region (WWF and IUCN, 1999).

Pairwise comparison matrix (multicriteria evaluation)

This kind of evaluation is made one by one (row vs. column) and always taking as a reference the rows. For example, if the variable "species richness" is being evaluated against "Shannon's diversity index" and it is considered that "species richness" is moderately less important than "Shannon's diversity index", then the cell should be filled with 1/3. On the contrary, if it is considered that "species richness" is moderately more important than "Shannon's diversity index", the cell should be filled with 3. For variables having equal importance the cell should be filled with 1.

Considering the definitions above, which verifiers and indicators do you consider more important to assess the "quality of a forest"? (An explanation of the used variables is on the third page)

Forest composition verifiers

	Species richness	Shannon´s diversity index	Simpson´s diversity index	Ratio of native vs. exotic or weed plant species
Species richness	1			
Shannon´s diversity index		1		
Simpson´s diversity index			1	
Native vs. exotic or weed plant species ratio				1

(Less important) 1/6 1/5 1/4 1/3 1/2 1 2 3 4 5 6 (More important)

Forest process verifiers

	Dead wood cover	Standing dead trees	Regeneration (#trees <5cm DAP)
Dead wood cover	1		
Standing dead trees		1	
Regeneration (#trees <5cm DBH)			1

Forest pattern verifiers

	DBH size distribution	Tree heights distribution	Basal area	Tree density	Canopy cover
DBH size distribution	1				
Tree heights distribution		1			
Basal area			1		
Tree density				1	
Canopy cover					1

Forest function (soil and forest floor) verifiers

	pH (0-15cm)	Organic matter content (%, 0-15cm)	Leaf litter cover
pH (0-15cm)	1		
Organic matter content (%, 0-15cm)		1	
Leaf litter cover			1

Tree health verifiers

	Presence of parasite tree epiphytes	Presence of defoliator/bark beetles	Foliage color
Presence of parasite tree epiphytes	1		
Presence of defoliator/bark beetles		1	
Foliage color			1

Forest area and fragmentation verifiers

	Area of forest type	Distance to roads	Number of fragments per forest type
Area of forest type	1		
Distance to roads		1	
Number of fragments per forest type			1

Forest management verifiers

	Species used for reforestation	Cover of recharge basins	Litter cover	Presence and indicators of grazers	Human affluence
Species used for reforestation	1				
Cover of recharge basins		1			
Litter cover			1		
Presence and indicators of grazers				1	
Human affluence					1

Forest ecosystem services verifiers

	Useful plant species	CO_2 sequestrationn (Carbon content in trees)	Rec. value	Water infil. cap.
Useful plant species	1			
CO_2 sequestrationn (Carbon content in trees)		1		
Recreational value			1	
Water infiltration capacity				1

Forest quality general indicators

	Composition	Processes	Pattern	Function	Tree health	Area and fragmentation	Management	Ecosystem services
Composition	1							
Processes		1						
Pattern			1					
Function				1				
Tree health					1			
Area and fragmentation						1		
Management							1	
Ecosystem services								1

Comments:

Definition of the variables used in the pairwise comparison matrixes

Forest composition verifiers
Plant species richness: Total number of plant species present in a given area.
Diversity: Total number of plant species plus their proportional abundance in a given area.
Simpson diversity index: To evaluate the degree of dominance between species.
Shannon diversity index: To evaluate the uniformity in the relative abundance of the present plant species.
Weed+exotic/native plant species ratio: Total weeds or exotic plant species divided by the total number of native species.

Forest process verifiers
Dead wood: Logs and dead wood in general on the surface. The relative percentage cover in relation to the total plot area and the degree of decomposition is evaluated.
Standing dead trees: Standing trees without foliage and clearly dead.
Regeneration: Number and relative percentage cover of saplings in the plot (with DBH <5 cm)

Forest pattern verifiers
DBH distribution: Variation and relative proportion of tree diameters (DBH ≥5 cm).
Tree heights distribution: Variation and relative proportion of tree heights.
Basal area: The area of the sampling plot occupied by the cross-section of tree trunks and stems at their base.
Density: Total number of trees (DBH ≥5cm) inside the sampling plot.
Forest canopy cover: Percentage cover of the crowns of the trees in the canopy layer.

Forest function (soil) verifiers
pH: The pH of soil water in the subsurface soil layer, 0 to 15 cm. The sample is compound taken randomnly inside the sampling plot.
Organic matter: In a sample like the latter point, the carbon percentage is calculated.
Leaf litter cover: The relative cover of leaf litter on the uppermost soil layer.

Tree health verifiers
Presence of parasite epiphytes: Number of trees with mistletoe per individual tree.
Presence of bark beetles**:** Number of trees affected from bark beetles or leaf eating insects.
Foliage color**:** Per individual tree in the sampling plot it's estimated if the foliage color is green or decolorated (brown, yellow, red; independent of seasonal changes).

Forest area and fragmentation verifiers
Area of forest type: Total area per forest type (e.g. *Abies*, *Quercus*, *Pinus*, etc.)
Distance to roads**:** Approximate distance from the sampling plot to paved and unpaved roads.
Number of fragments per forest type: Total number of polygons or fragments occupied by the forest type.

Forest management verifiers
Used species for reforestation: It is evaluated if the species used for reforestation coincide with the naturally present forest type.
Percent cover of recharge tubs: The recharge tubs are excavations of 1.5 m long, 0.5 m wide and 0.5 m deep, which are intended to retain rain water and promote infiltration.
Garbage cover: An estimation of the cover of garbage (plastics, paper, cans; waste material evidently deposited by humans) in relation to the sampling plot.
Degree of cattle intensity: Cattle grazing indicators like feces, grazed plants or the animals themselves (cows, sheep, horses, goats) in the sampling plot, assessed in a 1 to 4 scale.
Human affluence: In an arbitrary scale from 1 to 4, it is estimated the probability of how often and how many people could visit the sample plot.

Forest ecosystem services verifiers
Useful plant species: Total number timber and non-timber useful plant species.
CO_2 sequestrationn (carbon content in trees): Using the total wood volume in the sampling plot, the carbon content is estimated.
Recreational value: In an arbitrary scale of 0 to 10, the value of scenic beauty, accessibility, and safety are assessed.
Water infiltration capacity: (percent forest canopy cover + percent vegetation cover + percent cover of recharge tubs + altitude + aspect) – (percent naked soil cover + slope)

App. 7 Additional details on the procedure for the pairwise comparisons performed by experts in order to provide weights for the indicators and verifiers for forest quality assessment. A worked example is also provided.

In this example (steps 1 to 6 below), letters A, B and C represent different verifiers (e.g. regarding forest composition: species richness, Shannon diversity index, and alien vs. native plant species ratio). Once the specialist assigns the weights for every pair of variables (1), the opposite triangle of the matrix is filled with its inverse (2), and the values obtained are added by column. Then, every number in the cells is divided by the corresponding column sum (3). The resulting values are in turn summed and averaged (4), representing verifier weights in a 0 to 1 scale. To assess the consistency of the information given by specialists (e.g. not randomly assigned), in step (5) every value in the matrix is multiplied by the average obtained in step (4) and the results are summed. The next step (6) consists of dividing the result from step (5) over the result from step (4). The results are then averaged to get λ (7). In the next-to-last step (8), λ and the number of variables in the matrix are used to obtain the consistency index (CI), which is then divided by a constant (Random Index: RI) that depends on the number of elements being compared in a matrix (SAATY 1977). For n=3 RI=0.58; n=4 RI=0.9; n=5 RI=1.12; n=6 RI=1.24. If the consistency ratio (CR) is less than 0.1, there are no inconsistencies.

Step 1. Expert fills the upper half of the matrix

	A	B	C
A	1	2	½
B		1	1/3
C			1

Step 2. The complementary lower half of the matrix is filled with the inverse values. The column values are summed.

	A	B	C
A	1	2	½
B	½	1	1/3
C	2	3	1
	3.5	6	1.8

Step 3. Every value in the rows is divided by the column total.

1/3.5, 2/6, 0.5/1.8
0.5/3.5, 1/6, 0.33/1.8
2/3.5, 3/6, 1/1.8

Step 4. The divided rows are summed and averaged.

$0.2857 + 0.3 + 0.27 = 0.8557/3 = 0.28523$
$0.142857 + 0.16 + 0.16 = 0.462857/3 = 0.154$
$0.57142857 + 0.5 + 0.55 = 1.6214/3 = 0.5404$

Step 5. The averages are then multiplied by every row value and summed.

$0.28523*1 + 0.154*2 + 0.5404*1/2 = 0.86325$
$0.28523*0.5 + 0.154*1 + 0.5404*0.3 = 0.45661$
$0.28523*2 + 0.154*3 + 0.5404*1 = 1.57286$

Step 6. Divide the result from step (5) by the result from step 4.

$0.8623/0.28523 = 3.0264$
$0.45661/0.154 = 2.9649$
$1.57286/0.5404 = 2.91054$

Step 7. Average results to get λ.

$\lambda = (3.0264 + 2.9649 + 2.91054)/3 = 2.96728$

8. Calculate consistency index (CI)

$CI = (\lambda - n)/(n - 1) = (2.96728 - 3)/2 = -0.01636$

9. Calculate consistency ratio (CR)

$CR = CI/RI = -0.01636/0.58 = -0.0282$

App. 8 Stakeholders questionnaire.

MADE BY: VÍCTOR ÁVILA AKERBERG

NATIONAL AUTONOMOUS UNIVERSITY OF MEXICO
SCIENCES FACULTY
UNIVERSITÄT VON FREIBURG

DATE: __/__/___QUESTIONNAIRE #: ______INTERVIEWER: ____________

Documenting expresions, perceptions and thoughts, with this questionnaire it is pretended to get closer to the stakeholders of the conservation area of the Magdalena Contreras Muncipality (CAMC) to recognize and analyze the environmental problematic, the valoration and use of the goods and services that the forests in the area provide, in order to generate management strategies towards sustainable develoment.

1. INTERVIEWED´S IDENTIFICATION

1.2 Name ____

1.3 Age____________ Gender: Male ( ) Female ( )

1.4 Scholarity: Primary ( ) Secondary ( ) High school ( ) University ( ) Other ( )____________

1.5 Profession_________________________

1.6 Home______________Originary from the area? Yes ( ) No ( ) Where do you come from?_____________Are you a member of an agrarian community (community or ejido) Yes Which?_____________ No ( )

2. ALLOWED ACTIVITIES AND RECOGNITION OF THE AREA AS PROTECTED

2.1 Do you know the conservation area of the Magadalena Contreras Municipality? Yes____ No____

2.2 Do you know where it starts and how big it is? Yes___ start____________Extension_____No___

2.3 Do you know which of the following activities are allowed?

Acitivity	Yes	No	Activity	Yes	No
Tree felling			Animal recollection		
Bonfires			Walking and exercise		
Mushroom gathering			Cattle management		
Horse riding			Camping		
Motocross			Fuel wood recollection		
Plant and fruits recollection			Gotcha (paint ball war)		
Mountain bicycling			Fishing		
Other, which? _______________			Other, which?___________		

3. RELATIVE IMPORTANCE OF THE GOODS AND SERVICES PROVIDED

3.1 How important do you think are the following goods and services provided by the forests in the CAMC?

Good or service	Importance				Good or service	Importance			
	H	M	L	N		H	M	L	N
Soil maintenance, erosion control					Adventure tourism				
Clean water					Sports				
CO2 fixation					Inspiration for artistas, painters, musicians, etc.				
Habitat for animals					Fuelwood				
Habitat for plants					Sacred place				
Climate stabilization					Employment source				
Walking					For cattle management				
Camping					For scientific research				
Game hunting					To relax				
Home for local people					Other_____________________				
For environmental education					Other_____________________				

4. PERCEPTIONS ON THE ENVIRONMENTAL PROBLEMATIC

4.1 Do you notice a difference in the landscape now and before?

____

____

4.2 What could you find before that no longer exists or that it is difficult to find?

____

____

How long time ago?________________________

4.3 Do you think that the area is well protected (in good health)?

Yes ( ) No ( )

Why?____

4.4 What level of disturbance/influence have the following factors on the environmental problematic of the area (in the protection of the forests in the area)? H=high, M=medium, L=low, N=none

	Disturbance /influence					Disturbance /influence			
Factor	**H**	**M**	**L**	**N**	**Factor**	**H**	**M**	**L**	**N**
Air pollution					Motocross				
Litter					Gotcha (paint ball war)				
Tree plagues					Cattle management				
Visitors					Hunting				
Lumberjacks, loggers					Soccer fields				
Authorities					Irregular human settlements				
Groups of interest within ejidos and communities					Other, which?_______				
Land tenure problems					Other, which?_______				

4.5 What do you think about conservation? Why should we conserve the forests of this area?

____

4.6 Who has to do the conservation? How could we do to conserve the forests of this area?

____

5. ENVIRONMENTAL EDUCATION

5.1 What do you feel when you are/go in/to an area like this/that?

____

5.2 Do you consider that the people has the knowledge of the importance to keep in good health/form/conserved the forests in the area? Yes ( ) No ( )

Why?____

5.3 What do you think it could be done to inform the people about the area?

Workshops () Guided tours () Panphlets () Books () Signs () Conferences () Courses ()

Other ( ) What?____________________________________

5.4 And you in particular, is there something you would like to know/know more about the forests in the area?

	Yes		Yes
What animals is possible to find		If air pollution affects the forests	
What plants is possible to find		The forests 'health	
What mushrooms is possible to find		The owners of the land	
Which animals are dangerous		How to protect the forests	
Which plants and mushrooms are edible		Other__________________	
Trekking tours		Other__________________	
How much water there is		Other__________________	
The quality of the water		Other__________________	

6. COMMENTS AND SUGGESTIONS

____

____

11. References

ACEVES-QUESADA, LÓPEZ-BLANCO, J. & MARTIN DEL POZZO, A.L. 2006. Determinación de peligros volcánicos aplicando técnicas de análisis multicriterio y SIG en el área del Nevado de Toluca, centro de México. Revista Mexicana de Ciencias Geológicas 23 (2):113-124.

AGUILAR, A. 1998: Plantas medicinales del herbario del IMSS; su distribución por enfermedades. - Instituto Mexicano del Seguro Social, México, D.F., 167 S.

AGUILAR, A.G., EZCURRA, E., GARCÍA, T., MAZARI-HIRIART, M. & PISANTY, I. 1995: The Basin of Mexico. In: KASPERSON J.X., KASPERSON R.E. & TURNER B.L.I. (Eds.): Regions at risk: comparisons of threatened environments United Nations University Press, Tokyo.

ALMEIDA-LEÑERO, L. 1997: Vegetación, fitogeografía y paleoecología del zacatonal alpino y bosques montanos de la región central de México. PhD Thesis, University of Amsterdam, 255 S.

ALMEIDA-LEÑERO, L., NAVA-LÓPEZ, M., RAMOS, A., ESPINOSA, M., ORDÓÑEZ, M.D.J. & JUJNOVSKY-ORLANDINI, J. 2007. Servicios Ecosistémicos en la cuenca del río Magdalena, Distrito Federal, México. Gaceta Ecológica del Instituto Nacional de Ecología, SEMARNAT Número especial 84-85:53-64.

ALPÍZAR, F., BLACKMAN, A. & PFAFF, A. 2007. Payments for Ecosystem Services. Why Precision and Targeting Matter. Resources Spring:21-23.

ÁLVAREZ-ROMÁN, K.E. 2000: Geografía de la educación ambiental: algunas propuestas de trabajo en el Bosque de los Dinamos, área de conservación ecológica de la Delegación Magdalena Contreras. Tesis de Licenciatura en Geografía, Facultad de Geografía, UNAM, México, D.F., 127 S.

ÁLVAREZ DEL CASTILLO, C. 1987: La vegetación de la Sierra del Ajusco. Cuaderno de Trabajo 33. - Departamento de Prehistoria, Instituto Nacional de Antropología e Historia, México, D.F., 74 S.

ANDERSON, J.E. 1991. A conceptual framework for evaluating and quantifying naturalness. Conservation Biology 5:347-352.

APPS, M.J., KURZ, R.J., LUXMOORE, L.O., NILSSON, R.A., SEDJO, R.A., SCHMIDT, R., SIMPSON, L.G. & VINSON, L.T. 1993: Boreal Forests and Tundra. In: WISNIEWSKI J. & SAMPSON R.N. (Eds.): Terrestrial Biospheric Carbon Fluxes: Quantification of Sinks and Sources of CO2, pp. 39-53. Kluwer Academic Publishers, Netherlands.

AVERY, T. & BURKHART, H. 1994: Forest Measurements. - McGraw Hill, Inc., New York, 406 S.

ÁVILA-AKERBERG, V. 2002: La vegetación en la cuenca alta del río Magdalena: un enfoque florístico, fitosociológico y estructural. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México, D.F., 90 S.

ÁVILA-AKERBERG, V. 2004: Autenticidad de los bosques en la cuenca alta del río Magdalena. Diagnóstico hacia la restauración ecológica. Tesis de Maestría en Restauración Ecológica, Facultad de Ciencias, UNAM, México D.F., 110 S.

ÁVILA-AKERBERG, V., GONZÁLEZ-HIDALGO, B., NAVA-LÓPEZ, M. & ALMEIDA-LEÑERO, L. 2008. Refugio de fitodiversidad en la Ciudad de México, el caso de la cuenca del río Magdalena. J. Bot. Res. Inst. Texas 2 (1):605-619.

AVILA, C.H., AGUIRRE, J.R. & GARCÍA, E. 1994. Variación estructural en el bosque de oyamel (*Abies hickelii* Flous & Gaussen) en relación con factores ambientales en el Pico de Orizaba, México. Investigaciones Agrarias, Sistema de Recursos Forestales 3 (1):5-17.

BAKER, W.L. 1992. The landscape ecology of large disturbances in the design and management of nature reserves. Landscape Ecology 7:181-194.

BALVANERA, P., DAILY, G.C., EHRLICH, P.R., RICKETTS, T.H., BAILEY, S.A., KARK, S., KREMEN, C. & PEREIRA, H. 2001. Conserving biodiversity and ecosystem services. Science 291 (5511):2047-2048.

BEETLE, A.A. 1983: Las Gramíneas de México 1. - Comisión Técnico Consultiva para la Determinación de los Coeficientes de Agostadero-SARH, México, 260 S.

BEETLE, A.A. 1987: Las Gramíneas de México 2. - Comisión Técnico Consultiva para la Determinación de los Coeficientes de Agostadero-SARH, México, 344 S.

BINGHAM, G., BISHOP, R., BRODY, M., BROMLEY, D., CLARK, E., COOPER, W., COSTANZA, R., HALE, T., HAYDEN, G., KELLERT, S., NORGAARD, R., NORTON, B., PAYNE, J., RUSSELL, C. & SUTER, G. 1995. Issues in ecosystem valuation: improving information for decision making. Ecological Economics 14:73–90.

BLACK, C.A. 1965: Methods of soil analysis. Volume I. - American Society of Agronomy, Madison

BOJORGE-GARCÍA, M.G. 2002: Ecología de comunidades algales en una localidad del río la Magdalena, D.F. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México, D.F., 86 S.

BONILLA-BARBOSA, J.R. & VIANA-LASES, J.A. 1997: Listados florísticos de México. XIV Parque Nacional Lagunas de Zempoala. - Instituto de Biología, UNAM, México D.F., 31 S.

BOUMAN, B.A.M., VAN KEULEN, H., VAN LAAR, H.H. & RABBINGEN, R. 1996. The 'School of de Wit' crop growth simulation models: A pedigree and historical overview. Agricultural Systems 52:171-198.

BRAUN-BLANQUET, J. 1932: Plant sociology, the study of plant communities. - McGraw Hill, New York, 439 S.

BROWN, S. & LUGO, A. 1992. Aboveground biomass estimates for tropical moist forests of the Brazilian Amazon. Interciencia 17:8-18.

BUSTILLOS-HERRERA, J.A., VALDEZ-LAZALDE, J.R., ALDRETE, A. & GONZÁLEZ-GUILLÉN, M.J. 2007. Aptitud de terrenos para plantaciones de eucalipto

(*Eucalyptus grandis* Hill ex Maiden): Definición mediante el proceso de análisis jerarquizado y SIG. Agrociencia 41:787-796.
CAIRNS, J., JR. 1975: Quantification of biological integrity. In: BALLENTINE R.K. & GUARRAIE L.J. (Eds.): The integrity of water: a symposium, pp. 171-185. U.S. Environmental Protection Agency, Washington, D.C.
CAIRNS, J., JR., MCCORMICK, P.V. & NIEDERLEHNER, B.R. 1993. A proposed framework for developing indicators of ecosystem health. Hydrobiologia 263 (1):1-44.
CAIRNS, J., JR. & PRATT, J.R. 1995: The Relationship Between Ecosystem Health and Delivery of Ecosystem Services. In: RAPPORT D.J., GAUDET C. & CALOW P. (Eds.): Evaluating and Monitoring the Health of Large Scale Ecosystems, pp. 273-294. Springer Verlag, Heidelberg.
CAIRNS, M.A., BROWN, S., HELMER, E.H. & BAUMGARDNER, G.A. 1997. Root biomass allocation in the world´s upland forest. Oecologia 111:1-11.
CAIRNS, M.A., DIRZO, R. & ZADROGA, F. 1995. Forests of Mexico: A diminishing resource? Journal of Forestry 93 (7):21-24.
CALDERÓN DE RZEDOWSKI, G.C. & RZEDOWSKI, J. 2001: Flora Fanerogámica del Valle de México. - CONABIO, Instituto de Ecología A.C., UNAM, México, D.F., 1406 S.
CANTORAL-URIZA, E.A., ALMEIDA-LEÑERO, L., CIFUENTES-BLANCO, J., PANIAGUA-LEÓN, L., LUIS-MARTÍNEZ, M.A., NIETO-MONTES DE OCA, A., MENDOZA-HERNÁNDEZ, P.E., VILLARRUEL-ORDAZ, J.L., AGUILAR, V., ÁVILA-AKERBERG, V., OLGUÍN, H. & PUEBLA, F. 2009. La diversidad de una cuenca en la Ciudad de México. Ciencias 94:28-33.
CANTORAL-URIZA, E.A., CARMONA-JIMÉNEZ, J., GONZÁLEZ-GONZÁLEZ, J. & MONTEJANO-ZURITA, G. 1999: Algas indicadoras de la calidad del agua en el río la Magdalena, Delegación Magdalena Contreras, Distrito Federal, México. In: Tomo 1: AIRE-AGUA, pp. 299-332. CONSERVA, Consejo de estudios para la restauración y valoración ambiental, México, D.F.
CARRERA-HERNÁNDEZ, J.J. 2007: Spatio-temporal analysis of aquifer recharge and groundwater potentiometric levels in the Basin of Mexico through the development of a regional database and an open source tool for groundwater flow modelling. PhD Dissertation, Department of Civil Engineering and Applied Mechanics, McGill University, 353 S.
CASTILLO, A. 2000. Ecological Information System: Analyzing the Communication and Utilization of Scientific Information in Mexico. Environmental Management 24 (4):383-392.
CBD 1997: Convention on Biological Diversity. Recommendations for a core set of indicators of biological diversity. UNEP/CBD/SBSTTA/3/Inf.13, Montreal, Canada, CBD Secretariat
CEBALLOS-SILVA, A. & LÓPEZ-BLANCO, J. 2003. Delineation of suitable areas for crops using a Multi-Criteria Evaluation approach and land use/cover mapping: a case study in Central Mexico. Agricultural Systems 77 (2):117-136.

CEBALLOS, G., ARROYO-CABRALES, J., MEDELLÍN, R.A. & DOMÍNGUEZ-CASTELLANOS, Y. 2006. Lista actualizada de los mamíferos de México. Revista Mexicana de Mastozoología 9:21-70.

CLARK, M.J., URBANSKA, K.M., WEBB, N.R. & EDWARDS, P.J. 1997: Ecological restoration - the magnitude of the challenge: an outsiders view. In: Restoration Ecology and Sustainable Development, pp. 353-377. Cambridge University Press, Cambridge.

COLLINS, F.C. & BOLSTAD, P.V. 1996 A comparison of spatial interpolation techniques in temperature estimation: In, Proceedings of the Third International Conference/Workshop on Integrating GIS and Environmental Modeling. National Center for Geographic Information Analysis (NCGIA), Santa Barbara, California

Santa Fe, New Mexico

CONABIO 2006: Capital Natural y Bienestar Social. - Comisión Nacional para el Uso y Conservación de la Biodiversidad, México, 71 S.

CONABIO 2009: Biodiversity Conservation in Mexico. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad

CONAFOR 2006: Desarrollo Forestal Sustentable en México. Avances 2001-2006. Comisión Nacional Forestal, México, D.F.

CORBERA, E., GONZÁLEZ-SOBERANIS, C. & BROWN, K. 2009. Institutional dimensions of Payments for Ecosystem Services: An analysis of Mexico's carbon forestry programme. Ecological Economics 68 (3):743-761.

CORENADER 2003: El Suelo de Conservación del Distrito Federal. Comisión de Recursos Naturales y Desarrollo Rural, Secretaría de Medio Ambiente del Distrito Federal. In: http://www.sma.df.gob.mx/sma/corenader

CORNEJO-TENORIO, G., CASAS, A., FARFÁN, B., VILLASEÑOR, J.L. & IBARRA-MANRÍQUEZ, G. 2003. Flora y vegetación de las zonas núcleo de la Reserva de la Biosfera Mariposa Monarca, México. Boletín de la Sociedad Botánica de México 73:43-62.

CORRAL-RIVAS, J.J., BARRIO-ANTA, M., AGUIRRE-CALDERÓN, O.A. & DIÉGUEZ-ARANDA, U. 2007. Use of stump diameter to estimate diameter at breast height and tree volume for major pine species in El Salto, Durango (Mexico). Forestry 80 (1):29-40.

COSÍO-VILLEGAS, D. 2004: Nueva Historia Mínima de México. - El Colegio de México, A.C., México D.F., 315 S.

COSTANZA, R., DE GROOT, R.S., FARBERPARALLEL, S., GRASSO, M., HANNON, B., LIMBURGSTAR, K., NAEEM, S., O´NEILL, R., PARUELO, J., RASKIN, R., SUTTON, P. & VAN DEN BELT, M. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253-260.

COSTANZA, R., NORTON, B.G. & HASKELL, B.D. (Eds.), 1992: Ecosystem Health: New Goals for Environmental Management. Island Press, Washington, D.C., 304 S.

CRONQUIST, A. 1988: The Evolution and Classification of Flowering Plants, second edition. - The New York Botanical Garden, New York, 555 S.

CHAN, K.M.A., SHAW, R.M., CAMERON, D.R., UNDERWOOD, E.C. & DAILY, G.C. 2006. Conservation Planning for Ecosystem Services. PLoS Biology 4 (11):e379.

CHEE, Y.E. 2004. An ecological perspective on the valuation of ecosystem services. Biological Conservation 120 (4):549-565.

DAHLGREN, R.M.T., CLIFFORD, H.T. & YEO, P.F. 1985: The Families of the Monocotyledons. Structure, evolution and taxonomy. - Springer-Verlag, Berlin, 520 S.

DAILY, G.C. (Ed.), 1997: Nature's services. Societal dependence on natural ecosystems. Island Press, Washington, DC, 392 S.

DAILY, G.C. 2000. Management objectives for the protection of ecosystem services. Environmental Science & Policy 3:333-339.

DÁVILA, P., MEJÍA-SAULÉS, T., GÓMEZ-SÁNCHEZ, M., VALDÉS-REYNA, J., ORTIZ, J.J., MORÍN, C., CASTREJÓN, J. & OCAMPO, A. 2006: Catálogo de las gramíneas de México. - UNAM-CONABIO, México, D.F., 671 S.

DE GROOT, R.S., WILSON, M.A. & BOUMANS, R.M.J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41:393-408.

DE JONG, B., MONTOYA-GÓMEZ, G., NELSON, K., SOTO-PINTO, L., TAYLOR, J. & TIPPER, R. 1995. Community forest management and carbon sequestration: a feasibility study from Chiapas, Mexico. Interciencia 20 (6):409-416.

DE LA PAZ PÉREZ-OLVERA, C. 2000: Relación estructura propiedades fisico-mecánicas de la madera de algunas especies de encinos (*Quercus*) mexicanos. Tesis Doctoral, Facultad de Ciencias, Universidad Nacional Autónoma de México, 266 S.

DE LACY, T. & WHITMORE, M. 2006: Tourism and Recreation. In: LOCKWOOD M., WORBOYS G.L. & KOTHARI A. (Eds.): Managing Protected Areas: A Global Guide, pp. 497-527. Earthscan, London.

DE LEO, G.A. & LEVIN, S. 1997. The multifaceted aspects of ecosystem integrity. Conservation Ecology [online]1 (1):3.

DE RZEDOWSKI, G.C. & RZEDOWSKI, J. (Eds.), 2001: Flora fanerogámica del Valle de México, 2a ed. Instituto de Ecología A.C. y Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Pátzcuaro, Michoacán, 1406 S.

DIXON, R.K., BROWN, S., HOUGHTON, R.A., SOLOMON, A.M., TREXLER, M.C. & WISNIEWSKI, J. 1994. Carbon pools and flux of global forest ecosystems. Science 263:185-190.

DOF 2006: Programa de Manejo del Parque Nacional Desierto de los Leones. In: Diario Oficial de la Federación, pp. 24-76. Secretaría de Medio Ambiente y Recursos Naturales, México, D.F.

DUDLEY, N. 1996. Authenticity as a means of measuring forest quality. Biodiversity Letters 3:6-9.

DUDLEY, N., MANSOURIAN, S. & VALLAURI, D. 2005: Forest Landscape Restoration in Context. In: MANSOURIAN S., VALLAURI D. & DUDLEY N. (Eds.): Forest Restoration in Landscapes: Beyond Planting Trees, pp. 3-7. Springer, New York.

DUDLEY, N., SCHLAEPFER, R., JACKSON, W., JEANRENAUD, J.P. & STOLTON, S. 2006: Forest Quality: Assessing Forests at the Landscape Level. - Earthscan Publications Ltd. 192 S.

EPA 2009: Environmental Education. In internet: http://www.epa.gov/enviroed/basic.html. U.S. Environmental Protection Agency

ERN, H. 1976. Descripción de la vegetación montañosa de los estados mexicanos de Puebla y Tlaxcala. Willdenowia 10:1-128.

ERZ, W. 1992. "Ungestörte Natur" - Grundsatzüberlegungen, Widersprüche, Klärungen und Konsequenzen. WWF Tagungsbericht/Husum 6:55-83.

ESPINOSA-PÉREZ, M.I. 2005: Estimación del potencial de captura de carbono en el bosque de *Pinus hartwegii* en la cuenca alta del río Magdalena, D.F. Tesis de licenciatura en biología, Facultad de Ciencias, UNAM, México, D.F., 65 S.

ESPINOSA G., F.J. & SARUKHÁN, J. 1997: Manual de malezas del Valle de México. - Universidad Nacional Autónoma de México y Fondo de Cultura Económica, México D.F., 407 S.

ESRI 1998: ArcView Spatial Analyst Version 1.1. INC. Environmental Systems Research Institute, Redlands, California.

EZCURRA, E. 1990: De las chinampas a la megalópolis: El medio ambiente en la cuenca de México. - Fondo de Cultura Económica, México, D. F., 120 S.

EZCURRA, E., MAZARI, H.M., PISANTY, I. & AGUILAR, G. 1999: The Basin of Mexico: critical environmental issues and sustainability. - United Nations University Press, New York, 216 S.

FAO 2001: Criteria and indicators for sustainable forest management: a compendium. Forest Management Working Papers, Working Paper 5. Forest Resources Development Service, Forest Resources Division. Compiled by: CASTAÑEDA F., PALMBERG-LERCHE C. & VUORINEN P., FAO, Rome (unpublished).

FAO 2006: The Global Forest Ressource Assessment. FAO, Rome.

FENN, M.E., DE BAUER, L.I. & HERNÁNDEZ-TEJEDA, T. (Eds.), 2002: Urban Air Pollution and Forests - Resources at Risk in the Mexico City Air Basin. Springer Verlag, New York, 387 S.

FERNÁNDEZ, E.A., URIBE, C.F., RAMÍREZ, R.I., JESÚS, A.B. & VÁZQUEZ, M.A. 2002. Evaluación del avance de la mancha urbana sobre el área natural protegida de la Cañada de los Dinamos. Gaceta Ecológica del Instituto Nacional de Ecología 62:56-67.

FERNÁNDEZ, G.M. 1997: Programa de manejo para la conservación de la Zona Protectora Forestal Cañada de Contreras, Distrito Federal, México. Tesis de Maestría en Biolog¡a, Facultad de Ciencias, UNAM, México, D.F., 130 S.

FLORES-RODRÍGUEZ, A. 2006: Frecuencia de incendios forestales, su relación con la precipitación y la riqueza de especies vegetales, en la cuenca del río magdalena, D. F., México. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México D.F., 59 S.

FLORES, O. & CANSECO, L. 2004. Nuevas especies y cambios taxonómicos para la herpetofauna de México. Acta Zoológica Mexicana 20 (2):115-144.

FRAGOSO-LÓPEZ, P.I. 2003: Estimación del contenido y captura de carbono en biomasa aérea del predio "Cerro Grande" municipio de Tancítaro, Michoacán, México. Tesis de Ingeniero Agrónomo Especialista en Bosques, Facultad de Agrobiología "Presidente Juárez", Universidad Michoacana de San Nicolás de Hidalgo, 65 S.

GALEANA-PIZAÑA, J.M. 2008: Estimación del contenido y captura potencial de carbono, su valoración económica, en la cuenca del río Magdalena, Distrito Federal, México. Tesis de Licenciatura en Geografía, Facultad de Filosofía y Letras, UNAM, 80 S.

GARCÍA-GALVÁN, Y. 2008: Las plantas útiles de la cuenca del río Magdalena, D. F., una guía ilustrada. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México, D.F., 86 S.

GARCÍA, E. 1988: Modificaciones al sistema de clasificación climática de Köppen. - Instituto de Geografía, UNAM, México, D.F., 33 S.

GARZA, G. (Ed.), 2000: La Ciudad de México en el fin del segundo milenio. Gobierno del Distrito Federal y El Colegio de México, México, D.F., 767 S.

GAUCH, H.G. 1982: Multivariate Analysis in Community Ecology. - Cambridge University Press, Cambridge, 298 S.

GLEASON, H.A. 1926. The individualistic concept of plant associations. Bulletin of the Torrey Botanical Club 53:7-26.

GOLDMAN, R.L., TALLIS, H., KAREIVA, P. & DAILY, G.C. 2008. Field evidence that ecosystem service projects support biodiversity and diversify options. PNAS-Sustainability Science 105 (27):9445-9448.

GÓMEZ, G. 2003: Estado del conocimiento de *Abies religiosa* (H.B.K.) Schl. et Cham. Tesis de Licenciatura en Ciencias Forestales, Chapingo, Texcoco, Edo. de México, México, 450 S.

GRIJPMA, P. 2001: Producción forestal. - Secretaría de Educación Pública SEP/Trillas, México D.F., 134 S.

GUTIÉRREZ DE MACGREGOR, M.T., GONZÁLEZ-SÁNCHEZ, J. & ZAMORANO-OROZCO, J.J. 2005: La Cuenca de México y sus Cambios Demográfico-Espaciales. - Instituto de Geografía, UNAM, México, D.F., 155 S.

HARTKAMP, A.D., DE BEURS, K., STEIN, A. & WHITE, J.W. 1999: Interpolation Techniques for Climate Variables. Natural Resources Group. Geographic Information Systems Series 99-01: CIMMYT, International Maize and Wheat Improvement Center, Mexico.

HELLIWELL, D.R. 1969. Valuation of wildlife resources. Regional Studies 3:41–49.

HEMSTROM, M.A., KAROL, J.J. & HANN, W.J. 2001. Trends in terrestrial plant communities and landscape health indicate the effects of alternative management strategies in the interior Columbia River Basin. Forest Ecology and Management 153:105-126.

HERNÁNDEZ, O.P. 1990: Modelos de incremento de altura en cinco especies de coníferas en Atenquique, Jalisco, México. Tesis de Maestría en Ciencias Forestales, Colegio de Postgraduados, Montecillo, México., 111 S.

HERRERA-REVILLA, I., MARTÍNEZ, G.R. & HERNÁNDEZ, G. 1989. Contribución para la administración científica del agua subterránea de la Cuenca de México. Geofísica Internacional 28 (2):297-334.

HORNSTEIN, F.V. 1950. Theorie und Andwendung der Waldgeschichte. Forstwissenschaftliches Centralblatt 21:163-177.

HOWARD, A.F. 1991. A critical look at multiple criteria decision making techniques with reference to forestry applications. Canadian Journal of Forest Research 21:1649-1659.

HUERTA-MARTÍNEZ, F.M., VÁZQUEZ-GARCÍA, J.A., GARCÍA-MOYA, E., LÓPEZ-MATA, L. & VAQUERA-HUERTA, H. 2004. Vegetation ordination at the southern Chihuahuan Desert (San Luis Potosi, Mexico). Plant Ecology 174:79-87.

HUNSAKER, C.T. & CARPENTER, D.E. (Eds.), 1990: Ecological indicators for the environmental monitoring and assessment program. EPA 600/3-90/060. Office of Research and Development, United States Environmental Protection Agency, Research Triangle Park, North Carolina, USA,

HUNTER, M.L. (Ed.), 1999: Maintaining biodiversity in forest ecosystems. Cambridge University Press, Cambridge, 667 S.

HYMAN, J.B. & LEIBOWITZ, S.G. 2001. JSEM: a framework for identifying and evaluating indicators. Environmental Monitoring and Assessment 66:207-232.

INEGI 2005: II Conteo de Población y Vivienda. National Institute of Statistics and Geography. Online available: http://www.inegi.gob.mx/est/default.aspx?c=6789

INIFAP 2003: Monografías sobre diferentes coníferas y latifoliadas de clima templado. MUSÁLEM M.Á. Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, México, D.F.

IPCC 1994: Climate Change. The Supplementary Report to the Intergovernmental Panel on Climate Change Scientific Assessment. Cambridge University Press, Cambridge.

ITC 2005: ILWIS, Integrated Land and Water Information System 3.3. International Institute for Aerospace Survey, Geo Software Development, Sector Remote Sensing & GIS, IT Department, Enschede, The Netherlands

ITTO 1992: Criteria for the measurement of sustainable tropical forest management. Yokohama, Japan

ITTO 2009: About ITTO, The International Tropical Timber Organization. In: http://www.itto.int

JACKSON, M.L. 1982: Análisis químico de suelos. 4a ed. - Omega, Barcelona, 662 S.

JACMCWS 1995: Joint Academies Committee on the Mexico City Water Supply. Mexico City´s Water Supply, Improving the Outlook for Sustainability. - National Academy Press, Washington D. C., 238 S.

JALAS, J. 1955. Hemerobe und hemerochore Pflanzenarten. Ein terminologischer Reformversuch. Acta Soc. Fauna Flora Fenn. 72 (11):1-15.

JANKOWSKI, P. & RICHARD, L. 1994. Integration of GIS-based suitability analysis and multicriteria evaluation in a spatial decision support system for route selection. Environment and Planning B: Planning and Design 21:323-340.

JÁUREGUI, E. 2002: The Climate of the Mexico City Air Basin: Its Effects on the Formation and Transport of Pollutants. In: FENN M.E., DE BAUER L.I. & HERNÁNDEZ-TEJEDA T. (Eds.): Urban Air Pollution and Forests - Resources at Risk in the Mexico City Air Basin, pp. 87-117. Springer Verlag, New York.

JENKINS, M.A. & PARKER, G.R. 1998. Composition and diversity of woody vegetation in silvicultural openings of southern Indiana forests. Forest Ecology and Management 109 (1-3):57-74.

JIMÉNEZ-CISNEROS, B.E., MAZARI-HIRIART, M., DOMÍNGUEZ-MORA, R. & CIFUENTES-GARCÍA, E. 2004: El agua en el Valle de México. In: El Agua en México vista desde la Academia, pp. 15-32. Academia Mexicana de Ciencias, México, D.F.

JOHNS, M. 1997: The City of Mexico in the Age of Díaz. - University of Texas Press, Texas, 168 S.

JOHNSON, P.S. 1993: Perspectives on the ecology and silviculture of oak-dominated forests in the central and eastern states. USDA Forest Service General Technical Report NC-153

JUJNOVSKY-ORLANDINI, J. 2003: Las unidades de paisaje en la cuenca alta del río Magdalena, México D.F. Base fundamental para la planificación ambiental. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México, D.F., 70 S.

JUJNOVSKY-ORLANDINI, J. 2006: Servicios ecosistémicos relacionados con el recurso agua en la cuenca del río Magdalena, Distrito Federal, México. Tesis de Maestría en Restauración Ecológica, Facultad de Ciencias, UNAM, México, D.F., 70 S.

KANGAS, J., STORE, R., LESKINEN, P. & MEHT„TALO, L. 2000. Improving the quality of landscape ecological forest planning by utilising advanced decision-support tools. Forest Ecology and Management 132:157-171.

KARR, J.R. & DUDLEY, D.R. 1981. Ecological perspective on water quality goals. Environmental Management 5 (1):55-68.

KENT, M. & COKER, P. 1992: Vegetation Description and Analysis. A Practical Approach. - Belhaven Press, London, 363 S.

KING, R.T. 1966. Wildlife and man. New York Conservationist 20 (6):8-11.

KOLLMUSS, A. & BOWELL, B. 2007: Voluntary Offsets For Air-Travel Carbon Emissions. Evaluations and Recommendations of Voluntary Offset Companies. Tufts Climate Initiative, Tufts University, Medford, USA.

KOWARIK, I. 1999: Natürlichkeit, Naturnähe und Hemerobie als Bewertungskriterien. V-2.1 Beurteilungskriterien. In: KONOLD W., BÖCKER R. & HAMPICKE U. (Eds.): Handbuch Naturschutz und Landschaftspflege, pp. 1-18. ecomed, Landsberg.

KÜSTER, H. 2003: Geschichte des Waldes. Von der Urzeit bis zur Gegenwart. - C.H. Beck, München, 267 S.

LAM, N.S. 1983. Spatial interpolation methods: A review. American Cartography 10:129-149.

LANLY, J.P. 1995. Sustainable forest management: lessons of history and recent developments. Unasylva 46 (182):38-45.

LINDEMAN, R.L. 1942. The trophic-dynamic aspect of ecology. Ecology 23:399-418.

LINDENMAYER, D.B., FRANKLIN, J.F. & FISCHER, J. 2006. General management principles and a checklist of strategies to guide forest biodiversity conservation. Biological Conservation 131:433-445.

LOCKWOOD, M. 2006: Values and Benefits. In: LOCKWOOD M., WORBOYS G.L. & KOTHARI A. (Eds.): Managing Protected Areas. A Global Guide, pp. 101-115. Earthscan, London.

LOCKWOOD, M. & KOTHARI, A. 2006: Social Context. In: LOCKWOOD M., WORBOYS G.L. & KOTHARI A. (Eds.): Managing Protected Areas: A Global Guide, pp. 41-72. Earthscan, London.

LUIS-MARTÍNEZ, A.M. 1985: Distribución altitudinal y estacional de los papilionoidea (insecta: Lepidoptera), en la cañada de los Dinamos; Magdalena Contreras, D.F. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México, D.F., 113 S.

LUIS-MARTÍNEZ, A.M., LLORENTE, J.E., VARGAS, I.F. & WARREN, A.D. 2003. Biodiversity and biogeography of Mexican butterflies (Lepidoptera: Papilionoidea and Hesperioidea). Proceedings of the Entomological Society of Washington 105 (1):209-224.

MA 2003: Millennium Ecosystem Assessment. Ecosystems and Human Well-Being: A Framework for Assessment. - Island Press, Washington, DC, 245 S.

MA 2005: Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. - Island Press Washington, DC, 137 S.

MABBERLEY, D.J. 1987: The Plant Book. A portable dictionary of the higher plants. - Cambridge University Press 707 S.

MACÍAS-VÁZQUEZ, F. & RODRÍGUEZ-LADO, L. 2003: Primera aproximación al cálculo de los sumideros de Carbono en Sistemas Forestales y Suelos de Galicia, de acuerdo con el Protocolo de Kyoto. - Servicio de Publicaciones da Universidade de Santiago de Compostela, Santiago de Compostela, 151 S.

MADRIGAL, S.X. 1967. Contribución al conocimiento de la ecología de los bosques de oyamel (*Abies religiosa* H.B.K., Sch. et Cham.) en el Valle de México. Instituto Nacional de Investigaciones Forestales, México, D.F. Boletín Técnico No. 18:1-95.

MAGURRAN, A.E. 2004: Measuring biological diversity. - Blackwell Publishing, Oxford, 256 S.

MALCZEWSKI, J. 1999: GIS and Multicriteria Decision Analysis. - John Wiley and Sons, Inc., New York, 392 S.

MARKEWITZ, D. 2009: Indicators of Ecosystem Function Applicable to Sustainable Forest Management. Synthesis and Experimental Evaluation. NCSSF National Commission on Science for Sustainable Forestry, University of Georgia, Georgia, USA.

MARTÍNEZ, M. & MATUDA, E. 1953-1972: Flora del Estado de México. - Gobierno del Estado de México, Toluca, México, 526 S.

MASERA, O.R., ORDÓÑEZ, M.D.J. & DIRZO, R. 1997. Carbon emissions from Mexican forests: Current situation and long-term scenarios. Climatic Change 35:265-295.

MATTEUCCI, S.D. & COLMA, A. 1982: Metodología para el estudio de la vegetación. - Secretaría General de la Organización de los Estados Americanos, Programa Regional de Desarrollo Científico y Tecnológico, Washington D.C, 168 S.

MAZARI-HIRIART, M., DE LA TORRE, L., MAZARI-MENZER, M. & EZCURRA, E. 2001. Ciudad de México: dependiente de sus recursos hídricos. Ciudades 51

MCCAULEY, D.J. 2006. Selling out on nature. Nature 443 (7):27-28.

MCCUNE, B. & MEFFORD, M.J. 1999: PC-ORD. Multivariate Analysis of Ecological Data. MjM Software Design, Gleneden Beach, Oregon, USA.

MCWILLIAMS, W.H., BOWERSOX, T.W., BROSE, P.H., DEVLIN, D.A., FINLEY, J.C., HORSLEY, S., GOTTSCHALK, K.W., LISTER, T.W., MCCORMICK, L.H., MILLER, G.W., STEINER, K.C., STOUT, S.L., WESTFALL, J.A. & WHITE, R.L. 2003 Indicators of Regenerative Capacity for Eastern Northwoods Forests: In, Forest Science in Practice. Society of American Forests National Convention, Buffalo, New York, pp. 136-140.

MEDINA-GARCÍA, C., GUEVARA-FÉFER, F., MARTÍNEZ-RODRÍGUEZ, M.A., SILVA-SÁENZ, P. & CHÁVEZ-CARBAJAL, M.A. 2000. Estudio florístico en el área de la comunidad indígena de Nuevo San Juan Parangaricutiro, Michoacán, México. Acta Botanica Mexicana 52:5-41.

MEDINA-LEMUS, J.G. & TEJERO-DÍEZ, J.D. 2006. Flora y vegetación del Parque Estatal Atizapán-Valle Escondido, Estado de México, México. Polibotánica 21:1-43.

MELO, G.C. & ALFARO, S.G. 2000: Vegetación. In: GARZA G. (Ed.): La Ciudad de México en el fin del segundo milenio, pp. 340-360. Gobierno del Distrito Federal y El Colegio de México, México D.F.

MELO, G.C. & OROPEZA, O. 1975: Carta de la vegetación de la cuenca de México. - Elaborado para el Plan Director del Distrito Federal, México (mimeo)

MENDOZA, A. & PRABHU, R. 2000a. Multiple criteria decision making approaches to assessing forest sustainability using criteria and indicators: a case study. Forest Ecology and Management 131:107-126.

MENDOZA, G.A., MACOUN, P., PRABHU, R., PURNOMO, H. & HARTANTO, H. 1999: Guidelines for Applying Multi-Criteria Analysis to the Assesment of Criteria and Indicators. - Center fot International Forestry Research (CIFOR) Bogor, Indonesia, 79 S.

MENDOZA, G.A. & PRABHU, R. 2000b. Development of a methodology for selecting criteria and indicators of sustainable forest management: a case study on participatory assessment. Environmental Management 26 (6):659-673.

MENDOZA, G.A. & PRABHU, R. 2003. Qualitative multi-criteria approaches to assessing indicators of sustainable forest resource management. Forest Ecology and Management 174:329-343.

MERRILL, T.L. & MIRÓ, R. (Eds.), 1996: Mexico: A Country Study. GPO for the Library of Congress, Washington,

MEYER, M.C., SHERMAN, W.L. & DEEDS, S.M. 2003: The Course of Mexican History. 7th Edition. - Oxford University Press, New York,

MITTERMEIER, R.A., GOETTSCH, C. & ROBLES GIL, P. 1997: Megadiversidad. Los países biológicamente más ricos del Mundo. - Cemex S.A. de C.V., México,

MOBERG, F. & FOLKE, C. 1999. Ecological Goods and Services of Coral Reef Ecosystems. Ecological Economics 29 (2):215-33.

MROSEK, T., BALSILLIEB, D. & SCHLEIFENBAUM, P. 2006. Field testing of a criteria and indicators system for sustainable forest management at the local level. Case study results concerning the sustainability of the private forest Haliburton Forest and Wild Life Reserve in Ontario, Canada. Forest Policy and Economics 8:593-609.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974: Aims and methods of vegetation ecology. - John Wiley and Sons, New York, 574 S.

MUÑOZ-PIÑA, C., GUEVARA, A., TORRES, J.M. & BRAÑA, J. 2005. Paying for the Hydrological Services of Mexico's Forests: analysis, negotiations and results. Gaceta Ecológica del Instituto Nacional de Ecología 1:1-36.

MUSSET, A. 1992: El agua en el valle de México, siglos XVI-XVIII. - Centro de Estudios Mexicanos y Centroamericanos 245 S.

NAGENDRA, H. 2002. Opposite trends in response for the Shannon and Simpson indices of landscape diversity. Applied Geography 22:175-186.

NAVA-LÓPEZ, M. 2003: Los bosques de la cuenca alta del río Magdalena, D.F., México. Un estudio de vegetación y biodiversidad. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México, D.F., 64 S.

NAVA-LÓPEZ, M. 2006: Carbono almacenado como servicio ecosistémico y criterios de restauración, en el bosque de *Abies religiosa* de la cuenca del río Magdalena, D.F. Tesis de Maestría en Restauración Ecológica, Facultad de Ciencias, UNAM, México, D.F., 71 S.

NIETO DE PASCUAL, P.C. 1995. Estudio sinecológico del bosque de oyamel de la Cañada de Contreras, Distrito Federal. Revista Ciencia Forestal en México 20 (77):3-34.

NIXON, K.C. 1993: The genus *Quercus* in Mexico. In: RAMAMOORTHY T.P., BYE R., LOT A. & FA J. (Eds.): Biological diversity of Mexico: origins and distribution, pp. 447-458. Oxford University Press, New York.

NOM-ECOL-059 2001: Norma Oficial Mexicana, que determina las especies y subespecies de flora y fauna silvestres terrestres y acuáticas en peligro de extinción, amenazadas, raras y las sujetas a protección especial, y que establece especificaciones para su protección. Instituto Nacional de Ecología, Gobierno de México, p. 153

NORBERG, J. 1999. Linking Nature's services to ecosystems: some general ecological concepts. Ecological Economics 29:183-202.

NOSS, R.F. 1992: Issues of scale in conservation biology. In: FIEDLER P.L. & SUBODH K.J. (Eds.): Conservation Biology. The and practice of nature conservation, preservation and management, pp. 239-250. Chapman & Hall, New York.

NOSS, R.F. 1995: Maintaining Ecological Integrity in Representative Reserve Networks. - WWF Canada and WWF U.S., Washington, D.C.,

OBIETA, M.C. & SARUKHÁN, J. 1981. Estructura y composición de la vegetación herbácea de un bosque uniespecífico de *Pinus hartwegii* Lindl. Boletín de la Sociedad Botánica de México 41:75-125.

ODUM, E.P. 1953: Fundamentals of Ecology. - Saunders, Philadelphia, USA,

OLIVER, C.D. & LARSON, B.C. 1996: Forest stand dynamics. Updated edition. - John Wiley & Sons, New York, 544 S.

ONTIVEROS-DELGADO, A. 1980: Análisis físico y algunos aspectos socioeconómicos de la cuenca del río Magdalena.Tesis de Licenciatura en Geografía, Facultad de Geografía, UNAM, México, D.F., 113 S.

ORDÓÑEZ, A. 1999: Captura de carbono en un bosque templado: el caso de San Juan Nuevo, Michoacán. - INE-SEMARNAP México, D.F. , 72 S.

ORREGO, J. 2005: Carbon Knowledge Projects and Forest Landscape Restoration. In: MANSOURIAN S., VALLAURI D. & DUDLEY N. (Eds.): Forest Restoration in Landscapes. Beyond Planting Trees, pp. 171-175. Verlag, New York.

ORTEGA, A. & FARVOLDEN, R.N. 1989. Computer analysis of regional groundwater flow and boundary conditions in the basin of Mexico. Journal of Hydrology 110:271-294.

PALACIO-PRIETO, J.L., BOCCO, G., VELÁZQUEZ, A., MAS, J.F., TAKAKI-TAKAKI, F., VICTORIA, A., LUNA-GONZÁLEZ, L., GÓMEZ-RODRÍGUEZ, G., LÓPEZ-GARCÍA, J., PALMA, M., TREJO-VÁZQUEZ, I., PERALTA, A., PRADO-MOLINA, J., RODRÍGUEZ-AGUILAR, A., MAYORGA-SAUCEDO, R. & GONZÁLEZ, F. 2000. La condición actual de los recursos forestales en México: resultados del Inventario Forestal Nacional 2000. Boletín del Instituto de Geografía, UNAM 43:183-203.

PETERSON, D.L., SILSBEE, D. & SCHMOLDT, D.L. 1994. A case study of resource management planning with multiple objectives. Environmental Management 18 (5):729-742.

PIGRAM, J.J. & JENKINS, J.M. 1999: Outdoor Recreation Management. - Routledge, London, 329 S.

POKORNY, B. & DESMOND, H. 2004: Networking and Information Management for Enhancing the Implementation of Criteria and Indicators for Sustainable Forest Management. FAO/ITTO Expert Consultation on Criteria and Indicators for Sustainable Forest Management, Cebu City, Philipines.

PRABHU, R., COLFER, C.J.P., VENKATESWARLU, P., TAN, L.C., SOEKMADI, R. & WOLLENBERG, E. 1996: Testing criteria and indicators for the sustainable management of forests: Phase I. Final report. CIFOR, Jakarta.

QUINTANILLA, V. & CASTRO, R. 1998: Seguimiento de las cubiertas vegetales postincendios forestales en la zona mediterránea costera de Chile. In: Serie Geográfica. Incendios forestales, pp. 147-154. Departamento de Geografía y el servicio de publicación de la Universidad de Alcalá

RAISON, J.R., BROWN, A.G. & FLINN, D.W. (Eds.), 2001: Criteria and Indicators for Sustainable Forest Management. CABI Publishing in association with The International Union of Forest Research Organizations (IUFRO), London, 462 S.

RAMÍREZ, J. 1899: La vegetación de México. - Secretaría de Fomento, México, D.F., 271 S.

RAMOS RAMOS-ELORDUY, A. 2008: Propuesta de reclasificación y zonificación participativa de la Zona Protectora Forestal Cañada de Contreras, Distrito Federal, México. Tesis de Maestría en Ciencias Biológicas, Facultad de Ciencias, UNAM, México, D.F., 99 S.

RAPPORT, D. 1995. Ecosystem health: exploring the territory. Ecosystem Health 1:5-13.

RAPPORT, D., COSTANZA, R., EPSTEIN, P.R., GAUDET, C. & LEVINS, R.C. 1998: Ecosystem Health. - Blackwell Science, Oxford, 372 S.

REICHE, C. 1923. Die Vegetationsverhältnisse in der Umgebung der Haupstadt von Mexico. Botanisches Jahrbericht 58 (129):1-116.

REIF, A. & WALENTOWSKI, H. 2008. The assessment of naturalness and its role for nature conservation and forestry in Europe. Waldökologie, Landschaftsforschung und Naturschutz 6:63-76.

RODRÍGUEZ-FRANCO, C. 2002: Forests in the Basin of Mexico. In: FENN M.E., DE BAUER L.I. & HERNÁNDEZ-TEJEDA T. (Eds.): Urban Air Pollution and Forests - Resources at Risk in the Mexico City Air Basin, pp. 69-85. Springer Verlag, New York.

RODRÍGUEZ-FRANCO, C. & MAGAÑA, T.O.S. 1991 La situación actual de los bosques del Valle de México: In: TORRES-ROJO J.M. (Ed.), I Simposio Sobre el Papel de los Bosques del Valle de México en el Siglo XXI. Centro de Genética Forestal A.C.-INIFAP-PROBOSQUE, Chapingo, México, pp. 1-30.

ROJAS-GARCÍA, F. 2004: Contenido y captura potencial de carbono en el bosque de *Pinus hartwegii* del Parque Nacional La Malinche: Tlaxcala-Puebla. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México D.F., 68 S.
ROJAS-GARCÍA, F. 2008: Consideraciones para el balance de carbono: Evaluación del movimiento de biomasa en el Parque Nacional Malinche. Tesis de Maestría en Biología Ambiental, Facultad de Ciencias, Universidad Nacional Autónoma de México, 70 S.
ROLSTON, H. & WESTRA, L. 1994: Preface. In: An Environmental Proposal for Ethics: The Principle of Integrity, pp. xi-xiii. Rowman & Littlefield, Lanham, MD.
RZEDOWSKI, J. 1970. Notas sobre el Bosque Mesófilo de Montaña en el Valle de México. Anales de la Escuela Nacional de Ciencias Biológicas, I.P.N., México 18:91-106.
RZEDOWSKI, J. 1975: Flora y vegetación de la cuenca del Valle de México. In: Memoria de las obras del drenaje profundo del Distrito Federal, Tomo I, pp. 81-134. México, D.F.
RZEDOWSKI, J. 1978: Vegetación de México. - Limusa, México D.F., 432 S.
RZEDOWSKI, J. 1979: Principales comunidades vegetales. In: RZEDOWSKI J. & RZEDOWSKI G.C.D. (Eds.): Flora fanerogámica del Valle de México, Vol. I, pp. 47-54. Compañía Editorial Continental, México.
RZEDOWSKI, J. 1991a. Diversidad y orígenes de la flora fanerogámica de México. Acta Botanica Mexicana (14):3-21.
RZEDOWSKI, J. 1991b. El endemismo de la flora fanerogámica mexicana: una apreciación analítica preliminar. Acta Botanica Mexicana (15):47-64.
SAATY, T.L. 1977. A scaling method for priorities in hierarchical structures Journal of Mathematical Psychology. 15 234-281.
SÁNCHEZ-GONZÁLEZ, A. & LÓPEZ-MATA, L. 2003. Clasificación y ordenación de la vegetación del norte de la Sierra Nevada, a lo largo de un gradiente altitudinal. Anales del Instituto de Biología, Universidad Nacional Autónoma de México, Serie Botánica 74 (1):47-71.
SÁNCHEZ-GONZÁLEZ, A., LÓPEZ-MATA, L. & GRANADOS-SÁNCHEZ, D. 2005. Semejanza florística entre los bosques de oyamel *Abies religiosa* (H.B.K.) Cham. & Schltdl. de la faja volcánica transmexicana. Investigaciones Geográficas 56:62-76.
SÁNCHEZ, O. 1969: La flora del Valle de México. - Editorial Herrero, México, D.F., 569 S.
SANDERS, W.T., PARSONS, J.R. & STANLEY, R.S. 1979: The Basin of Mexico: Ecological Processes in the Evolution of a Civilization. - Academic Press, New York, 561 S.
SARUKHÁN, J. & DIRZO, R. 2001: Biodiversity-rich countries. In: LEVIN S.A. (Ed.): Encyclopedia of Biodiversity, pp. 30-45. Academic Press, San Diego, California.

SER 2009: Society for Ecological Restoration International Online. In internet: http://www.ser.org/
SHEPPARD, S.R.J. & MEITNER, M. 2005. Using multi-criteria analysis and visualisation for sustainable forest management planning with stakeholder groups. Forest Ecology and Management 207:171-187.
SILVA, L., ROMERO, F.J., VELÁZQUEZ, A., ALMEIDA-LEÑERO, L., VELÁZQUEZ, A. & ROMERO, F.J. 1999: La vegetación de la región de Montaña del sur de la Cuenca de México. In: Biodiversidad de la Región de Montaña del Sur de la Cuenca de México: bases para el ordenamiento ecológico UAM-X-SEMARNAP, México, D. F.
SIMULA, M., SYNNOTT, T., SIQUEIRA, G. & SOSA, V. 2005: Consecución del objetivo 2000 y la ordenación forestal sostenible en México. - International Tropical Timber Council, Yokohama, 136 S.
SOLOMON, S., QIN, D., MANNING, M., CHEN, Z., MARQUIS, M., AVERYT, K.B., TIGNOR, M. & MILLER, H.L. (Eds.), 2007: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 S.
SPILSBURY, M.J. 2005: The sustainability of forest management. Assessing the impact of CIFOR's Criteria and Indicators research. - CIFOR, Bogor, Indonesia, 126 S.

STORK, N.E., BOYLE, T.J.B., DALE, V., EELEY, H., FINEGAN, B., LAWES, M., MANOKARAN, N., PRABHU, R. & SOBERON, J. 1997: Criteria and indicators for assessing the sustainability of forest management: conservation of biodiversity. CIFOR Working Paper No. 17, Jakarta.
STYLES, B.T., RAMAMOORTHY, T.P., BYE, R., LOT, A. & FA, J. 1993: Genus Pinus: a mexican purview. In: Biological Diversity of Mexico: Origins and Distribution, pp. 397-420. Oxford University Press, Oxford.
SZÉKELY, A. 1994: Protección legal a la biodiversidad en México. Informe de trabajo. CONABIO, México, D.F. .
TANSLEY, A.G. 1935. The use and abuse of vegetational concepts and terms. Ecology 16 (3):284-307.
TER BRAAK, C.J.F. 1987: CANOCO–a FORTRAN program for canonical community ordination. Microcomputer Power Ithaca, New York.
TER BRAAK, C.J.F. & PRENTICE, I.C. 1988. A theory of Gradient Analysis. Advances in Ecological Research 18:271-317.
TER BRAAK, C.J.F. & SMILAUER, P. 2002: Canoco reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5). Microcomputer Power, Ithaca, New York.
THE-MONTRÉAL-PROCESS 2008: Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests. In: http://www.rinya.maff.go.jp/mpci/home_e.html

TILMAN, D. 1997: Biodiversity and Ecosystem Functioning. In: DAILY G.C. (Ed.): Nature´s Services: Societal Dependence on Natural Ecosystems, pp. 93-112. Island Press, Washington, DC.

TOLEDO, V.M. & ORDÓÑEZ, M.D.J. 1998: El panorama de la biodiversidad de México: una revisión de los hábitats terrestres. In: RAMAMOORTHY T.P., BYE R., LOT A. & FA J. (Eds.): Diversidad biológica de México: orígenes y distribución, pp. 739-757. Instituto de Biología, UNAM, México, D.F.

TORRES-PÉREZ, M.S. 2005: Estudio etnobotánico del parque ecológico Huayamilpas. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México, D.F., 65 S.

UNESCO 2009: United Nations Decade of Education for Sustainable Development (2005-2014, DESD). In internet: www.unesco.org/education/desd/, United Nations Scientific and Cultural Organization.

USHER, M.B. 1986: Wildlife conservation evaluation. - Chapman and Hall Ltd., London 394 S.

VÄHÄNEN, T. 2004: Criteria and Indicators for Sustainable Forest Management and Trade in Forest Products and Services. A Background paper for the Global Project: Impact Assessment of Forest Products Trade in Promotion of Sustainable Forest Management. http://www.fao.org/forestry/foris/data/trade/pdf/vahanen.pdf, FAO, Rome.

VALDIVIA-MARTÍNEZ, E. 2006: Recolección de la flora medicinal del sureste del Distrito Federal, México. Tesis de Licenciatura en Biología, Facultad de Ciencias, UNAM, México, D.F., 65 S.

VALENZUELA, T. 2001: Estimación del secuestro de carbono en bosques naturales de oyamel (*Abies religiosa*) en el sur del Distrito Federal. División de Ciencias Forestales, Universidad Autónoma de Chapingo, Texcoco, Estado de México, Tesis de Licenciatura en Ingeniería Forestal, 127 S.

VARADHAN, R. & WILLIAMS, J.R. 1998: Estimation of infiltration in the vadose zone: compilation of simple mathematical models. U.S. Environmental Protection Agency, Cincinnati, USA.

VARMA, V.K., FERGUSON, I. & WILD, I. 2000. Decision support system for the sustainable forest management. Forest Ecology and Management 128:49-55.

VAZQUEZ-GARCÍA, J.A. & GIVNISH, T.J. 1998. Altitudinal gradients in tropical forest composition, structure and diversity in the Sierra de Manantlán. Journal of Ecology 86:999-1020.

VELÁZQUEZ, A. 1994. Multivariate analysis of the vegetation of the volcanoes Tláloc and Pelado, Mexico. Journal of Vegetation Science 5:263-270.

VELÁZQUEZ, A. & CLEEF, A.M. 1993. The plant communities of the volcanoes "Tláloc" and "Pelado", México. Phytocoenologia 22:145-192.

VELÁZQUEZ, A. & ROMERO, F.J. (Eds.), 1999: Biodiversidad de la región de montaña del sur de la cuenca de México: bases para el ordenamiento ecológico. Universidad Autónoma Metropolitana, Unidad Xochimilco-Secretaría de Medio

Ambiente-Comisión de Recursos Naturales y Desarrollo Rural, México, D.F., 351 S.
VILLARRUEL-ORDAZ, J.L. & CIFUENTES-BLANCO, J. 2007. Macromicetos de la Cuenca del Río Magdalena y zonas adyacentes, Delegación la Magdalena Contreras, México, D.F. Revista Mexicana de Micología 25:59-68.
VILLARRUEL-ORTÍZ, J.L. & CIFUENTES-BLANCO, J. 2007. Macromicetos de la Cuenca del Río Magdalena y zonas adyacentes, Delegación la Magdalena Contreras, México, D.F. Revista Mexicana de Micología 25:59-68.
VILLASEÑOR, J.L. 2003. Diversidad y distribución de las Magnoliophyta de México. Interciencia 28:160-167.
VILLERS RUIZ, L., GARCÍA DEL VALLE, L. & LÓPEZ-BLANCO, J. 1998. Evaluación de los bosques templados de México: una aplicación en el Parque Nevado de Toluca. Investigaciones Geográficas Boletín 36:7-19.
VILLERS RUIZ, L. & TREJO-VÁZQUEZ, I. 1998. Impacto del cambio climático en los bosques y áreas naturales protegidas de México. Interciencia 23:10-19.
WALKLEY, A.L. 1947. A rapid determination of soil organic matter. Journal of Agricultural Science 25 (398):63-68.
WALTER, B., CARPENTER, S., ANDERIES, J., ABEL, N., CUMMING, G.S., JANSSEN, M., LEBEL, L., NORBERG, J., PETERSON, G.D. & PRITCHARD, R. 2002. Resilience management in social-ecological systems: a working hypothesis for participatory approach. Conservation Ecology 6 (1):14 http://www.consecol.org/vol6/iss1/art14.
WESTRA, L. & LEMONS, J. 1995: Perspectives on Ecological Integrity. - Kluwer Academic Publishers, Amsterdam, 279 S.
WHITMORE, T.M. & TURNER, B.L.I. 1986: Population reconstruction of the Basin of Mexico: 1150 B.C. to present. Technical Paper no. 1, Millennial Longwaves of Human Occupance Project. - Clark University, Worcester, MA,
WHITMORE, T.M. & TURNER, B.L.I. 1992: Landscapes of cultivation in Mesoamerica. In: BUTZER K.W. (Ed.): The Americas before and after 1492: Current geographical research, pp. 401-425. Annals of the Association of American Geographers 82, no. 3 (September)
WHITMORE, T.M., TURNER, B.L.I., JOHNSON, D.L., KATES, R.W. & GOTTSCHANG, T.R. 1990: Long-term population change. In: TURNER B.L.I., CLARK W.C., KATES R.W., RICHARDS J.F., MATHEWS J.M. & MEYER W.B. (Eds.): The earth as transformed by human action. Global and regional changes in the biosphere over the past 300 years, pp. 25-39. Cambridge University Press with Clark University, Cambridge.
WHITTAKER, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30:279-338.
WILLIAMS, L.O. 1951. The Orchidaceae of Mexico. Ceiba 2:1-321.
WILLIS, J.C. 1973: A dictionary of the flowering plants and ferns. - Cambridge University Press 1294 S.

WOLFSLEHNER, B., VACIK, H. & LEXER, M.J. 2005. Application of the analytic network process in multi-criteria analysis of sustainable forest management. Forest Ecology and Management 207:157-170.

WWF & IUCN 1999: Evaluation of Forest Quality: Towards a Landscape Scale Assessment. - Forest Innovations: a joint project between the International Union for the Conservation of Nature and the World Wide Fund for Nature 159 S.

WWF & IUCN 2000: Minutes, Restoration workshop. Segovia, Spain (unpublished).

ZAZO-MUNCHARAZ, J. & JIMÉNEZ-MARTÍN, J.M. 2000: Apuntes y notas de los caracteres culturales y otras características de interés de algunas frondosas forestales españolas

-U.P.M.-E.U.I.T.F., Madrid, 883 S.