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Landscape planning to achieve sustainability: The Iztaccíhuatl-Popocatépetl region, Mexico, case study.

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy by

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To the beginners of my academic kin:
Ernesto Chávez (in memorian) and Beatriz Cortés

To the sparkles of my life: Clarissa, Carolina and Laura

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ABSTRACT

The overall goal of this thesis is to investigate the applicability of a landscape planning methodology that is founded on an ecosystem-based approach and focused on the delineation of ecologically sensitive areas. Its design is concerned with an ecosystem-based management approach as part of a broader landscape planning process that is intended to achieve environmental sustainability objectives; the key idea is that an ecosystem/landscape scale may well be the most important for the attainment of sustainability. Considering this, this research supports the idea that the employment of a network of watershed-ecosystem units provides an appropriate framework for planning towards sustainability at the landscape scale. In addition, the design of this methodology also gives room to solve theoretical and practical problems. The main theoretical problem is related to the generation of overall schemes that are consistent with holistic-multidimensional viewpoints about patterns and processes in landscapes. On the other hand, two practical problems are also confronted: the need to employ ecological principles and spatial concepts in landscape planning and the development of strategies to define and delineate areas of interest to planners. In this research this point is focused on the delineation of ecologically sensitive areas.

In order to test the application of the planning methodology to a real-life context, the Iztaccihuatl-Popocatepetl volcanoes National Park region of Mexico was selected. This region is recognised as a typical example of a fragile mountain region.

The major contributions of the thesis are related to theoretical and practical issues in an ecosystem-based management approach. In practical terms, results derived from the practical case study provide important inputs (database, diagnosis and proposals) to improve the planning process of the Iztaccihuatl-Popocatepetl region. Also, this methodological approach can be useful to solve the problems linked to fragile mountain ecosystems. It is concluded that ecosystem-based management is taking shape as an ecologically well-founded potential landscape planning approach, capable of playing the role of creating more sustainable regional systems and of searching for enduring multifunctional landscapes for the future.

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Chapter 1 Introduction

The overall goal of this thesis is to investigate the applicability of a landscape planning methodology that is founded on an ecosystem-based approach and focuse on the delineation of ecologically sensitive areas.

The design of this thesis is concerned with an ecosystem-based management approach as part of a broader landscape planning process that is intended to achieve environmental sustainability objectives. However, despite the fact that an ecosystem/landscape scale may well be the most important for the attainment of sustainability, little literature exists on sustainability at this scale (Forman, 1994). Therefore, this research supports the idea that the employment of a network of watershed-ecosystem units provides an appropriate framework for planning towards sustainability at the landscape scale.

The ecosystem-based management approach was chosen in order to integrate sustainability as a precondition for management and to be consistent with a well-supported ecological landscape planning approach. Ecosystem-based management seeks to deal with sufficiently large spatial scales, working with real geographical units, setting goals in the context of environmental sustainability and resulting in the identification of a holistic, comprehensive, integrative and transdisciplinary landscape planning strategy. However, despite the powerful theoretical support for this type of approach, there are few experiences of efforts to integrate theory and practice in this particular way (Slocombe, 1993, 1998). Consequently, this research assumes that integrating an overall holistic scheme and theoretical topics of ecosystem and landscape ecology into a methodology could provide a means of bridging the gap between theory and practice. Thus, this thesis develops a methodology that focuses on sustainable landscape planning in practice and the utilization of methods capable of coping with complex problems.

From a theoretical perspective, this thesis integrates a unique approach whereby ecosystems and landscapes are considered to share similar characteristics to complex systems such as self-organisation, resilience and creativity. Therefore, the role of biodiversity in supporting the essential processes of ecosystems and landscapes is accentuated. And as a consequence of this, it is postulated that the protection and restoration of biodiversity is a key issue if environmental sustainability is to be achieved.

From a practical perspective, this thesis also attempts to contribute to ecosystem-landscape planning through the design and testing of a particular methodology. It is based on sustainable landscape planning as a framework that integrates models and principles from ecosystem and landscape ecology, and an overall holistic scheme based on logical models, methods and associated procedures, such as the analytical hierarchy process, image processing/remote sensing and geographical information systems technology. This methodology is focused on the delineation and mapping of ecologically sensitive areas in an ecosystem/landscape to facilitate and support indicative planning and public policy design.

In this research, it is assumed that theoretically, ecologically insensitive areas do not exist, yet it is understandable that there should be areas with irreplaceable ecological and cultural features or that represent a potential for the future (this aspect will be discussed in detail in chapter 3). However, environmentally sensitive areas are recognised practically as landscape elements or places that are vital to the long-term maintenance of biological diversity, soil, water or other natural resources both on the site and in a regional context. They might include wildlife habitat areas, steep slopes, wetlands and prime agricultural lands. When environmentally sensitive areas are interconnected, they can form networks or linked landscape elements that provide ecological, recreational, and cultural benefits to a community (Ndubisi, et al., 1995).

Although the consideration of environmentally sensitive areas in a land-use planning process varies among countries, a basic procedure consists in the identification of the type, location, and quantity of them, the assessment of their significance, the establishment of priorities, the development of policies for protecting them, and the incorporation of these policies into local comprehensive plans (Ndubisi, et al., 1995).

1. Context of this thesis

1.1 Sustainable landscape planning context

Sustainable landscape planning is a method of sustainable land use planning that is concerned with the allocation of resources at a macro scale in such a way as to emphasise environmental protection. In this context, it involves the setting and implementation of policies about how to allocate land use activities that are consistent with the sustainable use of the landscape (after van Lier, 1994). In addition, sustainable land use planning could be seen as an opportunity to influence spatial practices and to create new landscape structures in harmony with natural processes and with the relationships between people and land (van Langevelde, 1994).

Sustainable landscape planning also shares the purposes and procedures of sustainable land use planning. Both planning approaches pursue multiple land uses and their allocation for optimal use and protection of natural resources in the long term (environmental sustainability) while meeting the needs and aspirations of the present generation (socio-economic sustainability). They are also mainly oriented to setting policies for land use and the development of plans to improve spatial/physical conditions (van Lier, 1994). However, sustainable landscape planning is distinguished from sustainable land use planning by the emphasis made on landscape resources and environmental attributes as the primary determinants in decision-making. This emphasis and increasing environmental concerns have influenced the landscape planning paradigm. Nowadays, this urgency to deal with nature conservancy and development has given rise to the incorporation of ideas of multiple land use, sustained yield, carrying capacity and the acceleration of the movement towards holistic planning in relation to environmental issues (Steiner, et al., 1988, 1991; van Langevelde, 1994; Zigrai, 1996; Miklos, 1996; Naveh and Lieberman, 1994; Naveh, 2001; Fry, 2001; Tress and Tress, 2001). In essence, it means that sustainability has become the central pre-requisite for wise landscape planning.

Nowadays, sustainability is widely accepted as a new societal goal and the notion of sustainability refers to a specific type of society development. FAO (1998) defines it as the handling and conservation of natural resources and the orientation of technological and institutional change to ensure the continuous satisfaction of human needs for present and future generations. In essence, sustainable development means a continuous process of change that seeks harmony among the exploitation of resources, the direction of investments, the orientation of technological development and industrial change (van Lesterijn, 1994; Bossel, 2000).

The sustainability paradigm also includes the systems approach, another widely acknowledged and fundamental paradigm in environmental sciences (Golley and Bellot, 1999). Thus, the concept of sustainability comprises many dimensions. Using a coarse classification at least three dimensions could be distinguished: environmental, economic and social (van Lesterijn, 1994; Opschor, 1996; Bossel, 2000). The consideration of multi-dimensions implies facing complexity. Sustainability means facing up to multiple relationships, processes and change. If these are tricky, their combination is even more so. Therefore, the design of sustainable systems requires the acknowledgement of their complex nature, but complexity as a fundamental organising principle, not a synonym of complicated (de Waard, 1994).

An important point is that, despite sustainability being to a large extent a subjective notion, it is considered to be the major objective of any planning process (Golley and Bellot, 1999). Consequently, with this subjective notion, different sustainable scenarios can be set up, each one with its own validity (van Lesterijn, 1994).

In terms of landscape planning, sustainability is recognised as the main goal to be achieved (Ahern, 1995, 1999; Miklos, 1996; Christensen et al., 1996; Golley and Bellot, 1999). In fact, three main schools of thought, respectively, greenway planning (Ahern, 1995; Fabos, 1995; Fabos and Ahern, 1995; Linehan, et al., 1995), ecological landscape planning (Ruzicka and Miklos, 1982; Miklos, 1996; Zigari, 1996) and ecosystem management (Slocombe, 1993a, 1993b, 1998; Gumbrine, 1994, 1997; Yafee, 1996, 1999; Christensen et al., 1996), all consider the achievement of sustainability and sustainable development as the main target in land-use decision-making. These schools of thought also share a common concept of landscape.

Although the term landscape has many different interpretations, in landscape research and planning its meaning has prevailed as a region encompassing a huge area between 100 Km^2 and 2 500 Km^2 (Klinj and Udo de Haes, 1994). The meaning of region also implies that a landscape is conceptualised as a hierarchical system conformed by a complex of interacting land-uses, which have intensive economic, spatial or environmental relationships. This arrangement of land uses in a physical space defines the structure of a landscape. Furthermore, the function of a landscape is defined as the transport of economic goods, persons and environmental pollution between land uses (Forman and Godron, 1986; Turner, 1987; Cook and van Lier, 1994; Tress and Tress, 2001).

The region concept also implies that the structure and function of a landscape is a synthesis of social processes, or human practices, that spatially interact with natural processes in the landscape. Many human practices related to land-use are influenced by socio-economic developments and technological opportunities. They involve decisions that alter the landscape patterns to facilitate desired functions. For these reasons, landscape researchers claim the need for a holistic approach in landscape research and planning in order to achieve sustainability (Palang et al. 2000; Fry, 2001; Naveh, 2001; Tress and Tress, 2001). The ecosystem management school of thought claims explicitly that landscape research and planning should be based on three main issues: (1) sustainability as a pre-requisite for land-use planning and management, (2) a holistic approach to landscape research and planning, and (3) the employment of an anticipatory, flexible, research and planning (Slocombe, 1993, 1998; Grumbine, 1994; Christensen et al., 1996).

1.1.1 The context of environmental sustainability: sustainable development as a multi-dimensional concept

This research considers sustainable development and sustainability as "source concepts" of goals and purposes for decision making in an ecosystem-based landscape planning approach. The very outstanding consideration is that they are value-loaded concepts. It means that they are valued according to a social context. Therefore, there are multiple visions about sustainable development and multiple concepts of sustainability and a multi-dimensional view is needed to cope with their conceptualisation (Opschoor, 1994; Bossel, 1996,1998, 2000; Pezzoli, 1997).

Sustainable development was coined as an ethical consideration to be taken into account in economic development. According to Jaimieson (1998), during the decade of the 1980´s the phrase "sustainable development" migrated from an obscure report by the

International Union for the Conservation of Nature in 1980, through several "green" books, to become the central organizing concept in the Brundtland Commission report (WCED, 1987). This Commission defined it as the development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". By joining the words "sustainable" and "development", the Commission sought to reconcile the demands of environmental protection with concerns about poverty. Thus, the concept of sustainable development stems from those environmental and ethical roots, including concerns about unequal development and integenerational duties, all of them value-loaded concepts.

A logical consequence of the value-loaded concept of sustainable development is that there are many ways in which a society may formulate its goals to achieve sustainability and many means of moving towards sustainable development (Faber, et al., 1995). However, sustainability can be looked upon as a scientific problem for which only technical and economic solutions have to be sought (Opschoor, 1994). But in this thesis it is postulated that ethical principles are needed to formulate sustainability goals, where a social will is required as well as mature social organisations to realise these goals. In summary, the statement of sustainability goals is a social process in which different beliefs and disciplinary viewpoints converge.

Sustainable development is a multidimensional task. When considering aspects of the implementation of sustainable development, the basic question is: do sustainable alternatives exist? To answer this question, a multidimensional view of the problem is again required. According to Opschoor (1994) sustainable development requires that three conditions/criteria are simultaneously met:

1. Environmental or ecological viability (i.e. the observance of the need to maintain the environmental infrastructure)
2. Economic viability (i.e. constant or rising per capita welfare levels)
3. Social viability (reduction of inequality, enhancement of human capital and social investment).

However, this multidimensional vision of sustainable development could give as a result, that together, these three constraints may define an empty set in terms of strategies towards sustainable development. It means the absence of strategies that could achieve ecological, economic and social viability simultaneously. Another critical consideration is related to its implementation at local, regional and global scales. According to Opschoor (1994) the processes involved in a sustainable path may require trade-offs between ecological sustainability and current consumption levels. These trade-offs may imply cutting down drastically on consumption and/or production. Such strategies raise ethical and political objections spatially documentated.

In spite of all the problems described above, sustainable development is now widely accepted as a goal for human society, or at least, is the best social utopia that is realistically achievable (Opschoor, 1994). Although there are different disciplinary interpretations of the concept (Pezzoli, 1997) and paths towards sustainable development differ, a recent agreement is that the concept requires concern on four different dimensions (Bossel, 1996, 2000):

1) The viability of human society.
2) The efficiency in resources use.
3) The viability of the natural system.
4) Coexistence without over-exploitation.

Comprehensive attention to these aspects requires a holistic/systems approach and authors such as Grossman and Bellot (1999) even argue that the sustainable development paradigm already includes the holistic/systems approach.

The systems approach to sustainable development conceptualises it as a dynamic and context dependent concept. Dynamic implies constant evolutionary and adaptive change. Nature and society coevolve through constant change: societies and their environment change, technologies and cultures change, values and aspirations change. Bossel (1998) argues that such change must be evolutionary and self-organising, producing the widest possible spectrum of adaptive responses to new challenges and competing for the "fittest" solutions. For him, the diversity of processes and functions is one of the important prerequisites for sustainability. The basic idea is that the greater the number of different innovative responses, the better. An outstanding point here is the concept of cultural diversity, which is conceptualised as it is in ecology, as a characteristic of complex systems that allows timely adaptation. Bossel (1998) concludes that to allow and sustain such change, a sustainable society is also needed.

A systems approach sees human society as a complex system embedded in another complex system, the natural environment. The total system of which human society is a part, and on which it depends for support, is made up of a large number of components: environmental systems. Therefore, if the goal is sustainable development, the viability and sustainability of the total system and its components are important concerns. Sustainable development is possible only if subsystems as well as the total system are viable. For example, a region can only be viable if its economic, ecological and social systems are viable, where a viable system means that is able to survive, be healthy, and develop in its particular environment. In other words, system viability and sustainability mean that a system can exist and prosper in its environment only if its structure and functions are adapted to that environment (Norton, 1992).

According to Bossel (1998) recent system approaches to sustainable development identify the following essential subsystems: individual development system, social system, government system, infrastructure system, economic system, resources system and environmental system. These six subsystems correspond to "capital" (stocks) that must be maintained in a sustainable way: human capital, social capital, organisational capital, infrastructure capital, production capital, and natural capital. The sine qua non condition is that in order for the total system (human systems embedded in the natural system) to be viable, each of the subsystems must be viable. The six subsystems can be aggregated into three larger subsystems: a "Social system" or social capital = social system + individual development + government; a "Support system" or structural (built) capital = infrastructure + economic system; and a "Natural system" or natural capital = resources + environment.

Environmental sustainability, the main concern of this research, has to do with the processes linked to the maintenance, protection, and increase of the natural system or natural capital. However, these processes need a more precise definition.

1.1.2 Environmental sustainability as a multi-dimensional concept

One premise of this thesis is that environmental sustainability is a value-loaded concept (Opschoor, 1994; Bossel, 1996, 1997, 2000). This implies that environmental values are derived from people´s acts of individual evaluation. This means, sensu stricto, that these values can be perceived differently in different paradigms and political and cultural settings. To sustain something, means valuing it enough to put effort into maintaining its integrity. A commitment to sustainability of human and natural systems is therefore a fundamental value decision, an ethical decision. Bossel (2000) argues that environmental sustainability can be advocated from three viewpoints:

1) An ecocentric viewpoint acknowledges the intrinsic value of the processes and products of natural evolution and of human cultural evolution. If people value them, efforts must strive to ensure their future existence, development, and evolution, e.g. for sustainability.
2) An anthropocentric point of view, sees humankind as dependent on natural systems, and its survival interests compel it to be concerned for their sustainability.
3) A biocentric view, recognizes that nature (including humans) is a living, evolving system, and that the products of this creative process have value in their own right.

Another important premise is that environmental sustainability is totally dependent on sustainable social systems. Environmental sustainability is not possible in a society unaware that the production of food, fibre, and water carries extensive environmental costs. These costs are generally not included in the costs that people pay for these commodities. Also, without a well-educated urban community it will not be possible to generate the political will to supply resources to help tackle the problems related to the achievement of environmental sustainability.

On the other hand, environmental sustainability is a concept linked to ecological systems viewed as creative and self-organising systems, where self organising systems are those whose dynamics are largely a function of positive and negative feedback loops. In addition, systems creativity is associated with the multiplicity of their adaptive responses supported by their self-organising properties.

Norton (1992) in his new paradigm for environmental management defines environmental sustainability as a relationship between dynamic human economic systems and larger, also dynamic, but usually slower-changing ecological systems. For Norton (1992), sustainability means that the effects of human activities should remain within bounds, not destroying the health and integrity of the environmental systems that provide the context for these activities.

Behind this ethical support, health and integrity of ecological systems, are controversial, subjective and context dependent concepts. (for a fuller review and discussion see Barkmann and Windhurst, 2000 and Ulanowicz, 2000). However, these concepts raise the need of a multi-dimensional approach to environmental sustainability. Barkmann and Windhurst (2000) claim that when environmental sustainability is a concern, at least two dimensions could be tackled: as an ethical management principle dealing with all aspects of sustainable development and as a function of the realisation of integral and "healthy" states of the ecological interaction network.

On the one hand, the ethical issue of protecting the health and integrity of ecological systems means recognising the role that environmental systems have in supporting human, economic, recreational, aesthetic, and spiritual values. On the other hand, the health-integrity aspect deals with the response capacity of ecological systems to natural and man-produced disturbances. This last point gives place to the cornerstone concept of environmental sustainability, namely that environmental systems are self-organising systems, having the property of maintaining a degree of stable functioning over time. As a consequence, they provide a sufficiently firm context to which human individuals and cultures can adapt their practices. Both concepts are integrated in the so-called basic moral principle of environmental sustainability: "No generation has a right to destabilise the self-organising systems that provide the context for human activities" (Norton, 1992, p25).

But, what does health-integrity mean in ecological systems? In a simple form, a system is healthy if it maintains its complexity and capacity for self-organisation.

Moreover, an ecological system maintains its integrity a stronger concept that includes conditions of health if it retains its total diversity (Norton, 1992). Total diversity is the total sum of species and associations that have held sway historically, as well as the degrees of organisation, which maintain that diversity through time (population, community, ecosystem and landscape complex structures).

Ecological complexity is recognised as the cornerstone of environmental management (Norton, 1992). Complexity is directly related to self-organisation, and health and integrity as essential characteristics of ecological systems-complexity are the result of interactions (of components, processes, and of systems with other systems). This point leads to an ethical focus of this thesis: the obligation to protect biodiversity to the greatest possible extent, as the basis of ecological health and integrity. In addition, it implies keeping the remaining parts of ecological systems from harm, where past action has already destroyed the integrity of large systems. The most important aspect of this ethical goal is the need to protect ecological complexity.

The author of this thesis shares the view of many specialists: Norton (1992), Müller and Nielsen (2000), Jorgensen and Muller (2000), Golley (2000) and others, that ecological systems are self-organising. Consequently, their management must have as a central goal the protection of the system's creativity as the capability to produce multiple self-organising alternatives to face environmental changes. This is also an attribute supported by ecological complexity.

1.1.3 Environmental sustainability and landscape planning.

It is important to clarify what has been referred to landscape here. In order to avoid the debate on the multiple meanings of landscape, this thesis focuses on the concept of landscape at a regional scale. The term landscape was originally used to mean region or territory, and this meaning has been used since the early Middle Ages (830 A. D.) in most of the German languages. The words "lantscaf", "lantscaft" were used to translate the Latin term "regio", meaning territory, region (Hard, 1976, cited by Tress and Tress, 2001). According to Tress and Tress (2001), Old English manuscripts, such as the Anglo-Saxon Genesis, uses the term "landscipe" as a synonym for region. For a detailed review of the concept of landscape see Tress and Tress (2001).

Can land-use planning play a role in creating sustainable rural systems? This is a provocative question posed by van Lier (1998). The same question could be extended to landscape planning: Can landscape planning play a role in creating sustainable landscapes? The answer is that land-use planning, and landscape planning as a strategy for land-use planning have an important task in this regard and they are fields of great opportunities for land-use planners. But what does a sustainable land-use and environmental sustainability relationship mean?

Sustainability in land-use and environmental planning is a goal often criticized as being both vague and a paradox. It is many times mentioned but on few occasions precisely defined. Landscape planning schools of thought are not the exception. However, since the early 1990's the concept of sustainability has been explicitly mentioned as a goal in greenway, ecosystem management, ecological landscape planning, sustainable land use and sustainable landscape planning schools of thought (Ruzicka and Miklos, 1982; Slocombe, 1993a, 1993b, 1998; Gumbrine, 1994, 1997; van Lier, 1994, 1998; Ahern, 1995; Fabos, 1995; Fabos and Ahern, 1995; Linehan, et al., 1995; Christensen et al., 1996; Miklos, 1996; Yafee, 1996, 1999; Zigari, 1996; Botequilha y Ahern, 2002). The sustainability concept in each school of thought is described below.

The greenway approach recognises sustainability as a specific globally accepted goal and paradigm for the future. According to Ahern (1995), the so-called Generation 3 of greenways offers a promising planning strategy to address the challenge of making landscapes sustainable, primarily through the employment of characteristics and benefits associated with networks. For greenway planning, the strategic "battle" is the struggle for sustainable landscapes, against the forces of fragmentation, land degradation, urban expansion and uncontrolled land-use change. The strategic objective is to establish an enduring network capable of supporting the basic ecological functions; protecting key natural and cultural resources and permitting other uses that do not impact landscape sustainability.

For greenway planning, multiple uses is an essential feature for sustainability, and this model focuses on networks and linear areas, which are implicitly contained within a larger landscape context. Based on this landscape context, the purpose of sustainability is to achieve multiple benefits through a combination of spatially and functionally compatible land-uses within a network (Ahern, 1995).

In its turn, the ecosystem management approach considers sustainability as a precondition rather than an afterthought (Christensen, et al., 1996). Sustainability is seen as a goal that maximises ecological integrity or ecosystem health, subject to the need for sustainable human uses (Grumbine, 1994). However, from its most ecocentric viewpoint, this raises ecosystem protection to a first priority when balanced against the wants and needs of the people (Stanley, 1995). Considering this viewpoint, sustainability implies restoring and maintaining ecosystem functions while allowing human use on a sustainable basis (Yaffee, 1999).

As a precondition for management, sustainability focuses on what Lubchencko (1995, cited in Christensen et al., 1996) named "intergenerational sustainability". It emphasises the conscious advocacy of policies and activities that improve the sustainable capability of ecosystems to produce goods and services for current and future generations.

On the other hand, sustainable land-use planning sees the achievement of both ecological and socio-economic sustainability as its main challenge. This, a land-use planning process that integrates goals related to conservation and re-creation (restoration) of natural resources and goals associated to durable socio-economic existence goals. Sustainable land-use planning has established as its main purpose the long-term improvement of the countryside, i.e. achieving sustainable rural systems (van Lier, 1994,1998).

Ecological landscape planning regards sustainability as a result of the preservation of the ecological stability of landscapes and the protection of the quality of the environment. Landscape planning is conceptualised as a framework of applied landscape ecology, whose mission is to react to the demands and needs of society under environmental constrains (Zigrai, 1996).

Finally, sustainable landscape planning sees sustainability as a multidimensional concept that implies the maintenance of land-use patterns that are ecologically, socially and economically viable (Botequilha and Ahern, 2002). Subsequently, these two authors go on to emphasise the importance of scale in sustainability planning and propose the landscape scale as the appropriate context for planning. The need for suitable instruments to apply sustainability concepts to planning and management is highlighted too; thus, a framework of landscape metrics and a planning methodology is proposed as a contribution to this field. This methodology is employed in this thesis as a framework for the decision-making process to delineate ecologically sensitive areas.

Ultimately, despite the different meanings of sustainability, sustainable ecologically-based approaches to land-use planning and management are desirable. Focusing on landscape planning, environmental sustainability would be a goal linked to "environmental carrying capacity", and "intergenerational equity and area-related aspects". It could be defined in a broad sense as: "Sustainability in a landscape means that the use and management of its ecological potential does not reduce its capacity to meet society's future environmental and economic needs" (Saunders and Briggs, 2002 p3). It could also be defined in a more delimited form, as the natural limits set by the carrying capacity of the natural environment (physically, chemically and biologically), so that human use does not irreversibly impair the integrity and proper functioning of its natural processes and components (de Groot et al., 2000). The concept of carrying capacity of the environment refers to the amounts of solar energy flux, nutrients, water, etc, per unit of organism supported, either, directly (plants) or indirectly as food or animal biomass. For humans however, the carrying capacity of a region depends on their material consumption. It is not only determined by food demand, but also by the demands of other resources (water, energy, minerals, waste absorption, etc.). For a more in-depth review about aspects related to environmental capacity, see Bossel (1996), and for topics related to the concept of "environmental carrying capacity of the landscape" see Hrnciarova (1996).

This thesis supports the role of contemporary landscape planning in seeking to create more sustainable regional systems. The sustainable land-use vision is that of a long-lasting multi-functional landscape for the future. In addition, sustainable landscape systems are a challenge and a great opportunity to take advantage of. Many concepts, theories, definitions, policies and actions should be integrated, probed and developed to achieve a more holistic and comprehensive view of landscapes. According to this author, the ecosystem management school of thought and its ecosystem-based resource management variant have taken up these scientific challenges.

This thesis adopts the ecosystem management school of thought as a landscape planning approach for a number of reasons:

1. Ecosystem management is a potential landscape-planning alternative to achieve environmental sustainability, yet is complex to implement. Therefore, the requirements for the development of organised methodologies toward its implementation are identified as a challenge for this thesis.
2. Ecosystem management represents a successful form of an ecologically-based landscape planning approach that integrates ecological knowledge within a complex framework of socio-political values. To date, it is the landscape planning alternative that has earned the broadest scientific and economic support in the world. Furthermore, it has the greatest quantity of applications and field experiences around the world (Yaffee, 1996). However, it is still a young and fuzzily-defined process that requires more evidence research to integrate ecological knowledge into land-use planning and management. This thesis seeks to contribute to this field by approaching the research problems involved in the management of fragile ecologically sensitive areas.
3. Ecosystem management, despite the problems in its implementation is in practice a successful landscape planning alternative. The study of Yaffee et al. (1996) yields optimistic results of its application in the USA. Gumbrine (1998) also reports success in its application in Canada and Australia. Thus, it is interesting to explore the potential of this successful practical approach in a more restricted resource environment (human and material), as with the case study of this thesis.

1.2 Ecosystem management context

Ecosystem management is taking shape as the most ecologically supported landscape planning approach (Christensen et al., 1996; Grumbine, 1994, 1997; Franklin, 1997). Nowadays, it is increasingly providing a basis for establishing the goals and framework for land, wildlife and protected area management (Yaffee, et al., 1996, Slocombe, 1998). Although the term ecosystem management means different things to different people (Grumbine, 1994, 1997; Slocombe, 1993; Yaffee, et al., 1995; Yaffee, 1999), in broad terms, it is the process of managing and understanding the interaction of the biophysical and socio-economic environments within a self-maintaining regional or larger system.

Ecosystem management is also an all-encompassing process for managing areas at various scales in such a way that ecosystem services and biological resources are preserved, while appropriate human uses and options for livelihood are sustained (Haeuber and Franklin, 1996). Ecological services are biological, physical, and chemical processes that occur in natural or semi-natural ecosystems and maintain the habitability of the planet. The major services are allocation of energy, maintenance of soil fertility, and the regulation of the hydrologic cycle (de Groot, 2002). Biological resources on the other hand, include the natural range of variation in genes, species, and ecological communities along with the processes that maintain them (Wilson and Peter, 1998).

As a planning concept, ecosystem management is a form of an ecologically-based approach that integrates the scientific knowledge of ecological relationships within a complex framework towards the general goal of protecting ecosystem integrity over the long term (Grumbine, 1994). In addition, ecosystem management looks for institutional, administrative, as well as scientific ways to manage entire ecosystems, instead of the other small, arbitrary management units that are found almost everywhere (Slocombe, 1998).

According to the report from the Ecological Society of America Committee on the scientific basis for ecosystem management (Christensen, et al., 1996), ecosystem management projects must include the following components:(1) long term sustainability as a fundamental value; (2) clear operational goals; (3) sound ecological models and understanding; (4) understanding complexity and interconnectedness; (5) recognition of the dynamic character of ecosystems; (6) attention to context and scale (7) acknowledgement of humans as ecosystem components; and (8) commitment to adaptability and accountability.

From a management perspective, ecosystem management is a process-oriented, and not management towards an end: It rather seeks to protect and restore the ecological integrity of landscapes, while building sustainable economies and coevolving effective organizational and decision-making structures. It is also a long-term process of understanding decision making that requires multiple sources of integration, expertise and numerous stakeholders. It seeks to be a process of organizational change, in which agencies and groups must act in ways that have not been traditional practised. Finally, it includes strategies of ecological restoration to re-create critical natural system components and processes over long periods (Yaffee, et al., 1996).

Ecosystem management is also considered a learning process. According to Yaffee et al (1996, p25), the overall message to practitioners about the process of ecosystem management is "know land and know your neighbours". As a learning process, it postulates that learning from experience can help to move steadily towards an environmental sustainability, and that the knowledge required to understand the landscape and the interests that are affected by the outcomes of land management are much greater than before.

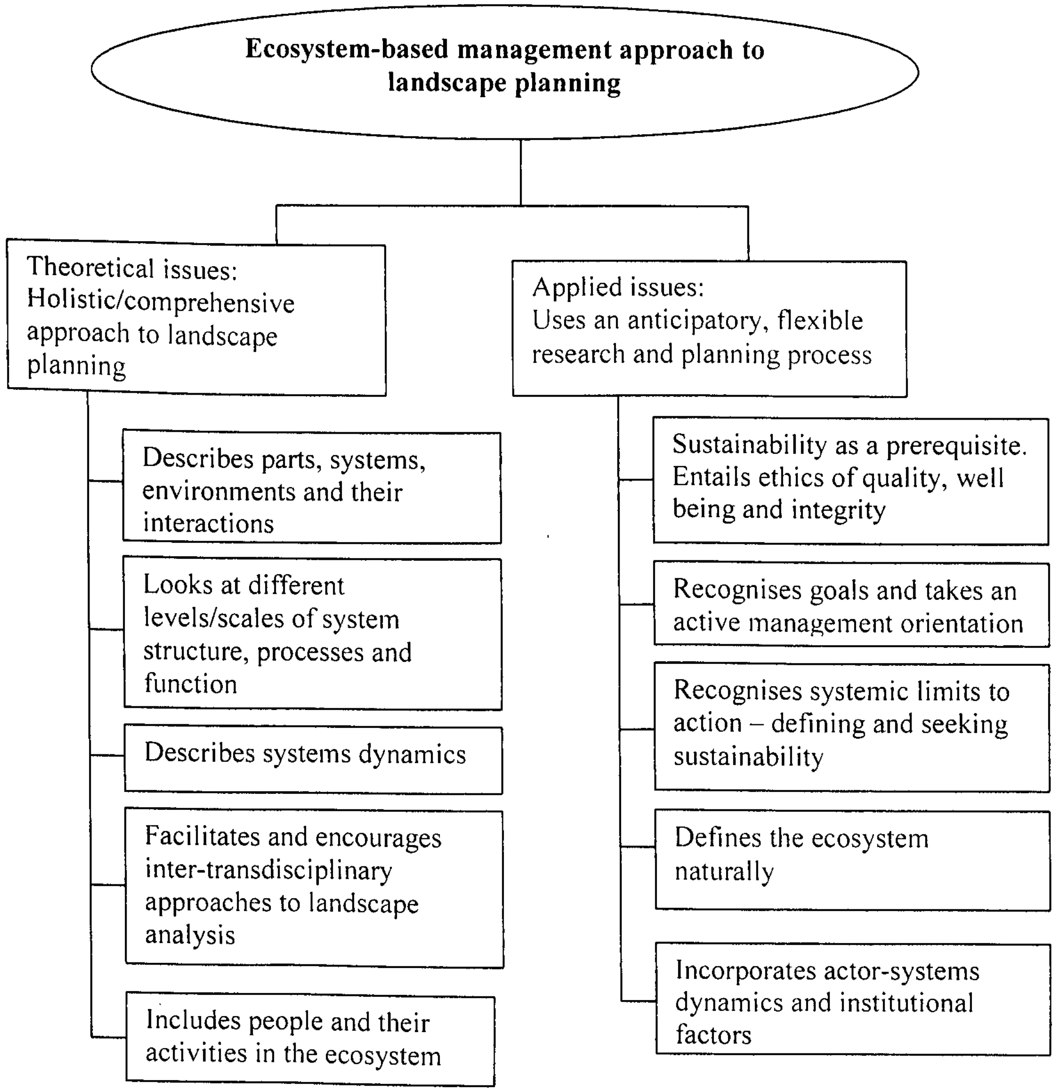
According to Yaffee (1999), ecosystem management is considered to be the main policy in the USA to manage all federal lands and natural resources. It has been adopted as a philosophical paradigm to guide the management of federal forests (Thomas, 1996). However, as an all-encompassing process and paradigm, it does not have a precise definition and there is no well documented and widely accepted organised methodology for its implementation (Slocombe, 1998). In order to face these problems, important efforts have been made during the last decade to characterise its practices. These efforts focused on its essential components as resource management approaches and their objectives. Grumbine (1994), Slocombe (1993a, 1993b, 1998), Yaffee (1996, 1999) and Yaffee et al. (1996, 1997) have led different, but complementary, efforts to characterise current ecosystem management practices, mainly in the USA and Canada. As a consequence of the results, according to Yaffee (1999), three related but different dimensions (faces) could be identified in ecosystem management practice: (1) an anthropocentric, environmentally sensitive multiple use, aimed at fostering multiple human uses of the landscape subject to environmental constrains; (2) a biocentric, ecosystem-based approach to resource management, aimed at promoting the ecological integrity while allowing human use on a sustainable basis; and (3) an ecocentric, ecoregional management, aimed at managing at the ecoregional level, restoring and maintaining ecosystem functions while allowing human use on a sustainable basis.

This last dimension has a focus on landscape and ecosystem processes. It sees ecosystems as integrated spatial units, defined as geoecosystems, fitting within a nested hierarchy of geographical units. These characteristics of the ecoregional dimension are shared with another important approach to ecosystem management: ecosystem-based management. This approach, developed in Canada during the 1990s, intends to achieve an integrative and transdisciplinary focus on regional/landscape planning. According to Slocombe (1998), this approach has a theoretical and practical basis derived from the ecosystem approach in different disciplines, and its application to protected areas and regional planning.

1.3. Ecosystem-based management context

Conceptually, according to its ecosystem approach roots, ecosystem-based management is a systems approach to landscape planning. It looks for an integrative vision of huge territorial spaces employing different spatial units; watersheds, bioregions, economic or political regions, and so on. Ecosystem-based management claims that a territory must be seen as a whole (including its natural and social components) and through a collaborative approach manage decision-making processes. It puts a strong emphasis on data collection and monitoring, working across administrative boundaries, adaptive management, interagency co-operation, organisational change, and with a strong focus on maintaining ecological integrity. Its most remarkable characteristic is that it integrates theoretical and applied issues. Firstly, it seeks to apply a holistic/comprehensive viewpoint of the landscape/region, and secondly it fosters the use of an anticipatory, flexible research and planning process (see Figure 1.1).

Figure 1.1. Ecosystem-based management approach to landscape planning



Source: The author after Slocombe (1993, 1998) and Grumbine (1994).

A holistic approach means: (1) to assume a dialectic position with respect to the interactions between a whole and its parts, and (2) a synthesis of knowledge from different disciplinary viewpoints. Holism or a holistic approach is recognised as a way of thinking alternative to atomism or Cartesian reductionism. The Cartesian world viewpoint or paradigm sees the world as a clock; phenomena are the consequences of the coming together of individual atomistic bits, each one with its own intrinsic properties, determining the behaviour of the system as a whole. This paradigm when applied to any discipline from atomic physics to economics, abstracts the individual parts from their relations to their context. Thus, objects are reduced, whenever is possible to physical forces, and interactions among them are treated deterministically. It means that a model of causation is assumed that is deterministic and reversibly-mechanistic. Nevertheless, this paradigm is recognized to be inadequate when facing the behaviour of complex systems, where the multiple direct and indirect relations between parts of a system difficult a cause effect approach (Levin and Lewontin, 1985).

In contrast, holism or holistic approach is a dialectic paradigm based on the logic that parts imply a whole, and a whole implies parts. Parts and whole have a special relationship to each other, in that one cannot exist without the other. According to this paradigm, parts acquire properties by virtue of being parts of a particular whole, which is their context. They do not have these properties in isolation or as parts of another whole. This premise implies that it is not that the whole is more than the sum of its parts, but that the parts acquire new properties according to the whole of which they are forming a part. The dialectic relationship between parts and whole arises when the parts acquire properties by being together. Subsequently, they impart new properties to the whole. Furthermore, these new whole properties are reflected in changes in their parts, and so on. In this way, parts and whole evolve as a consequence of their interrelationship, and the interrelationship itself evolves (Levins and Lewontin, 1985). This dialectic relationship between parts and whole has been considered to be an appropriate paradigm to deal with complexity and complex systems (Koesler, 1967; Laszlo 1994).

In terms of landscape research and planning, it has been argued that a holistic theory of landscapes has to be based on a hierarchical point of view of the world, rooted in general systems theory (Naveh, 2001). Systems theory has been seen as the most general and robust form to tackle complex systems, which are open and ever changing. This theory focuses on the analysis of how systems maintain their complex form and functions over continuous exchanges of energy and materials with their environment. In this general form, systems theory is hierarchical and open ended, and causation flows both ways in the system (Koestler, 1967). In this context, landscapes and ecosystems have been considered as hierarchical and complex systems that should be analysed from a holistic viewpoint (Borman and Likens, 1979; Ruzika and Miklos, 1982; Haber, 1990; Naveh and Lieberman, 1994; Ruzicka, 1995; Schaller, 1994; Farina, 1998; Muller and

Jorgensen, 2000). Modern ecosystem theory is immersed in holistic ideas about the properties of ecosystems (Bormann and Likens, 1979; Muller and Jorgensen, 2000) and there has been an international call for the application of a holistic approach to landscape research (Palang et al. 2000; Li, 2000; Naveh, 2001; Tress and Tress, 2001). Nowadays, the watershed-ecosystem theory has proved to be a holistic approach that opens the possibility to use watersheds as black boxes, without the need to study first their composing elements at the lowest levels (Bormann and Likens, 1979).

In general terms, the holistic approach applied to ecosystem and landscape research seeks an analysis where:

1. Ecosystems and landscapes can be seen as an uncertain whole in reciprocal interaction with lower and higher wholes, but not completely determined by them.
2. Some properties at ecosystem and landscape levels can be defined for these levels and become interesting objects of study regardless of how they are eventually explained. Among such properties are biodiversity, biomass accumulation, primary production, hydrological and biogeochemical control, connectivity, and the shifting mosaic steady state pattern (Bormann and Likens, 1979; Cook and van Lier, 1994).
3. Properties of the landscapes and the properties of constituent ecosystems can be linked by many-to-one and one-to-many transformations. Many-to-one-ness means there are many possible configurations of ecosystems that preserve the same qualitative properties at the level of the landscape (spatial pattern as a shifting mosaic). This view allows landscapes to be seen as similar, despite spatial pattern changes and allows its persistence over time even though the individual parts are constantly changing (shifting mosaic steady state paradigm (Bormann and Likens, 1979)). In contrast, the one-to-many relation of parts to landscapes reflects the fact that not all properties of the parts (ecosystems, communities and ecotopes) are specified by rules at the parts level. Therefore, the one-to-many-ness is conceptualised as a non-deterministic or random influence of the higher level on the lower. Together, the many-to-one and one-to-many couplings between levels determine the emergence of new properties (Adapted from Levin and Lewontin, 1985).

In addition, properties that explain the structure, function and change of landscapes are scale dependent. The measurements of spatial patterns and heterogeneity are dependent upon the scale that is considered. Natural and social processes occur at specific time and spatial scales. Thus the hierarchy paradigm has been applied to landscape ecology, in order to provide guidelines for defining the functional components of a landscape, and establishing different ways in which components, at different scales, are related to one another. The application of the hierarchy paradigm permits the complexity of landscapes to be partially simplified by decomposing them into a hierarchical framework, in which each scale level may have its own properties and mechanisms (Naveh and Lieberman, 1994; Naveh, 2001).

In other respects, a holistic approach to landscapes also means a synthesis of multi-dimensional viewpoints. It is considered that, when a complex system is analysed or conceptualised, a single viewpoint is not enough. Therefore, different dimensions should be taken into account. For this reason, it is argued that inherent in a holistic approach is the interdisciplinary character of ecosystems/landscape ecology and planning.

Problem solving at the ecosystem/landscape level requires knowledge and awareness of the complex interactions between social and natural components. Usually, problems at landscape level are related to the needs for multi-functional landscapes. The analysis and solution of these problems depends on the contribution of various disciplines (Naveh, 2001).

According to Palang et al., (2000), Fry (2001), Naveh (2001) and Tress and Tress (2001) multi-functional landscapes require research and management approaches that cross traditional subject boundaries. These authors argue that planning and management decisions for improving farm production, biodiversity, wild habitats, attractive landscape, leisure and recreation or other environmental functions, cannot be made outside the context of human needs and wishes. In addition, they argue as well that single-subject approaches fail to incorporate all these aspects and, moreover, fail to consider how promoting one countryside interest will interact with others. This current situation favours integrated approaches to landscape research and planning.

Integrated approaches mean researching beyond traditional subject boundaries. In terms of landscape research, it implies going beyond traditional parallel studies and the comparison of their results (parallel studies mean research teams working in parallel to investigate different aspects of a common problem) (Fry, 2001). Parallel studies have been a common approach to studying the relationships between landscape functions. Nevertheless, although they bring useful information, they do not permit a deeper understanding of landscapes to be attained. In contrast, going beyond these parallel studies, when combined with the knowledge to understand the way multi-functional landscapes operate, gives rise to interdisciplinary studies. These studies seek to create new knowledge and solve a common research goal involving several unrelated academic disciplines, which have contrasting research paradigms. According to (Tress, et al., 2004), true interdisciplinarity occurs when joint theories evolve between disciplines. Transdisciplinary research begins when, in addition, there exists a high degree of integration and new theories, and when models and methods merge across disciplinary boundaries (Fry, 2001). In other respects, Tress et al. (2004) support the idea that transdisciplinary studies are those that integrate academic researches from different disciplines with non-academic participants, such as land managers and the public, to create new knowledge and research a common goal.

An ecosystem-based management approach attempts to apply an anticipatory and flexible, research and planning process (Slocombe, 1994, 1998). Anticipatory characteristics are proposed due to the acknowledgement that ecosystems and social systems are uncertain and unpredictable. Such uncertainty arises from their complexity. In ecosystems, uncertainty arises from the distribution and importance of many species and elements, as well as from a limited understanding of the complex relationships between organisms and elements. In addition, it is also supposed that uncertainty dominates complex social systems, since it is not possible to predict many of the main actions of social organisations, except perhaps in the very short time. This is because persons, who have changing perceptions about what is possible or desired, direct human organisations as a function of the situation where they are inserted (Matus, 1989). Matus claims that social actions do not operate on cause-effects principles (a deterministic relation) but on initiative-response principles, and this is why society and social actors develop unimaginable and unpredictable actions. For these reasons, recognising uncertainty means to use anticipation instead of prediction in the planning process. The planner's main concern must not be prediction, but the way to systematise forethought and to acknowledge that unlikely events (surprises) do happen (Matus, 1989; Holling, 1993).

The treatment of uncertainty implies consideration of a flexible planning process. Uncertainty in ecological systems leads to a conservational attitude towards natural resources and it also leads to the assumption of their adaptive management, i.e., to assume an adaptive resource management. This kind of resource management accepts that the actual knowledge, related to ecosystems functions and the best management practices, is provisional and subject to change with new information. In this context, management goals, protocols and directives should be viewed as hypotheses. This means seeing them as temporal proposals that should be monitored and assessed. In addition, monitoring programs become specialised kinds of research programs designed to test and provide feed-back on current management proposals (Holling, 1978; Christensen et al., 1996). On the other hand, uncertainty in social systems implies the development of procedures to face quasi-structured (poorly structured) problems, i.e. problems where not all the elements are known and neither are the relations among their variables. Furthermore, these problems only follow laws partially. In order to face this kind of problem it is proposed the construction of scenarios as the means of treating uncertainty. Scenarios are a set of conditions and assumptions for carrying out a plan. They are built as a response to a general question: "what will happen if…." The construction of scenarios is seen as an appropriate way for a planning process to proceed, supported more by anticipatory strategies than by prediction capabilities. Finally, flexibility to social change also means confronting social and institutional dynamics. Changes in organisational cultures and commitments will be critical to the implementation of adaptive management. It must be recognised that there must be sufficient institutional stability and sustainable commitment to achieve successful long-term outcomes.

In terms of time scales, ecosystem-based management must deal with these that exceed human lifetime and certainly the timelines of other political, social and economic agendas. Public and private management agendas are often forced to make fiscal year decisions about resources whose behaviour is best measured in centuries. Ecosystem based management must deal also with spatial scales where spatial borders of ecosystems are not congruent with management jurisdictions. Therefore, reconciliation of objectives and actions of the various stakeholders within the domain of an ecosystem must be a central element in the implementation of sustainable management strategies. In addition, often other stakeholders should be taken into account, who have no title of legal jurisdiction but are dependent on, or have an interest in, the goods or services provided by an ecosystem. Thus, strategies must be developed to incorporate long term and multistakeholder planning and commitment, while recognising the need to make short-time decisions. This means that managers and decision makers must be committed to improving outcomes over biological time scales and to have an understanding of stakeholders' dynamics and a mandate for action in the face of uncertainty.

In an ecosystem based management approach, management goals and orientation are in the context of environmental sustainability. They are related to achieving ecological integrity while allowing human uses on a sustainable basis. Management at an ecoregional scale is considered critical in achieving these goals. The primary focus is on a landscape-ecosystem scale, with an ecosystem structure and function taking central stage. As a result, restoration or maintenance of ecological processes, such as nutrient cycling, disturbance regimes or hydrological flows become just as important to maintaining species composition and diversity (Yaffee, 1999). However, to some advocates of this approach, including the author of this thesis, species are not important management foci. If the landscape is taken care of, the species associated with it will take care of themselves. Therefore, biodiversity depends on ecosystem diversity (Barnes et al., 1998).

In this context, goals relative to achieving ecological integrity, based on ecosystem diversity maintenance while allowing human uses are a planning challenge and an opportunity to apply landscape and ecosystem theoretical principles and concepts. This challenge requires on the one hand, research to supply information related to the characteristics of ecosystems and its components, and the economic and social factors that threaten them and on the other hand, tasks related to identifying and prioritising natural areas for protection. This thesis proposes a research strategy based on the delineation of ecologically sensitive areas at a watershed-ecosystem scale to integrate these research and planning tasks.

1.4 Ecologically sensitive areas context

The ecologically sensitive areas play a key role in contributing to the achievement of nature conservation in this research. This thesis claims that nature conservation in terms of land-use planning processes should be focused on the delineation of ecologically sensitive areas and the design of public policies to achieve their protection, conservation or restoration.

The concept of ecologically sensitive areas has always been employed in the context of nature conservancy concerns. These concerns are based on the value of these areas in terms of material and leisure benefits to human beings. Like the sustainability concept, an ecologically sensitive area is also a value-loaded concept. Referring to this concept of value, closely linked to spectators' viewpoints, this thesis considers that ecologically insensitive areas do not exist. It is logical to think that if there are some ecologically sensitive areas then some ecologically insensitive areas should also exist. Austrian landscape planners have solved this dilemma. In the context of a two-way relationship between nature and society (nature affecting the development of society and vice versa), they argue that only areas in which changes have no material effects on people can be deemed insensitive-and these are not found on Earth (BMLFUW, circa 2000). However, there are particular areas that host irreplaceable ecological and cultural assets or open up potential for a future regional development. Thus, these areas should be identified, delineated and environmentally conscious policies should be designed to protect them.

In a broad definition, ecologically sensitive areas are landscape elements, or places, that are vital to the long-term maintenance of biological diversity, soil, water or other natural resources, on a site and/or regional context. They include wildlife habitat areas; steep slopes, riparian areas, wetlands and prime agricultural lands are landscape elements that are important for nature conservancy. These landscape elements are considered vital to: (1) the long-term conservation of biological diversity and maintenance of essential ecological processes (e.g. biomass accumulation, and hydrological and biogeochemical regulation); (2) provide habitats for wild plant and animal species; and (3) provide opportunities for understanding nature for educational purposes, in local and regional context (Ndubisi, et al., 1995).

On the other hand, the topic of "ecologically (or environmentally) sensitive areas" is addressed frequently in policy and planning contexts. However, there is no consensus on their material content or technical support. There are a number of different conceptions, depending on the user and the project concerned. For European countries, which generally consider risk criteria, ecologically sensitive areas are those areas whose natural, cultural and geographical values are susceptible to factors of deterioration. They are susceptible, due to an existing ecological balance between them and/or those that depend on them. They are also susceptible because of the change in the balance of harmony of the entire landscape (Miklós, 1996). For Canadian environmental authorities, which employ biodiversity care criteria, ecologically sensitive areas are lands associated with high species diversity or rare or endangered habitats and/or populations. Their role is to support unusually high diversities of plant and/or animal communities and populations and habitats of rare, threatened or endangered species. These areas usually contain a critical habitat or limited range in terms of habitat, this refers to the limited supply of a resource or resources-providing breeding, shelter or feeding sites for wildlife. Ecologically sensitive areas contain plant and/or animal associations and/or habitats that might be remnants of once larger habitats that have virtually disappeared. Generally, they include the entire area of Natural Parks, Nature Reserves, Natural Monuments and sites of scientific interest, as well as protected landscapes and peripheral zones of the Protected Nature Areas and buffer zones along water courses (Environmental Canada, 2000).

Private planners of British Columbia (Silva Forest Foundation, 2000) have also used disturbance criteria to estimate sensitivity of parts of the landscape to human uses. They employ a Ecosystem Sensitivity to Disturbance (EDS) rate. The rating system is based solely on a group of physical factors: slope gradient, slope shape, soil depth to a water impermeable layer and site moisture conditions. Various combinations of these factors result in high or extreme EDS ratings. Sites that generally receive high or extreme rates include riparian ecosystems and steep terrains (slopes greater than 60%).

As can be seen, risk to human activities and biodiversity care criteria are predominant in the processes used to select and delineate ecologically sensitive areas. However, for a more complete view of them, other criteria should be taken into account. For this reason, the basic idea of this thesis is to tackle the selection and delineation of ecologically sensitive areas as a multi-criteria decision-making process.

A practical problem arises from the question how to delineate ecologically sensitive areas? For this thesis, the decision has been to depict it as a multi-criteria problem because of the many factors involved. This research focuses this problem on the development of criteria that consider those factors associated with the identification and delineation of these areas and give place to a practical and methodologically well supported decision-making process.

The pioneers of a multi-criteria approach in ecologically sensitive areas are the planners of the Federal Ministry of Agriculture, Forest and Water Management of Austria (BMLFUW, abbreviation of its German title). Austrian planners suggested that the employment of technical and political criteria was needed to define this term. This purpose was met through the design of a catalogue of key criteria. These key criteria have a purpose-oriented design; they are aligned directly along the lines of interest of a society and areas of political responsibility.

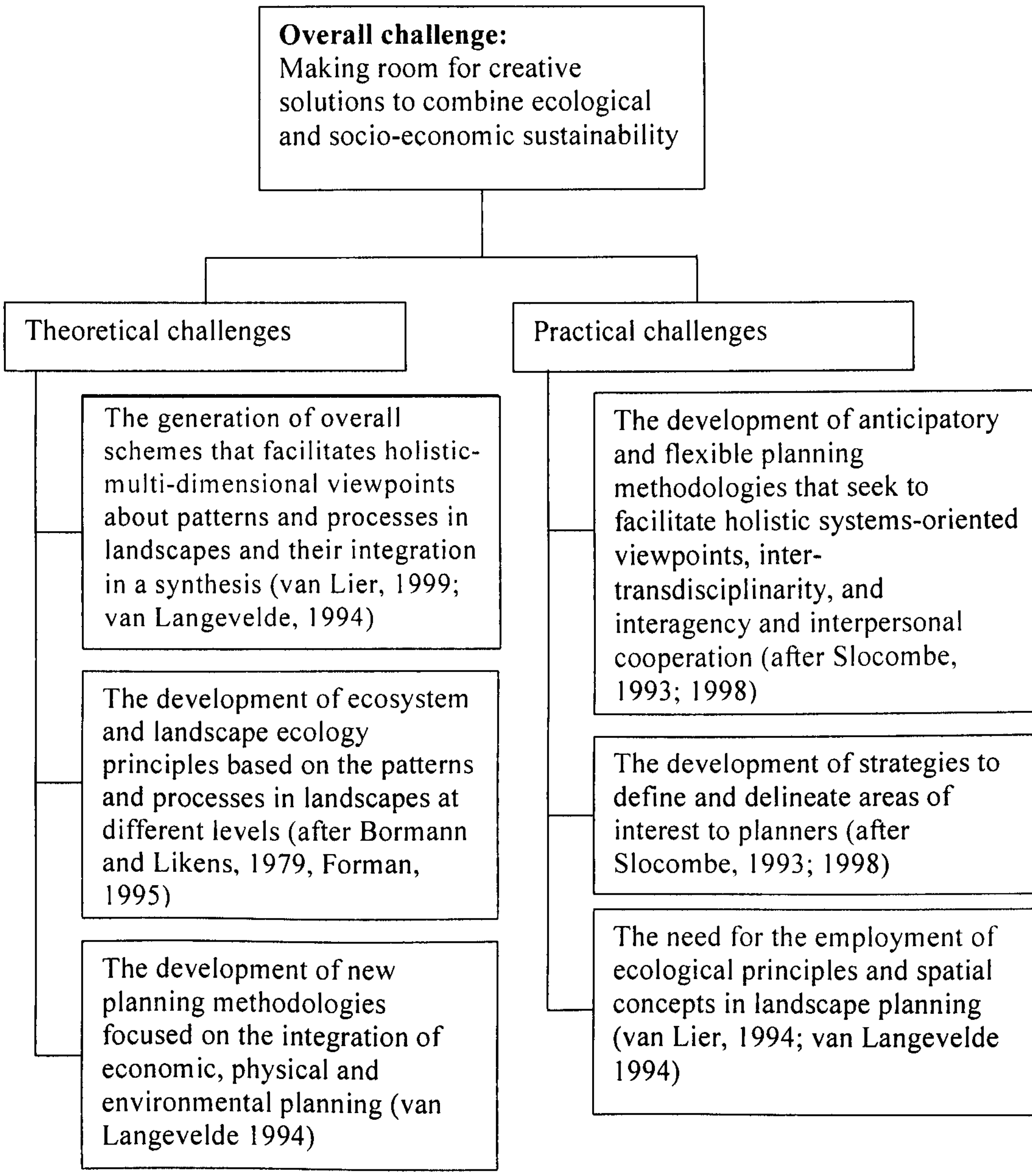
They constructed a catalogue employing three key criteria: ecological and cultural value, fragility of habitat, and potential for sustainable development (BMLFUW, circa 2000). Moreover, groups of attributes/indicators were attached to these three criteria, e.g. rarity and diversity were attached to the ecological and cultural value criterion. In its turn, subsets of indicators were associated to each attribute/indicator group, e.g. rare habitats and rare landscapes were included into the rarity indicator group. Afterwards, the complete hierarchy was used as a checklist to assess different areas with respect to their ecological sensitivity.

This hierarchical-multi-criteria approach is the best antecedent of the multi-criteria approach developed in this thesis. Austrian planners developed a scientifically supported and practical criteria catalogue. The three criteria selected and the sets of attributes and sub-attributes represent an important contribution to the multi-dimensional-holistic approach to landscape analysis. The checklist, as an instrument of expert judgement, is an interesting instrument and a starting point for more elaborate expert judgements based on weighting procedures. The basic idea is to include weight judgements into criteria and their subsets of attributes and sub-attributes. This thesis will develop an expert judgement strategy based on the Analytical Hierarchy Process, which will be described in more detail in chapter three.

1.5 Challenges of an ecosystem-based management project

An ecosystem-based management approach that seeks to be a scientifically well-supported landscape planning approach, offers interesting research challenges in theoretical as well as practical terms (Figure 1.2). Firstly, it shares with other land use planning approaches the challenge of achieving sustainability. Ecosystem-based management recognises it as a precondition for planning (Christensen, 1996, Slocombe, 1998). In addition, this approach, attempting to achieve sustainability, also poses theoretical challenges related to the use of holistic procedures, the development of ecosystem and landscape principles and the development of planning methodologies focused on a sustainable countryside.

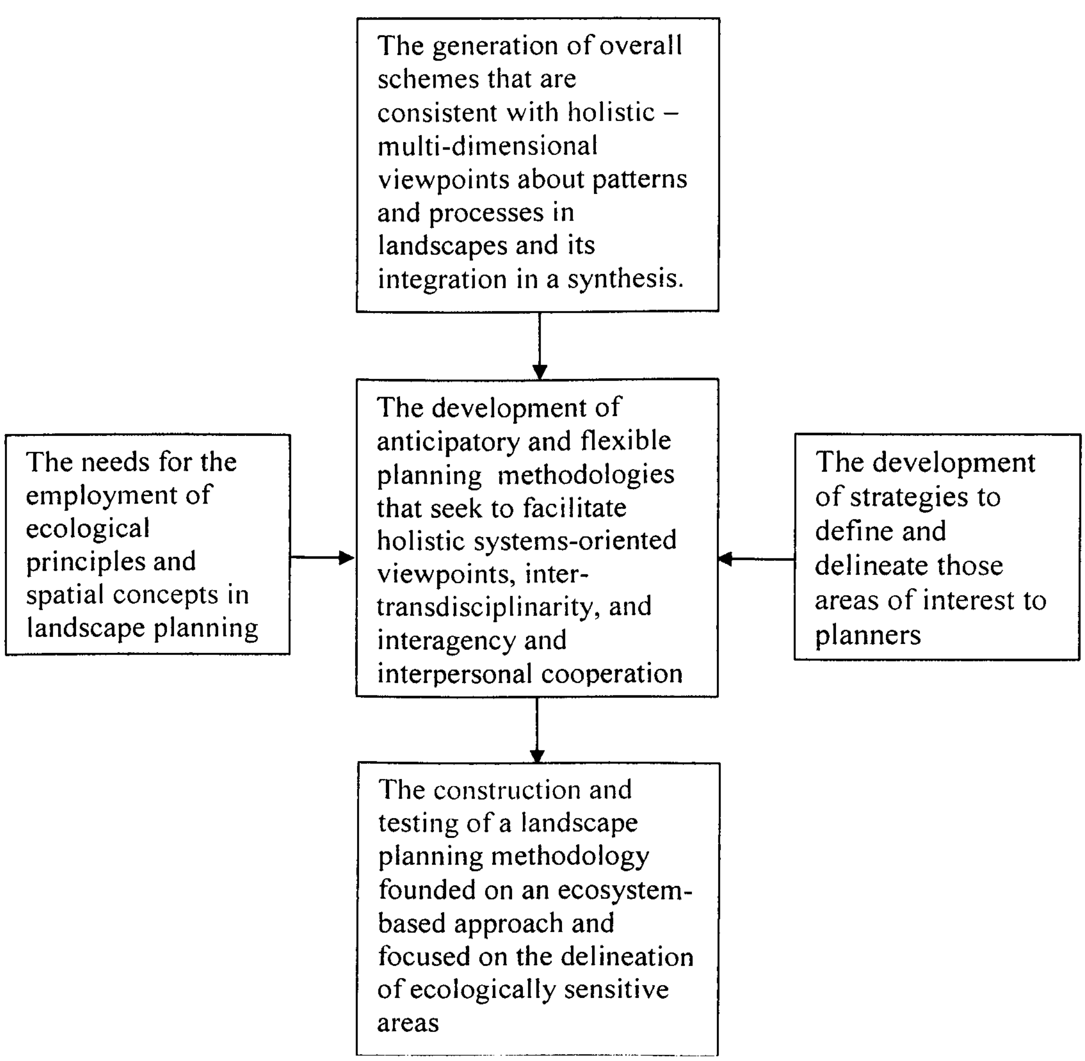
Figure 1.2 Research challenges.



From all the above, this thesis assumes a practical challenge: the development of anticipatory and flexible planning methodologies that seek to facilitate holistic systems-oriented viewpoints, inter-trasdisciplinarity, and interagency and interpersonal cooperation. This research supposes that the confrontation of this challenge gives enough room for constructing and testing a landscape planning methodology based on an ecosystem-based management approach. However, it is important to remark that an ecosystem-based management approach also implies an attempt to tackle partially at least three further challenges. One theoretical problem is related to the generation of overall schemes that are consistent with holistic-multi-dimensional viewpoints about patterns and processes in landscapes. This thesis assumes the development of this scheme as its main theoretical challenge. On the other hand, two practical problems are also confronted: the need to employ ecological principles and spatial concepts in landscape planning and the development of strategies to define and delineate areas of interest to planners. The first one is considered as a basic challenge bridging the gap between ecosystem and landscape ecology theory and landscape planning. In this research this problem is dealt with seeking the integration of the watershed-ecosystem paradigm (Bormann and Likens, 1979) and the ecological network spatial principle (van Lier, 1994, 1998) with landscape research and planning. On the other hand, confronting the definition and delineation of areas is seen as a way to give focus to the planning process. The delineation of a particular kind of area may take the form of a target that permits a clearer identification of the needs for theoretical constructs, adaptive results derived from other research and the generation of overall schemes to address the problems related to their delineation. This thesis thus focuses on the delineation of ecologically sensitive areas.

The relations between these four challenges gives rise to the main goal of this thesis: the construction and testing of a landscape planning methodology founded on an ecosystem-based approach and focused on the delineation of ecologically sensitive areas. These relations and the general scope of the thesis are shown in Figure 1.3.

Figure 1.3 Challenges assumed and the scope of this thesis.



1.6 Research goal and objectives

The goal of this research is: to investigate the applicability of a landscape planning methodology founded on an ecosystem-based approach focusing on the delineation of ecologically sensitive areas.

In order to achieve this goal the following objectives have been defined:

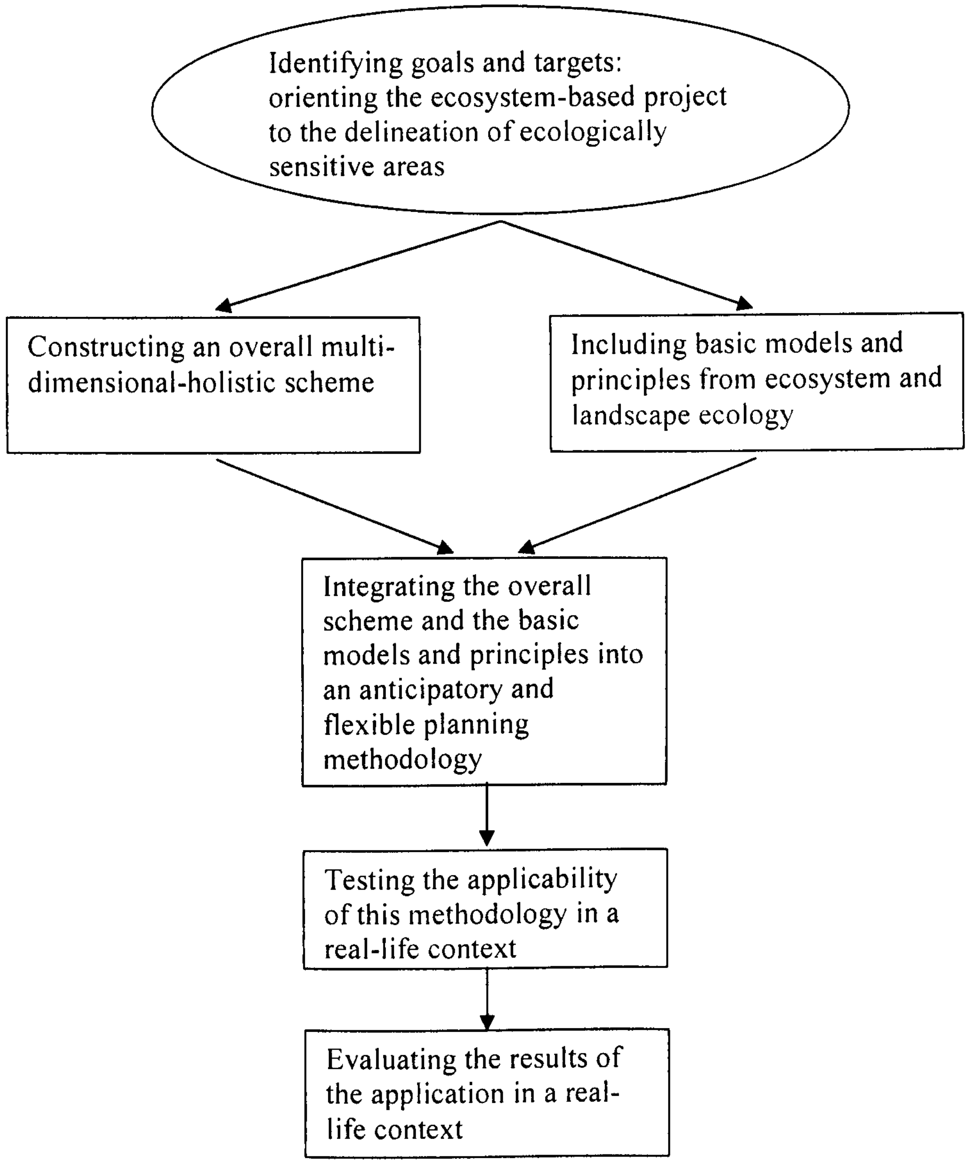
1. To investigate and validate the need for an overall scheme that facilitates holistic-multidimensional viewpoints in an ecosystem-based management project focused on the delineation of ecologically sensitive areas
2. To investigate the potential of the integration of multi-dimensional models, methods and procedures into a landscape planning methodology that is founded on an ecosystem-based approach, focused on the delineation of ecologically sensitive areas.
3. To investigate the applicability of the watershed-ecosystem paradigm (Bormann and Likens, 1979) and the ecological network principle (van Lier, 1994, 1998) in the context of an actual ecosystem-based management project.
4. To integrate the overall holistic-multidimensional scheme, the strategies to define and delineate ecologically sensitive areas, and the application of the watershed-ecosystem paradigm and the ecological network principle into an anticipatory and flexible planning methodology.
5. To consider and validate the applicability of this planning methodology to a real-life context.

1.7 Research design

In terms of planning theory, this research seeks an integration of some aspects of procedural and substantive planning approaches (Faludi, 1973). In terms of a procedural approach, the design of this research considers the construction of a methodology that helps to provide some guidelines for the development of ecosystem-based management projects. This involves the identification of methods that deal with the formulation of objectives and planning goals, a multi-dimensional assessment of ecosystems and landscapes, and the analysis of complex-wicked problems related to nature conservancy. On the other hand, the design of this research considers some aspects of a substantive planning approach. It attempts to develop understanding of the landscape through the application of some models and principles from ecosystem and landscape ecology.

The implementation of an ecosystem-based management project is attempted of a multi-dimensional viewpoint of landscapes and the application of the ecosystem-watershed model and the ecological network principle as a way to provide guidelines and legitimate interventions in the landscape. The integration of both approaches is displayed in Figure 1.4.

Figure 1.4 The logical framework of this research.



This figure describes the logical framework of this research. The first task is the identification of goals and targets, which is widely recognised as a critical need in landscape and ecosystem management (Slocombe, 1998). Addressing this need, our research focuses on the delineation of ecologically sensitive areas as its key target. Ecologically sensitive areas have three characteristics that are appropriate for an ecosystem-based management project: (1) Ecological sensitiveness means a multi-dimensional approach. An area can be ecologically sensitive according to multiple criteria such as biological or cultural value, environmental risks and so on. (2) The delineation and further protection of these areas leads to the analysis of complex/wicked regional problems related to nature conservancy.

(3) Their delineation and further protection also provides the target needed to guide the activities in this ecosystem-based management research.

The second task is the need to develop an understanding of the landscape. It is assumed in this research that this can be addressed by two strategies. By supporting a multi-dimensional-holistic viewpoint of landscapes and by including models and principles that are ecologically well-supported. It is also assumed that the development of an overall scheme that is consistent with a holistic viewpoint on landscapes should be based on:

The employment of remote sensing methods to have complete images of ecosystems and landscapes. In addition, working with images from different dates allows the spatial and temporal dynamics of ecosystems and landscapes to be tackled.

The use of geographical information systems to store and process geographically referenced information (information layers).

The application of multi-criteria analysis as a logical model to support and enhance multi-dimensional viewpoints on landscapes and ecosystems.

The use of procedures to analyse complex problems, such as those related to nature conservancy.

In terms of models and principles that are ecologically well-supported, this research adopts the ecosystem-watershed model (Bormann and Likens, 1979) and the ecological network principle (van Lier, 1994, 1998). The ecosystem-watershed model provides the theoretical and empirical support for this ecosystem-based management project and the ecological network principle provides a spatial model for landscape analysis and planning based on connectivity. Improving connectivity between protected areas is one of the planning strategies in this project.

Following a logical sequence, the integration of the target with theoretical assumptions is proposed as the third task of this research. It is expected that the focus, the overall scheme and the basic models and principles can be integrated into an anticipatory and flexible planning methodology. Here, it is assumed that a methodological framework will be selected that possesses the needed anticipatory and flexible characteristics. Thus, a methodology is selected that is as complete as possible and gives emphasis to the implementation and monitoring of the plan (Botequilha and Ahern, 2002).

Testing the applicability of the methodology in a real-life context is the fourth task to be accomplished. This research adopts a case study as the strategy to carry out the task.

This research strategy was selected after considering its theoretical and practical advantages.

Theoretical advantages are related to the scheme of the holistic analysis of complex problems that this research attempts to develop. A case study allows the adoption of a holistic research strategy rather than one based on isolated factors, and enables the use of a variety of research methods and data sources. It can also be designed to test or illustrate a theoretical point. It represents thus a practical solution to one of the main concerns in adopting a holistic approach, that a potentially useful hypothesis might be rejected. On the other hand, a case study used as a research strategy offers practical advantages to confront the challenges in the practice of planning, such as the investigation of a phenomenon as it naturally occurs, the concentration of efforts on one research site and the search for a remedy to problems present in the chosen area. (After Holling (1995), Descombe (1998), Blaxter et al., (2001)).

In order to test the application of the planning methodology to a real-life context, the Iztaccihuatl-Popocatepetl volcanoes National Park region of Mexico was selected. Pragmatic and suitability criteria were employed in this selection. There were also personal, institutional and research considerations of convenience, as there are currently institutional concerns and interests to develop a nature conservancy plan for this region.

According to the criteria exposed in chapter 13 of Agenda 21, the Iztaccihuatl-Popocatepetl volcanoes region could be recognised as a typical example of a mountain region that is experiencing environmental degradation. This region exemplifies environmental problems that are characterised by glacier loss and associated water source depletion, accelerated soil erosion and a consequent loss of soil, landslides which have increased risks to human settlements and an alarmingly rapid loss of habitat and genetic diversity caused by increasing human impact. On the human side, the region is characterised by widespread poverty among mountain inhabitants and loss of indigenous knowledge. The low income from agriculture and livestock products has reduced incentives for the continuation of farming activities. Most of the region's young people under 40 years old are working at nearby urban areas, either Mexico or Puebla cities, or they are temporal or definitive migrants to the USA. Old people, children and women, inhabit many of the mountain towns. As a consequence, there are many abandoned crop and livestock fields in the municipalities surrounding this National Park. Another harmful consequence is related to the loss of many traditional crops. This implies the loss of crop genetic resources and the extinction of many crop varieties. Taking into account all these problems, this region could be a fragile ecosystem, the protection of which requires particular attention.

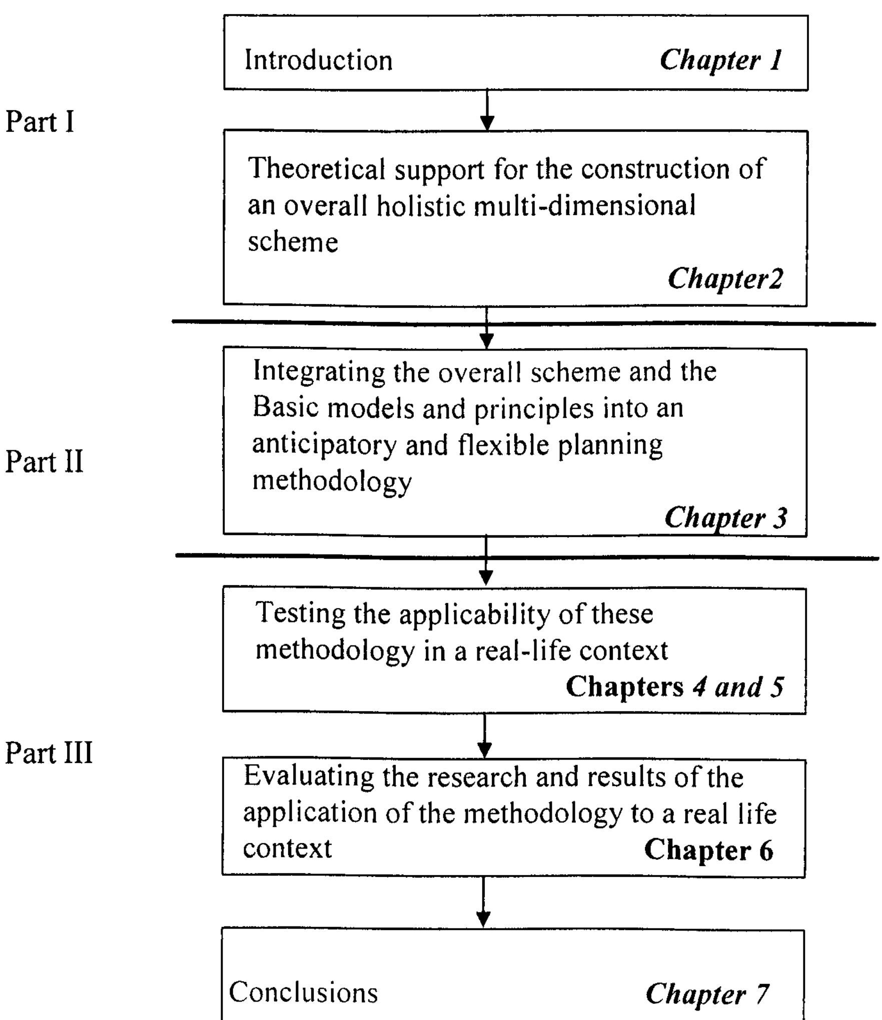
The region of Iztaccihuatl-Popocatepetl volcanoes is appropriate as a typical instance and as a test site for the methodology. Besides the problems enumerated before, this region permits the development of a case study characterised by complex-wicked problems related to the protection of biodiversity in a hard, social, economic and cultural context.

Finally, the evaluation of the results of applying this methodology in a real-life context is considered the fifth task. It is assumed that there is a need for a multi-scale evaluation of the results of the development of the case study, because of the results of different procedures employed at each planning phase, the overall results of each phase and the global results from the entire planning process. Thus, an evaluation that is as complete as possible is attempted, based on the weaknesses and strengths of the results and the procedures employed. This task led to some recommendations about the ways to improve procedures, logical models and methods employed in this research.

1.8 Structure of the thesis

The structure of this thesis is presented in three parts and follows the logical framework of the research already described (Figure 1.5).

Figure 1.5 The structure of the thesis



Part I (chapters 1and 2) takes up research objectives one and three: investigating and validating the need for an overall scheme that considers holistic-multi-dimensional viewpoints in an ecosystem-based management project focused on the delineation of ecologically sensitive areas; and to investigate the applicability of the watershed-ecosystem paradigm (Bormann and Likens, 1979) and the ecological network principle, (van Lier, 1994, 1998) in the context of a real-life ecosystem-based management project. This part integrates the basic issues that theoretically support an ecosystem-based management approach, including a multi-dimensional view of it and its context. Moreover, it includes the needed theoretical support to construct an overall holistic-multi-dimensional scheme. Thus, theoretical issues are organised to addresse the theoretical support, to conceptualise, from a holistic perspective, ecosystems and landscapes and the logical support behind models, spatial principles, methods, procedures and general methodology used to construct the particular holistic scheme of this thesis.

Part II deals with research objectives three and four: to investigate the potential of the integration of multi-dimensional models, methods and procedures into a landscape planning methodology. This section is developed in chapter 3, which is related to the construction of an anticipative and flexible landscape planning methodology for an ecosystem-based management project. Here, the key issues of part one are treated, such as the delineation of ecologically sensitive areas as a target, the holistic conceptualisation of ecosystems and landscapes and models, spatial principles, methods and procedures. Particular emphasis is given to those phases of the methodology that provide flexibility and anticipation characteristics.

Part III engages research objective five: validating the applicability of this planning methodology to a real-life context. It tests of the methodology in a real-life context through a case study, and evaluates the results derived from this work. A mountain region in Mexico is selected: the Iztaccihualt-Popocatepetl volcanoes National Park region. This part includes chapters 4, 5 and 6. Chapter 4 presents the main arguments supporting the Iztaccihuatl-Popocatepetl volcanoes region as an appropriate case study and provides an overall background of this region. Chapter 5 presents the results derived from the application of the different phases of the constructed methodology. Particular emphasis is given to the rationale behind the different processes carried out during the application of the methodology. Chapter 6 discusses and evaluates research results, the extent to which the objectives were achieved. Chapter 7 presents the general conclusions of the thesis, including a summary of the research, lessons learned during its course, and an agenda for further studies.

Chapter 2. Theoretical and practical bases for implementing an ecosystem-based management approach and an ecologically sensitive areas strategy

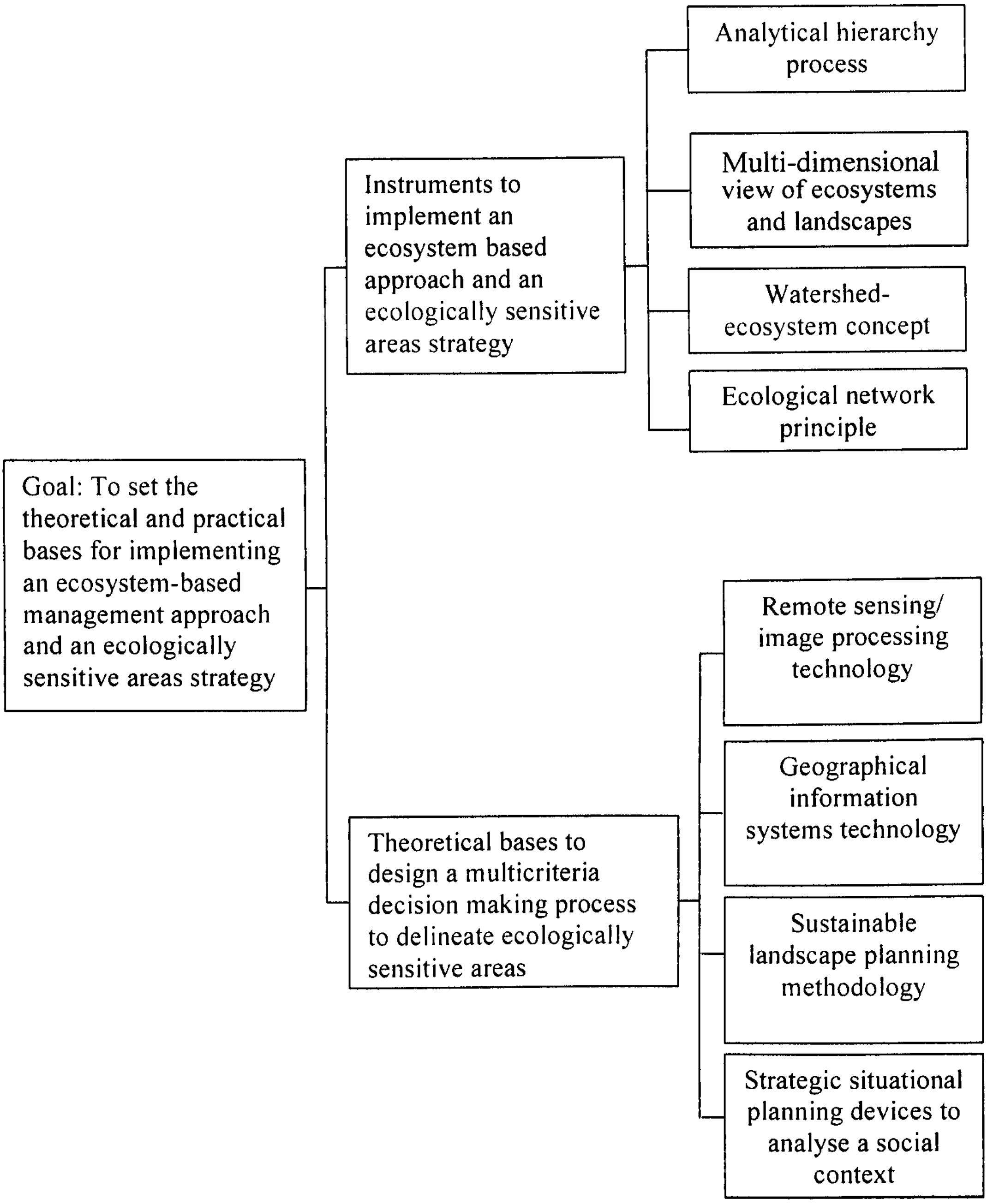
2. 1 Introduction

The goal of this chapter is to set the theoretical and practical bases for implementing an ecosystem-based management approach combined with ecologically sensitive areas delineation strategy.

This chapter is structured in two parts. The first part explores the theoretical basis of designing a multi-criteria decision making process to delineate ecologically sensitive areas. It is organised to explore a multi-dimensional view of ecosystems and landscapes and discusses features of the Analytical Hierarchy Process that enables it to serve as an appropriate multi-criteria decision analysis approach to cope with multi-dimensional views. The watershed-ecosystem concept and network principle are explored to provide geographical-related bases for subsequent application.

The second part explores the instrument to implement an ecosystem-based approach and an ecologically sensitive areas delineation strategy (Figure 2.1). It reviews the practical importance of image processing, remote sensing and geographical information systems technology as a framework within which the analytical work can be undertaken. The sustainable landscape planning methodology is explored as a framework for an ecosystem-based approach and a review is presented of the explanatory network as a device employed in strategic situational planning.

Figure 2.1 Outline of chapter 2



2.2 Theoretical bases to implement an ecosystem based approach and an ecologically sensitive areas strategy

Paraphrasing Holling (1996), the most important challenge in ecosystems and landscape planning theory is related to the following question: What attributes of the ecosystem-landscape patterns and processes can be manipulated to maintain or restore their capacity to cope with natural or man-made disturbances? This author claims that it is also the basic question to be answered if environmental sustainability is to be achieved. The rationale behind this opinion is that many of the characteristics linked to environmental sustainability, such as resilience, integrity and homeorhesis in ecosystems, are indicators of their response capacity to disturbances. Many of the characteristic linkend to enviromental sustainability, such as resilience, integrity and homeorhesis in ecosystems, are indicator of heir response capacity to disturbances. Resilience refers as the capacity of a system to return to initial state after a disturbance. Integrity is considered as the structure properties of an ecosystem to cope with disturbances. Homeorhesis is conceptualised as the property of a natural system to reinitiate a trajectory, related to an ecological essential process (i.e. aggradation, biogeochemistry control, decomposition) after a disturbance (Bormann and Likens, 1979; Norton, 1992; Holling, 1996; Muller and Jorgensen, 2000; Ulanowictz, 2000)

Until now the analysis of properties related to the structure and function of the landscape and ecosystem has exaggerated the tensions between two scientific approaches: one reductionist and certain perspective, and other, integrative and uncertain (Fry, 2001; Grzybowski and Slocombe, 1988; Holling, 1996; Naveh, 2000; 2001; Palang et al., 2000; Tress and Tress, 2001). The reductionist approach emerges from a tradition of experimental science, where a narrow focus is chosen in order to construct and prove hypotheses. It is experimentally based and, as a consequence, the chosen scale has to be small in space and cues a short time scale. This approach has dominated population ecology, but has failed to explain complex processes at other biological scales such as ecosystems and landscapes (Levin and Lewontin, 1985).

The other is an approach based on the integration of parts. It is a transdiciplinary approach because it uses the results of the first, but identifies gaps, develops alternative causative hypotheses and constructs and uses models as devices for experimentation and management. A holistic approach is a process of scientific inference where conclusions are continuously challenged by posing and testing alternative explanations. Multiple lines of evidence are sought in order to invalidate alternatives, leading to a convergence towards a credible line of argument. There is a deep concern that useful hypotheses might be rejected, i.e., a greater concern about Type II error (rejection of a true hypothesis) than about Type I error (accepting a false hypothesis) (Holling, 1996).

The premise of the holistic approach is that knowledge of complex systems, such as ecosystems and landscapes, is always incomplete and surprises are inevitable. As a consequence, unanimity of agreement is rarely achieved among peers, and there is only an increasingly credible line of tested arguments. Another source of uncertainty is related to the dynamics of ecosystems and landscapes. They are a moving target that evolves because of the impacts of management and the progressive expansion of the scale of human influences. Thus, knowledge should be movable to reduce uncertainty where that is possible. But it is important to recognise that ecosystems and the human activities associated with them are inherently uncertain.

Despite the recognition of the need for more wide-ranging approaches to ecosystems and landscape planning, few examples of literature exist on how to reduce uncertainty, and foster actions to maintain or restore the capacity of ecosystems and landscapes, to cope with natural or man-made disturbances and create incentives for maintaining sustainable systems (Forman, 1995; Holling, 1996). However, since the second half of the 1990s, important theoretical efforts have been made to support the holistic approach in ecosystem and landscapes studies as exemplified by Fry (2001), Naveh (2000; 2001), Palang et al. (2000) and Tress and Tress (2001) in landscape theory; and Christensen et al. (1996), Holling (1996), Jorgensen and Müller (2000), and O'Neill (2000) in ecosystem theory.

2.2.1 The multidimensional concept of ecosystems and landscapes

One of the main characteristics of the ecosystem-based management approach is that it attempts to solve the problems linked to the use of the terms ecosystem and landscape only as mental constructions. This approach employs a multi-dimensional vision. Landscapes and ecosystems, besides being mental constructions, are also viewed as geographical units, complex systems, dynamic systems and geographical entities integrating nature and society (Slocombe, 1993a, 1993b, 1998; Christensen et al., 1996; Yaffee, 1999; Tress and Tress, 2001). This holistic view is a key concept for this thesis because it supports the selection of multiple criteria to delineate ecologically sensitive areas. This conceptualisation is briefly described below and a particular emphasis is given to their practical features. The importance of biodiversity in the dynamics of ecosystems and landscapes and its integrative role in this multi-dimensional view are highlighter later.

2.2.1.1 Landscapes/ecosystems as geographical units

Ecosystem-based management emphasises landscape-scale management (a regional scale) as a fundamental goal for management. Landscapes and ecosystems are seen as real geographical units that can be mapped and fit together in a nested hierarchy (Rowe, 1992). A nested hierarchy is a central concept in ecosystem-based management. According to Naveh (1994), ecosystems are sub-components of the landscape and this research adopts the watershed-ecosystem concept, which supports this hierarchical concept. A watershed is a terrestrial ecosystems concept (Bormann and Likens, 1979) that permits the building of a nested hierarchy. Larger watersheds (ecoregions or landscapes) are comprised of smaller watersheds (ecosystems).

For all of the reason outlined above a nested hierarchy of watershed-ecosystems supports the procedures to define the limits of environmental units in this thesis.

2.2.1.2 Landscapes and ecosystems as complex systems

Many times the ecosystem-based management approach employs the terms ecosystem and landscape as concepts, implying systems thought (Grzybowski and Slocombe, 1988; Christensen, et al., 1996; Slocombe, 1992; 1993a; 1993b; 1998). That is, component parts of the management problem are fundamentally interconnected across space and time. As a result of this, decision makers need to appreciate the complexity and dynamics of these interconnections and consider the implications of different spatial and temporal boundaries (Yaffee, 1999).

Ecosystem/landscape complexity and the vast array of interconnections that underlie their functions are supported by biological diversity and structural complexity and they give support to essential processes such as primary production and decomposition. Biological diversity is central to the productivity and sustainability of Earth's ecosystems/landscapes. Organisms, biological or biotically derived structures (dead wood, coral skeletons) and biotic processes are the means by which the physical elements of the ecosystem are transformed into the goods and services on which mankind depends (De Groot et al., 2002). Photosynthesis, the capture of physical energy and its conversion to organic structures, is the primary basis for primary productivity on Earth. Conversely, decomposition is the break down of organic structures into their physical elements, including mineral nutrients and energy. Organisms also create structures and communities that interact with and alter_that interact with, and alter, the physical world habitat for other organisms that carry out additional processes. This biotic complexity has important influences on the hydrological cycle, through condensation, interception and evapo-transpiration (liquid water transformed into a vapour during photosynthesis) and on the control of geomorphological processes, such as erosion (Bormann and Likens, 1979)

However, with complexity comes uncertainty. Lack of precision in predicting ecosystem/ landscape behaviour derives from the fact that uncertainty rules over our present knowledge of ecosystems and landscapes. It has been recognised that there are limits to the precision of predictions about the complex nature of these systems and their interactions. As a consequence of this, it is recommended to deal with uncertainty explicitly, by acting conservatively and managing adaptively (Holling, 1978, Lee, 1993). That is, setting a course of action based on a set of hypotheses, monitoring what happens and evaluating the directions based on what one learns.

In this thesis, the complex systems concept, and heterogeneity as a measurement of complexity support the landscape diversity criteria employed to delineate ecologically sensitive areas and for defining the biocentres of a landscape. Also, the role of vegetation cover on hydrologic and erosion control is recognised and included as a criterion in the delineation of areas that are ecologically sensitive to erosion.

2.2.1.3 Ecosystems and landscapes as dynamic systems in space and time

One of the most important challenges to an ecosystem-based approach is to understand and manage areas that change. The natural dynamics of ecosystems/landscapes occur as a continuous long-term change and as a constant response to natural and human-made disturbances.

Complexity and biodiversity also impact on resistance and resilience to disturbance, and provide the genetic resources necessary to adapt to long-pattern change. Biological diversity provides for both stability (resistance) and recovery processes (resilience) when disturbances disrupt important ecosystem processes. Holling (1996) has suggested that ecosystem resilience should be viewed as the magnitude of disturbance that can be absorbed before the variables and processes that control the ecosystem's behaviour change. Resistance often results from complex links among organisms, such as food webs or different temporal and spatial arrangements of species. These links provide alternate pathways for flows of energy and nutrients. Additionally, species diversity explains the ability of ecosystems to recover processes such as productivity, and hydrological and biogeochemical control following a disturbance (Bormann and Likens, 1979).

Further support for this view comes from Christinsen et al. (1996) who see the variety of species as the biological building blocks for ecosystem response and evolution. Indeed, long-term adaptations of ecosystems/landscapes to changes in climate and other environmental variables are strongly dependent upon available biological diversity. Given ever-changing environments, the capacity to adapt is central to the long-term sustainability of ecosystem/ landscapes functions. For example, empirical evidence has demonstrated that relatively unimportant species, restricted to particular micro sites during one climate regime, may become important as the climate changes (Delcour and Delcour, 1991, cited by Christinsen et al., 1996).

In practical terms, at its most fundamental level, an ecosystem-based management approach seeks to maintain biodiversity as a means of building resilience against catastrophic events in biological, economic, organisational and political systems (Holling and Meffe, 1996). This approach also recognises the urgent necessity for planning under the adaptive management paradigm to maintain resilience (Holling, 1978; Lee, 1993). In terms of environmental sustainability, despite its theoretical nature, resilience requires particular attention to design indicators to estimate the health and integrity of an ecosystem and it could be considered as a criterion for delineating ecological sensitive areas in future studies.

This research postulates thus that the protection of key elements in the ecosystems and landscapes, such as ecologically sensitive areas, is a means of improving ecological resilience.

2.2.1.4 Humans as components of landscapes/ecosystems

The role of humans should be recognised, not only the cause of the most significant challenges to environmental sustainability, but is also an integral component which must be included to achieve sustainable management goals (McDonnell and Picket, 1993).

However, the role of humans in ecosystem and landscape management is a topic of much debate. Humans have the historical responsibility for the major negative impacts on ecosystems and landscapes; yet at the same time, they have the potential to integrate human activities and conserve nature. Tress and Tress (2001) see this issue as a result of human evolution and estimate that current ecosystems and landscapes are the visible product of this historical process.

Moreover, landscapes and ecosystems are in fact the product of natural and cultural processes. Cultural effects on landscapes and ecosystems are ubiquitous. Most ecosystems and landscapes have already been substantially altered by human actions and are isolated and removed from their normal ecological context (McDonnell and Picket, 1993). In addition, managed landscapes and ecosystems are transformed into new entities in order to create economic or social opportunity. As a consequence, guidelines for a wiser management are needed. Picket et al. (1992) propose that human-generated changes must be constrained within the functional, historical, and evolutionary limits of nature. However, while this proposal permits the reduction of deleterious impacts, there are still many inconsistencies to be addressed, yet the reduction of deleterious impacts is the main goal in nature protection efforts.

The most significant challenge in ecosystem-based management is to address the inconsistency between the spatial and temporal scales at which humans manage resources and that at which landscape/ecosystem processes operate (Christensen et al., 1996). Boundaries between properties and jurisdictions rarely match the domain of landscape/ ecosystem processes. These mismatches are often the origin of many conflicts related to resource management, e.g. a river that is a border invites conflict over the resources dependent on water-driven landscape/ecosystem processes. As a consequence, conflict resolution and the identification, and involvement of stakeholders in the development of management plans is a key ecosystem-based management strategy.

This thesis acknowledges the importance of collaborative approaches in ecosystem-based management, but it only focuses on the reduction of deleterious impacts in order to delineate ecologically sensitive areas.

2.2.1.5 Ecosystems and landscapes as mental entities

Beyond the theoretical concepts of ecosystems and landscapes as holistic and complex systems, as well as the artistic and humanistic expressions of them, there are practical elements that can be derived considering ecosystems and landscapes as mental entities.

Many indicators used for planning the conservation of natural and cultural features of landscapes are linked to cultural views. Many concepts employed to delineate ecologically sensitive areas such as rare landscapes, rare landscape forms and elements, rare plants and animals, unique scenario characteristics, unique landscape elements and so on are linked to the people's identity and culture. Often cultural views of landscapes give rise to people's concerns for their protection and improvement, and mobilise citizen initiatives and pressures. Yaffee, et al. (1996) recognized the role of these people's concerns in the implementation of ecosystem management projects. People often recognise the uniqueness of many ecosystems and landscapes and the need for their protection, producing citizen initiatives to protect them or citizen's pressure on agencies to take action.

Ecosystem-based management considers that understanding ecosystems and landscapes as specific places can be a powerful symbol and mobilising force. The sense of place provides some of the force that binds people together and is critical to the development of an effective civic culture (Kemmis, 1990, cited by Yaffee, 1999).

Despite the holistic approach adopted for this research, this landscape dimension is not tackled here. It is considered beyond the scope of this thesis because of the time needed to involve the great diversity of human groups in this huge region.

2.2.2 The analytical hierarchy process: a holistic method in multi-criteria decision-making

Multi-dimensional views require appropriate epistemological frameworks to cope with them while cost-benefit analysis can be effective when the objective is to maximize economic efficiency. Multi-criteria decision analysis can be more appropriated used when the social implications, ecological and environmental conservation or biophysical impacts of decisions are also important to decision makers. Furthermore, multi-criteria decision analysis allows criteria that cannot easily be expressed in quantitative measures to be included in the analysis (Brown et al., 2001).

Multi-criteria decision analysis applied to landscape and environmental planning typically includes economic efficiency, equity within and between generations, environmental quality and various interpretations of environmental sustainability (Jaubert et al., 1997; Malczewski et al., 1997; Mc Millan et al., 1998; Turner et al., 1999). The main strength of multi-criteria decision analysis is that it provides both ecological and economic information as a basis for decision-making on landscape and environmental management (Turner et al., 1999).

Multi-criteria decision analysis is considered as a way to illuminate policy trade-offs and aid decision-making in contexts where a range of often competing, policy criteria are considered to be socially and politically relevant (Nijkamp, 1989). Many techniques of multi-criteria decision analysis are adopted as a part of trade-off analysis because of their flexibility in handling complex information, and being sensitive to the construction of values within priority setting. Multi-criteria decision analysis as a process usually generates information on the decision problem from available data and ideas, leading to solutions (alternatives) of a decision problem and providing a transparent understanding of the structure and content of the decision problem (Brown et al., 2001).

A separate issue is the information availability to all stakeholders and the extent to which this information would in fact be taken into account in real policy-making situations. In real life, much ecological information is incomplete and may not adequately influence the final decisions especially in the socio-economic system. For example, a short-term commercial interest and related financial gain may appear to be more persuasive than long-term ecological conservation arguments. Many times an alternative way to face these problems, which relay on partial or incomplete information, is to turn to expert judgements or local common sense. This implies the employment of multi-criteria decision making approaches based on experts' judgements or people's choices. The analytical hierarchy process is a potential, systematic and well methodologically supported alternative to include experts' judgements or people's choices.

According to Saaty (1995), the Analytical Hierarchy Process is in a way a holistic approach, in which all the factors and criteria involved in the problem are laid out in advance in a hierarchy or in a network system that consider dependencies. The Analytical Hierarchy Process can be used to analyse complex systems by breaking them down into their constituent elements, structuring the elements hierarchically, and then composing, or synthesizing, judgements on the relative importance of the elements at each level of the hierarchy in a set of overall priorities. These hierarchies permit all possible outcomes that can be thought of are joined together. Then, judgement and logic can be employed to estimate the relative influence of the criteria on the overall answer to the problem.

This approach requires knowledge and experience with the subject, but it is not totally dependent on the ability to reason logically. Feeling and intuition play as important role as the ability to reason precisely in deciding the outcome (Saaty, 1995). The Analytical Hierarchy Process incorporates judgements and personal values in a logical way that depends on imagination, experience, and knowledge to structure the hierarchy of a problem and on logic, intuition, and experience to provide judgements. The Analytical Hierarchy Process permits to connect elements of one part of the problem with those of another to obtain a combined outcome. It is a process of identifying, understanding, and assessing the interactions of a system as awhole.

2.2.3 The Analytical Hierarchy Process as a decision-making method

The Analytical Hierarchy Process as a method has wide applications in multi-criteria decision making, in planning and resource allocation, and in conflict resolution. In a brief, it is a general theory of measurement. It is used to derive ratio scales from both discrete and continuous paired comparisons in multi-level hierarchic structures. Saaty (1995) claims that the old adage that cannot compare apples and oranges is false. Apples and oranges have many properties in common: size, shape, taste, aroma, colour, seediness, juiciness, etc. Therefore apples and oranges could be compared through different levels: size, shape, taste and so on.

These comparisons may be taken from actual measurements or from a fundamental scale that reflects the relative strength of preferences and feelings. Thus, it is possible to be indifferent to size and colour, but have a strong preference for taste, which again may change with the time of day. The basic thesis of this author is that this sort of complicated comparison occurs in real life over and over again, and some kind of mathematical approach is required to determine priorities and make tradeoffs. In addition, the Analytical Hierarchy Process has a special concern with departures from consistency in the comparisons and the measurement of this departure. It means that if the degree in which a person is constant to the same principles of thought when there exists more than one pair of comparisons related to the weight given to the different criteria or its attributes in the comparisons. The Analytical Hierarchy Process involves both physical and psychological attributes in reaching the judgements. Physical attributes mean the tangible attributes that could be counted or measured. By contrast, the psychological are the intangible attributes, comprising the subjective ideas, feelings, and beliefs of the individual and of a society.

In a different way, the Analytical Hierarchy Process employs a hierarchic or a network structure to model a problem, as well as pair wise comparisons to establish relations within the structure. In the discrete case, which is employed in this research, these comparisons lead to dominance matrices (the matrices derived from comparing different entities with respect to an attribute). From these matrices ratio scales are derived in the form of principal eigenvectors (a vector gives the quantitative value of the preferences over the comparisons). These matrices are positive and reciprocal (Saaty, 1995).

In terms of group decision-making, the Analytical Hierarchy Process provides a framework for group participation in decision-making and problem solving. The conceptualisation of any problem by the analytical hierarchy process requires one to consider ideas, judgements and facts accepted by others as essential aspects of the problem. Group participation is viewed as the way to shape unstructured reality through participation, bargaining, and compromise. Thus, it is possible to include in the process any information derived scientifically or intuitively.

Experts and group participation are the corner stone to structure the decision making process for delineating ecologically sensitive areas. Thus, the Analytical Hierarchy Process is used in this research as a method for structuring criteria and attributes, hierarchical frameworks, weighting processes, expert participation and judgements.

As can be see multi-dimensional views lead to the employment of multiple criteria. Each criterion linked to a particular viewpoint or dimension through an ecosystem/ landscape can be seen. However, in terms of landscape planning, the integration of multi-dimensional views based on multiple criteria should be consistent with space units and principles. For this reason, this thesis tackle one spatial principle (ecological network principle) and one space unit (watershed-ecosystem) to integrate both. Watershed-ecosystem unit was selected to be consistent with an ecosystem-base management approach. Besides, it is a spatially explicit unit that avoids the endless discussion about the boundaries of an ecosystem. On the other hand, the ecological network principle was selected based in its utility to face fragmentation problems related to conservation of nature. This principle fosters connectivity of well-conserved natural areas (a network) as an alternative to counteract these problems.

2.2.4 Watershed ecosystem as an environmental unit for research and management

An ecosystem as a geographical unit is defined as a spatially explicit unit on the earth that includes all organisms, along with all components of the abiotic environment within its boundaries (Likens, 1992; Golley, 1993). Recognising that ecosystem functioning includes inputs, outputs, and cycling materials and energy, as well as the interactions of organisms, ecosystem scientists define ecosystems boundaries operationally. These limits facilitate the monitoring, study, or manipulation of these processes. Thus, in geographical terms, terrestrial ecosystems are a watershed or a lake (Christensen et al., 1996).

A watershed as a terrestrial ecosystem is a concept developed by Bormann and Likens (1979). These authors utilised the watershed as the geographical unit suitable to experiment with, monitor, and study the inputs, outputs, and cycling materials and energy, as well as the interactions of organisms in a terrestrial ecosystem. The hydrological criteria applied to define watersheds permits the building of a nested hierarchy. Larger watersheds are comprised of smaller watersheds. This nested hierarchy is supported by the distribution of water on the surface of the Earth. Water is the integrative resource in all ecosystems. Through the hydrological cycle, water is continually cycled among great reservoirs creating a communication network that links organisms, materials, and processes (Healy, 1998). Rivers play a multiple role. They link habitat types, landforms and habitats and they are the most sensitive indicators of human-induced changes to an ecosystem.

Watersheds not only make sense ecologically, they also constitute a natural and real geographical unit on which management institutions can be based. They constitute spatial units appropriate to address the current problems of environmental impact assessment and the needs of the integral management of resources. It means that those institutions related to environmental impact assessment and regional environmental accounts count with basic units to carry out inventorying and monitoring activities. In addition, the nested hierarchy of watersheds permits input-output analysis to monitor the effects of human activities and counteract in situ, those that threaten the environmental quality.

2.2.5 Ecological network principle

Van Lier (1994,1998) developed the ecological network principle, although the concept of network attracted the attention of landscape planners before the 1990s. Fabos and Ahern (1995) mentioned that since the 1960s the greenway planning approach had as a goal to employ the greenways for connecting all the "green areas" in the USA. This thesis selects this principle to lead the spatial vision for connecting ecologically sensitive areas.

The guideline of this principle is to achieve connectedness among natural areas in a landscape. It is based upon the island theory of MacArthur and Wilson (1967) and the application of this theory to mainland situations. Fragmentation of nature (natural areas are breaking down into smaller areas) in rural systems has created "nature islands". The increasing isolation of these islands determines whether certain populations of plants and animals can survive over time. The concept of an ecological network is a reaction to this fragmentation and isolation. An ecological network is a constellation of landscape elements that is functional for the dispersion of a species in a landscape. Connectivity, key species, stepping-stones, core regions and metapopulations are the main issues considered in the network approach. Connectivity refers to the process or measure of the connexion between different patches of a landscape. Key species are those that characterise particular properties or processes of a landscape. The spatial concept of stepping-stones is related to connectivity, where the connexion between the different patches is seen as a series of stepping-stones. Core regions refer to high quality patches, such as ecologically sensitive areas. They are labelled using different ecological quality criteria, e.g. biodiversity, habitat quality and so on. Metapopulations is a spatial concept of a population. It considers a population divided into sub-populations dispersed on the different patches into a landscape.

A further set of space concepts was chosen to support the delineation of geographical units. They are landscapes and ecosystems as watershed-ecosystem units that permits to build a nested hierarchy as was discussed in 2.2.1 and will be tackled in detail in the following section.

2.3 Instruments to implement an ecosystem-based approach and an ecologically sensitive areas delineation strategy

According to the study of Yaffee et al. (1996), the six most commonly reported strategies utilised to implement ecosystem management projects were research, stakeholder involvement, ecosystem restoration, promotion of compatible human land uses, education and outreach, and land protection through the purchase of lands in the neighbourhood of protected areas.

This thesis will focus on the research strategy. Research is seen as a key strategy because of the spatial and temporal dynamics of the ecosystems and landscapes. Frequently, ecosystem state changes generate disagreeable or unexpected surprises for scientists, stakeholders and policy makers (Gunderson, 2001), e.g. lost of hydrological control caused by a pest, different species composition as a response to stress, and so on. Research is also, considered as a part of all stages of a project and for providing integrated assessments. On one hand, research helps a natural resource manager to determine which issues (biological, social, and economic) should be faced. On the other hand, the assessments can set alternative explanations to different management situations, and reduce the uncertainty inherent in them (Gunderson, 2001).

In order to manage an ecosystem, a planner needs to be aware of the types of ecological systems being management and their components. Thus, creating an inventory of natural capital has been considered as an important component of research, including identifying natural areas and their components and prioritising those areas for protection (Yaffee, et al., 1996). Inventories often include ecological factors, and social and economic indicators. In several cases, inventories could be used as a reliable assessment of problems in a particular area, in order to be employed by all stakeholders in fashioning remedial actions. Also, inventories could be utilised to carry out monitoring to determine whether management practices were having the desired effect on the ecosystem. This research will focus only on the inventory tasks related to identifying natural areas and their components. In addition to the prioritising procedures based on multi-criteria decision analysis, other research instruments are employed to identify those natural areas, which need to be under protection. These include remote sensing/image processing technology and geographical information systems technology.

2.3.1 Geographical information systems (GIS) and remote sensing (RS) procedures as research instruments

Recently, the availability of spatial data and cartographic data handling devices have made regional and landscape-scale studies more feasible. The technological devices that have made landscape and ecosystem assessments feasible include: powerful computers, global positioning devices, image processing/remote sensing, GIS, multivariate analysis, multi-criteria decision analysis and geostatistics software packages (Johnson and Gage, 1997). Two devices in particular have made it possible to quantify spatial patterns of landscapes: GIS and image processing/remote sensing technology.

The latter allows quantitative assessment of the different components of landscapes that interact at a variety of spatial and temporal scales. When GIS is used in concert with geostatistics, multivariate analysis and multi-criteria decision analysis, complex relationships in the landscapes can be identified and predicted (Johnson and Gage, 1997). Today, GIS is a fundamental device for natural resource managers and landscape ecologists concerned with the analysis of spatially referenced data. GIS technology can produce visual material on landscape characteristics and patterns, which provide policy makers with a better perspective on the area for which policies are designed and evaluated.

The use of GIS technology in ecosystem research is a recent phenomenon of the last decade. Its procedures have rapidly become part of the mainstream in ecosystem and landscape research and have a particular importance to ecosystems and landscape ecology. These systems permit the handing of ecological data at a variety of scales in a hierarchical fashion. Indeed, GIS devices have been applied for different purposes (Johnson and Gage, 1997): (1) to produce secondary data from primary data, e.g. slope and aspect from elevation points; (2) to quantify association between spatial features, e.g. land use and geology and/or soils; (3) to quantify landscape patterns and spatial relationships, e.g. diversity of landscape patches; (4) to quantify temporal patterns, e.g. vegetation cover; quantify temporal change, e.g. land use conversion; and (5) to link spatial data with models, e.g. hydrological or ecosystem models.

These applications (except 5) are considered in the development of a methodology to delineate ecologically sensitive areas in the case study of this thesis. The linkage of spatial data with models was not considered because of lack of hydrological and ecosystems models in the case study. In addition, GIS devices are used in concert with analytical hierarchy process software (EXPERTCHOICE).

Despite the image processing technologies have been available for at least three decades for regional analysis, until the early to mid 1980s most landscape characterisation studies relied on interpretation of aerial photographs (Johnson and Gage, 1997). This image processing technology is based on the premise that absorption and reflection properties of objects can be used to identify and classify objects remotely on the ground. Airborne sensors detect thermal and spectral signatures in specific band intervals. Bands are used singly, and in combination, to classify targets on the ground. The spatial resolution of commonly used sensors ranges from 10 x 10 m pixels (cells) to 1 x 1 km pixels. Newly deployed sensors use side-borne radar, which penetrates darkness and cloud cover to detect surface texture. For a detailed review of remote sensing systems and their applications see Muller, et al. (1993).

Remote sensing techniques applied to landscape planning help to capture qualitative and quantitative data of objective attributes of the ecosystems and landscapes. These data are obtained from satellite images, videography, radar images and aerial photographs on the ground. They have the following advantages (Henk and Clewers, 1993):

1. They help to establish thematic boundaries related to different spatial attributes of ecosystems and landscapes, i.e. vegetation cover limits.
2. They have a wide variety of observation techniques and algorithms to process digital images, thus, it is often is possible to design optimal pathways to get particular data, e.g. different pathways to define different land-use categories.
3. They can be employed at any time. Stored images could be viewed and processed at any time helping to determine dynamic processes on ecosystems and landscapes, i.e. changes in land use patterns or succesional stages.

4. They give place to a holistic view of ecosystems and landscapes. A complete region and components could be seen as a whole, as geographical entity, i.e. a huge basin or watershed and its hydrological components.

This thesis takes advantage of all of the above in employing satellite images for landscape analysis in the case study. The applications of remote sensing in this research are related to detect land use patterns, vegetation mapping, land use/land cover mapping and detecting temporal change in land use.

2.3.2 Planning instruments to support ecosystem-based management

Recently, Botequilha and Ahern (2002) have proposed a new and interesting idea for landscape planning to achieve sustainability: sustainable landscape planning. These authors argue that sustainable landscape planning emerges as a natural outcome of the evolution of the planning discipline in the 21st century, where new social values, such as the key concept of sustainability, are increasingly being recognised and embedded into planning methods and legislation. Unlike greenways and ecosystem management, this proposal implies a systematic methodology based on the former ecological landscape planning approach of Ahern (1999) and other methodologies developed mainly during the 1990's. This thesis follows this methodology as a framework for different reasons: it is systematic; it gives enough room to integrate different models, methods and procedures; it is consistent with the needs of flexibility during the planning process, and; it includes a new phase related to the implementation, monitoring and assessment of the proposals.

2.3.2.1 Conceptualising sustainable landscape planning

Until recently, there has been no precise definition of sustainable landscape planning. However, sustainable landscape planning could be broadly defined as a framework of ecological knowledge applied to all physical planning activities guided to achieve environmental sustainability (Botequilha and Ahern, 2002). According to van Lier (1998), physical planning is a part of land-use planning. It is related to the studies and policies aimed to decide what type of land-use activity should take place and where. In this sense, it distributes the often-scarce space between several potential users, with the optimisation of the land-uses as a main objective. Often, it involves regional or national plans. In such plans the future land-uses are grouped together and restricted to a certain area (or areas) for each land use type. Also other restrictions are included in the scale of intensity of the particular type of land use.

For this research sustainable landscape planning is viewed as an ecocentric landscape planning approach. It seeks to incorporate ecological knowledge into planning activities in order to contribute significantly towards a more sustainable environment. Here, sustainable environment is considered as an area in which ecological integrity and basic human needs are currently maintained over generations. In terms of land-use planning, it means to consider land uses to provide basic human needs, and simultaneously to act in concordance with ecological principles. These principles are embedded in applied sciences such as ecosystem management and landscape ecology. These principles have been reviewed in deep in section 2.2

2.3.2.2 Sustainable landscape planning methodology

According to Bothequilha and Ahern (2002), sustainable landscape planning has as its background previous methodologies as landscape planning, environmental impact assessment, ecosystem management, rural planning and landscape ecological planning.

Sustainable landscape planning as a methodology has five planning phases: landscape focus, landscape analysis, landscape diagnosis, landscape prognosis and landscape syntheresis. These phases are described below:

Landscape focus. This phase defines and addresses the goals and objectives of the plan. It is the problem identification phase. Goals can be determined by political agendas, the goals or mandates of planners, or as opportunities arising from the occurrence of a particular event localized both in place and time. These goals will determine and focus on starting priorities, influencing all the subsequently processes developed. Therefore, it is important to develop a clear statement of goals and objectives. However, in sustainable landscape planning goals and objectives may be reviewed as many times as appropriate through the planning process, as a result of its conceptualisation as a highly dynamic and iterative process. Also, the goals and objectives are reviewed after its first implementation when the plan is assessed as proposed by adaptive management. Bothequilha and Ahern (2002) emphasise the adoption of adaptive management in sustainable landscape planning. Adaptive management represents a strategic approach to decision making when information is uncertain or incomplete (Holling, 1978). Planning and/or management decision are considered as experiments based on the best available knowledge. In adaptive management, policies are designed as hypothesis and management implemented as experiments to test that hypothesis. These decisions are structured by reasonable assumptions and monitored over time. Thus, over time, adaptive management yields new information and knowledge that can inform future planning and management decisions. Adaptive management support the idea that the role of good experimenter is that the consequences of the actions be potentially reversible and that the experimenter learns from the experiment.

Another outstanding issue in this phase refers to define the resource management concept, i.e. selecting ecosystem-based management implies consideration of the multi-functional aspects of landscapes, such view guides thinking concerning the holistic/ multi-dimensional approaches in planning. As well a potential involving of stakeholders and public along the process.

Landscape analysis. Describes the study area and its context in several dimensions. It identifies the processes of interest that determine landscape functions, and how they are influenced by the different elements that form the physical landscape.

In this phase the landscape structure is described. It means identifying the largest patches in the landscape related to biodiversity conservation, the land use classes and proportions in the landscape and their change over time, and other metrics that describe the landscape composition and pattern, e.g. connectivity indexes, surface/perimeter ratios and so on.

Landscape diagnosis. This phase represents a landscape diagnostic. It attempts to answer the following question Is the landscape functioning well? If not, where it is not functioning well and why? This is analogous with the evaluation phase of Steinitz's ecological landscape planning methodology (Steinitz, 1997). This diagnostic is similar to a medical doctor diagnostic. The main idea is to identify the landscape systems that are dysfunctional. It is performed based on landscape analysis and aims to identify landscape dysfunctions and land use conflicts. For instance, to identify landscape area which have been loosing their natural vegetation cover, those natural areas threatened for human activities, those areas on risk for natural processes and so on.

Landscape prognosis. Prognosis comes from the Greek word pro (before) and gnosis (knowledge) (Bolos, 1992, cited by Botequilla and Ahern, 2002). This phase is directed to develop possible visions of how the landscape could change to meet goals. In addition, it implies an assurance that directions of those proposed changes will lead towards more sustainable conditions. This is the phase for evaluating and comparing different alternatives about the potential landscape changes and associated consequences. It is considered that the wider the spectrum of alternatives, the more useful it becomes both for public discussion and for increasing transparency in the decision-making process.

Landscape syntheresis. Syntheresis come from the Greek work syntereo, which means to preserve (Bolos, 1992, cited by Botequilla and Ahern, 2002). In this phase is where the actual plan is designed and implemented. It also includes the monitoring of the on-going processes and changes. Evaluation of the changes on processes occurring as a consequence of the proposed plan's new configurations allows feedback into the planning process. It is useful in assessing the efficiency of the proposed actions in meeting the original goals. Often is also helpful to revaluate goals and allow changes in the plan according the new findings, this supporting a more dynamic and iterative planning process. This phase supports the adaptive management approach described above.

2.3.3 Strategic situational planning approach to identify negative and favourable factors related to the protection of ecologically sensitive areas

This thesis adopts the design of the explanatory network as a procedure to analyse the political context of the planning activities to protect ecosystems and landscapes. This analysis permits to identify the opportunities and threats for the different landscape planning proposals. Strategic situational planning view social real-life problems, as quasi-structured problems (poorly structured) where it does not know all the elements that integrate it, neither all the relations between variables. This approach considers the social reality as a multidimensional synthesis of determinant factors: economical, political, ethical, cultural, and social (Matus, 1989).

The strategy for problem analysis is to describe the problem as systematically and accurately as possible. It seeks to focus on a target problem extracted from a set of them, frequently called crisis or wicked problem. After this, all the issues around it are described as problem's environment. The selected wicked problem is then analysed by developing a causal and explanatory network. The aim of this explanatory network is to identify key problems and the causal relationships between them. These key problems and the construction of alternatives to solve them are the corner stone of the strategic situational planning process (Matus, 1989). This thesis employ this explanatory network as a device in the procedures related to make a diagnostic of the ecosystem/landscape, during the phase of diagnosis in the planning methodology proposed. It is detailed in chapter 3.

2.4 Conclusions

This chapter has surveyed from a multi-dimensional perspective on ecosystems and landscapes and the employment of multi-criteria decision analysis as epistemological support to tackle them. As a consequence:

1) A holistic view is considered as a key concept for this thesis. It influences the philosophy of this thesis and the selection of criteria to delineate ecologically sensitive areas.

2) The role and importance of biodiversity in this multi-dimensional view leads to it's protection as the main goal in environmental sustainability. Its importance also supports the decision to employ an ecologically sensitive areas delineation strategy.
3) Multi-criteria decision analysis is seen as an appropriate epistemological methodology to cope with multi-dimensional views.
4) The endless problem in landscape planning of partial or incomplete information leads to consider Analytical Hierarchy Process as a systematic and a methodologically supported alternative trying to include experts' judgements and/or people's choices

Afterwards, the ecosystem-watershed concept and the network principle are also seen providing support for holistic views on ecosystems/landscapes. Both are based on the concept of a nested spatial hierarchy that provides global views.

This chapter has also tackled a review of the research instruments for ecosystem-based management. Emphasis is given to the practical support of remote sensing procedures and geographical information systems technology. As a consequence this author postulates that remote sensing and geographical information systems technologies also permits global views of ecosystem and landscape planning.

Planning instruments for ecosystem-based management have also analysed. The concepts and methodology of sustainable landscape planning are reviewed. In addition, the procedures from the strategic situational planning related to the analysis of the political context planning are reviewed too. This review permits on one hand, sustainable landscape planning methodology to be considered as an appropriate organised methodology to implement ecosystem-based management process. The analysing of political context, employing procedures from strategic situational planning recognising the importance of a SWOT analysis.

Finally, multi-dimensional approaches look complex and hard to develop for the needs of integration of views, concepts, methods, instruments, procedures and so on.. This challenge is faced in chapters 3, 4 and 5, where a landscape planning methodology is developed and tested through a case study.

Chapter 3. Designing an appropriate planning methodology for an ecosystem-based management project and the delineation of ecologically sensitive areas

3.1 Introduction

The goal of this chapter is to design an appropriate planning methodology for an ecosystem-based management project and its associated strategy, the delineation of ecologically sensitive areas. Previous chapters made clear the need for a multi-dimensional approach in the conceptualisation and analysis of ecosystems and landscapes. Furthermore, it is clear that if multi-functional approaches to ecosystem and landscape planning are intended, then it is important to adopt a global view. In addition, there is a growing recognition that many dimensions influence decision-making in the management of ecosystems/landscapes and that there is a need for a management strategy that can adapt to changing pressures.

This author argues that a multi-dimensional approach to ecosystem/landscape planning requires a methodology that integrates multi-functional views of these phenomena and multi-criteria decision analysis procedures. Moreover, the importance of collaborative approaches is acknowledged in facing the challenges of cross-sectoral, multi-level co-operation in economic, social and environmental decision-making. Such ideas lead to a planning process characterised by being integrative, based on multi-functional goals and on a flexible decision-making process that includes feedback mechanisms.

Drawing on previous chapters, this chapter establishes an appropriate planning methodology to give support to ecosystem/landscape planning. This methodology is focused on the strategy of delineating ecologically sensitive areas, a strategy associated with an ecosystem-based management approach, and with the integration of multi-criteria decision-making to their delineation. In this planning approach ecologically sensitive areas are seen as the basic units for the conservation in an ecosystem or landscape perspective and are thus adopted as the management units for ecosystem/landscape planning based on networks.

Sustainable landscape planning phases were selected as the framework for the methodology considering its systematic, flexibility and wholeness characteristics. Despite the abundance of landscape planning methodologies, sustainable landscape planning methodology was chosen because it is an integrative and feedback-based methodology (Botequilha and Ahern, 2002). These qualities permit the addressing management proposals that are easily adaptive. It includes two key phases for adaptive management; a focus phase and a syntheresis phase. The focus phase has to do with the statement of goals and purposes and problem identification. When goals are derived from such value-loaded concepts as environmental sustainability, ecosystem integrity or healthy ecosystems, this phase plays a key role. During this phase meanings, agreements and the selection of criteria to assess sustainability, integrity and health are specified. Here, the selected criteria also lead to the design of indicators for monitoring the achievement of the goals of the plan. Consequently, there is another phase related to the implementation, monitoring and evaluation of the plan: the syntheresis phase (from the Greek word syntereo, which means to preserve). Syntheresis is the very support of the plan and it is narrowly linked to the practical issues of the plan. It tackles the problems of implementation and provides feedback to the focus phase. Focus and syntheresis phases give the needed flexibility to implement adaptive management. Each phase of sustainable landscape planning is developed, integrating particular issues to underscore the binomial: multidimensional view approach-multicriteria decision-making. Table 3.1 shows an overview of the proposed methodology, pointing out the research instruments suggested to deal with each phase and its desired outcomes.

Table 3.1 A planning methodology for an ecosystem-based management project focused on the delineation of ecologically sensitive areas.

Planning phase	**Research instruments**	**Outcomes**
Focus	Systems approach to set sustainability goals Analytical Hierarchy Process	Goals and objectives of the ecosystem-based management project Geographical units definition Geographical limits Criteria selection
Analysis	Analytical Hierarchy Process Remote Sensing Geographical Information Systems	Criteria hierarchy Weighting criteria Landscape/ecosystem database

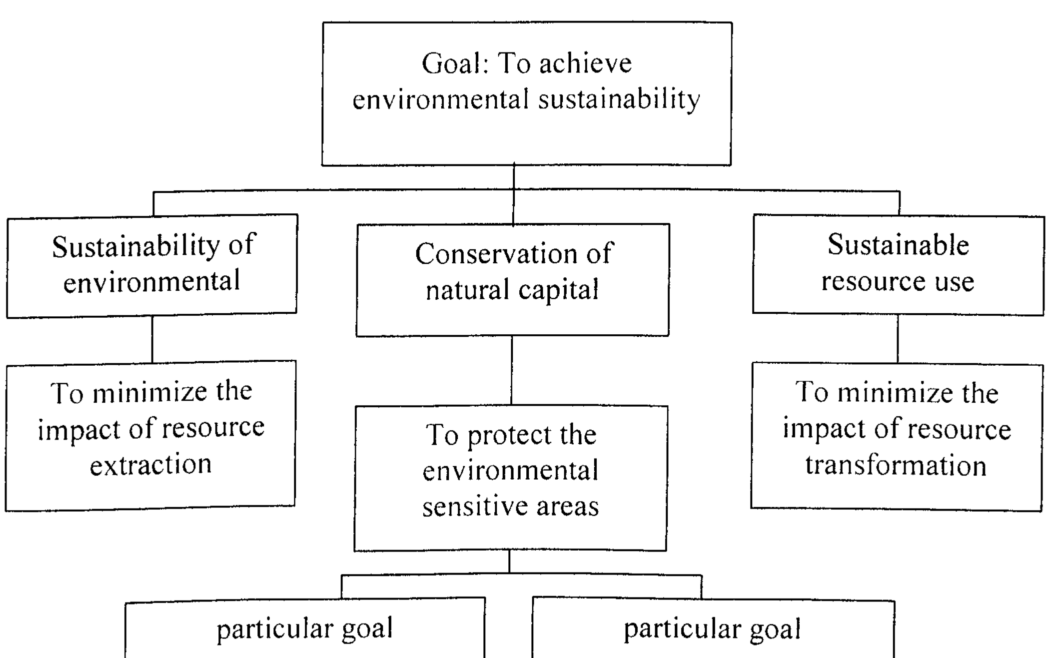
Diagnosis	Analytic Hierarchy Process Geographical Information Systems Strategic Situational Planning methods	Priority vector calculation Delineation of ecologically sensitive areas based on biodiversity value Delineation of ecologically sensitive areas based on erosion risk. Delineation of ecologically sensitive areas based on land-use change risk. Social context analysis: threats and opportunities for biodiversity protection.
Prognosis	Analytic Hierarchy Process Geographical Information Systems Strategic Situational Planning methods	Design of a network of ecologically sensitive areas into an ecosystem/landscape Evaluation of the regional potential to achieve sustainable development Design of a plan to achieve regional sustainability Construction of scenarios Design of maps for different scenarios
Syntheresis	Analytical Hierarchy Process Remote Sensing Geographical Information Systems	Selection of criteria and indicators Design of the monitoring process Assessment of ecosystem-based management projects

3.2 Focus phase

This phase addresses the definition of goals and objectives for the plan and the selection of a resource management strategy. This is, at the same time the problem identification phase. The sources for defining goals are twofold those linked to the environment of ecosystem-based management projects and those related to the planners' own goals. According to Yaffee et al. (1996) most ecosystem management projects in the USA were motivated by the incentives derived from policies and programs of government agencies. Many stakeholders joined the projects because they recognised opportunities for all to gain through joint actions. However, many times the planners lead the planning process as a result of a mandate or following their own initiatives. This is the common case in the delineation of ecologically sensitive areas, where the initiatives have arisen from an environment of scientific planners.

The definition of goals implies the determination of a focus and priorities. In this circumstances the Analytical Hierarchical Process could be applied to develop a clear statement of goals and objectives. However, the employment of value-loaded concepts, such as environmental sustainability, for goal setting implies difficulties in terms of precision, criteria selection and indicator construction. This author proposes a hierarchical approach applied to the definition of environmental sustainability goals, following a basic idea of van der Bergh (1986) and the idea that, to achieve sustainability, emphasis should be given to the process more than to a target. The rationale behind this selection is the employment of hierarchies as models to address complexity; the case of the definition of environmental sustainability goals is seen as a complex problem in this research. The hierarchy proposed is as follows (Figure 3.1).

Figure 3.1 Setting goals in environmental sustainability



Environmental sustainability, the main concern of this research, is linked to the maintenance and protection of the natural systems or natural capital. However, this goal needs a more precise definition.

Based on the hierarchy of Figure 3.1, the goal of environmental sustainability is broken down into complex and simple goals. The conservation of natural capital, sustainable use of resources and that of environmental services have all been identified as complex goals. Subsequently, the conservation of natural capital, the goal related to the delineation strategy for ecologically sensitive areas, is broken down into simpler goals, such as to protect them, to minimize the impact of resource extraction (e.g. forestry, mining) and minimize the impact of human transformation of these resources (e.g. pollution and land use change). Consequently, the goal related to the protection of ecologically sensitive areas could be broken, according to specific issues of the areas analysed and their context.

Another outstanding point in this phase refers to the definition of the concept of resource concept in the ecosystem management approach. This point is related to the planner's vision of how to achieve ecosystem/landscape management goals, i.e. selecting an ecosystem-based management project implies the consideration of the multifunctional aspects of ecosystems/ landscapes, landscapes and ecosystems as geographical units, multi-criteria approaches to planning and the involvement of stakeholders and the public during the process. In terms of the delineation of ecologically sensitive areas this means:

1) Delineate them into geographical units with clear boundaries, and
2) Involve experts in the process of selecting and weighting criteria for their delineation.

3.2.1 Defining geographical units

This author proposes to face the problems related to the delineation of geographical units using the spatially nested hierarchy of watershed-ecosystems. This hierarchy permits the definition of different scales of territorial units for ecological analysis and resource management, as well as for environmental sustainability planning. The reasons that support this proposal are now discussed. Considering a problem-solving approach, one important difficulty in an ecosystem-based management project is determining boundaries that are objective and establishing a meaningful degree of autonomy for the "system" inside the boundary. Without such boundaries, the ecosystem is simply an arbitrary patch on the global landscape. Another important problem is that of defining a set of causal relationships within these boundaries, that have broad ecological meaning and are also subjected to human manipulation and adjustment. Without such relationships the management of ecosystems is impossible (Healey, 1998). This author supports the idea that using watersheds as the ecological units for structuring ecosystem management helps to solve these issues.

Second, watersheds are the key natural geographic units in the hydrological cycle. They capture water from the atmospheric reservoir and cycle it, either back to the atmosphere or to the soil, surface water and oceanic reservoirs. Each watershed has its own geological, hydrological and biological characteristics and is small unit of the landscape that permits quantitative measurements of bio-geochemistry input and output (Bormann and Likens, 1979). In addition, stream and river catchments form independent, relatively autonomous and easily identifiable units within the overall context of the hydrological cycle. Furthermore, larger catchments comprise smaller catchments and stream segments that form a nested hierarchy of ecosystem units (Frissell, et al., 1986). This makes possible the logical subdivision of larger watersheds with varying degrees of ecological uniformity. Moreover, each watershed within the nested hierarchy can be characterised as a mosaic of habitat or community types at several geographic scales and levels of detail. This last point is basic to the strategy of the delineation of ecologically sensitive areas.

Third, from a resource management perspective, an ecosystem-watershed constitutes a natural geographic unit on which management institutions can be based. This is a feature that is particularly important for linking science with policy making. The familiarity of the watershed concept provides a basis of common understanding that helps to explain more complex topics to policy-makers of ecosystem management, such as ecological integrity and natural networks (Healey, 1998).

As a final point, it can be said that using watersheds as units for ecosystem management allows a particular emphasis to be put on the linkages between land and water and enables the derivation of new guidelines to the traditional approaches on watershed management. It permits the recognition of soil erosion as a major destabilizing force in disturbed ecosystems and recognition of the causes that explain occasionally massive erosion results, such as sloppy harvesting techniques or poorly planned and constructed roads. Furthermore, watersheds as units also permit the identification of consequences linked to soil erosion, such as mud floods during storm peaks or ecosystems returned to an extremely early development stage.

3.2.2 Criteria selection

Criteria selection is the most important task in the implementation of the Analytical Hierarchy Process. Criteria are factors or standards that support the choice or judgement between alternatives, e.g. which soil cover contributes more to erosion, or which heterogeneity values explain high biodiversity values. Criteria sometimes include attributes, qualities ascribed to each criterion that are also employed in judgements (Saaty, 1994). Criteria and attributes are the main support of decision-making processes; therefore, their selection has to follow some guidelines. According to Ridgley (1995), the following features should be taken into account:

1. Criteria should be judiciously independent. This means the judgement of an alternative in relation to an attribute of a criterion does not depend on other judgements made employing other attributes.
2. Criteria should be comprehensible. This means that if the values (intensity or level) of the criteria related to a given objective are known, this should be sufficient to determine how well these criteria contribute to reaching or satisfying this objective.
3. Criteria should be meaningful. If the value of an attribute or criteria changes with respect to some alternative, then the preference for this alternative can change. This implies that the change in the value of an attribute or criterion produces a bias in the selection process because it is sensitive to these changes.
4. Criteria should be distinguishable, differences between them should be clear. Also, they must have the same meaning for all the experts involved in the judgements. In addition, redundancy in the attributes should be avoided implying that a characteristic or quality cannot be shared by different criteria.

3.2.3 Problem identification

The problems related to nature's capital conservation, involved in an ecosystem-based management project and the delineation of ecologically sensitive areas can be conceptualised as complex and quasi-structured problems (poorly structured), where the planner does not know all the elements or all the relationships between variables. As a consequence, this author suggests a strategy for problem identification developed in strategic situational planning (Matus, 1989).

The basic idea here is to define a complex problem following classical system analysis. First of all, the observer's view is settled, and the strategy then consists of analysing the complex problem as systematically and accurately as possible and constructing a network of interrelated problems. This involves focusing on a target problem, embedded in a set of interrelated problems. Then, these problems are described as the target problem's environment. For implementing this strategy a seven-step methodology is proposed:

1) Defining the complex problem. This refers to the description of the context of the target problem. It is described as a complex problem derived from a set of inter-related and/or accumulated unsolved problems. It is the macro problem of which the target problem is a part.
2) Identification of a problem to be analysed. This is the result of an exercise of targeting.

From the compound of problems, one or a few of them are selected as the target problem.

3) Characterising the most important problems from the problem environment. From the problem, a selection of the most important problems related to the target problem is made. All of them have cause-effect relationships with the target problem.
4) Describing the significance of the target problem. Here the relevance of the target problem is described to the actor or actors who have decided to analyse and solve it.
5) Identifying the main social actors involved in causing, tolerating and facing the problem. This is the description of all the social actors involved in the creation, maintenance and solution of the target problem and the critical resources that they have under their control.

This thesis employs this approach to analyse the complex social context involved in an ecosystem-based management project. It is suggested that this approach is a systematic way to identify negative and positive factors that could influence the goal of protecting ecologically sensitive areas. Furthermore, this complex problem analysis is a key point for an ecosystem/landscape diagnostic.

3.3 Analysis phase

This phase describes the study area and its context in several dimensions. It identifies the processes of interest that determine ecosystem/landscape functions and how they are influenced by the different elements that compose the physical landscape. The basic idea is to create analytical parameters that reflect the different patterns on the landscape as well as their spatial expression on maps.

In this phase, the ecosystem/landscape structure is described. This means, the identification of the largest patches related to biodiversity conservation, the land use classes and proportions and their change over time and other metrics that describe the composition and pattern, e.g. number and relative proportion of patches, connectivity indexes, surface/perimeter ratios and so on. It also includes the identification of clusters, patches and isolated patches, in addition to the neighbourhood and connective metrics that can support the application of the network principle described in chapter three.

According to this proposed methodology, this phase has four steps: criteria hierarchy construction, weighting criteria processes, the involvement of experts in Analytic Hierarchy Process and landscape/ecosystem data base construction.

3.3.1 Criteria hierarchy construction in the delineation of ecologically sensitive areas

Problems related to achieving a goal are structured with reference to the Analytical Hierarchy Process, either in the form of a hierarchy, or as a network in the case of existing interdependencies between the elements of one level, or feedback from lower levels in the hierarchy. The hierarchy has long been seen as a suitable representation for handling complexity and is widely used in general systems theory, cybernetics and hard systems thinking .

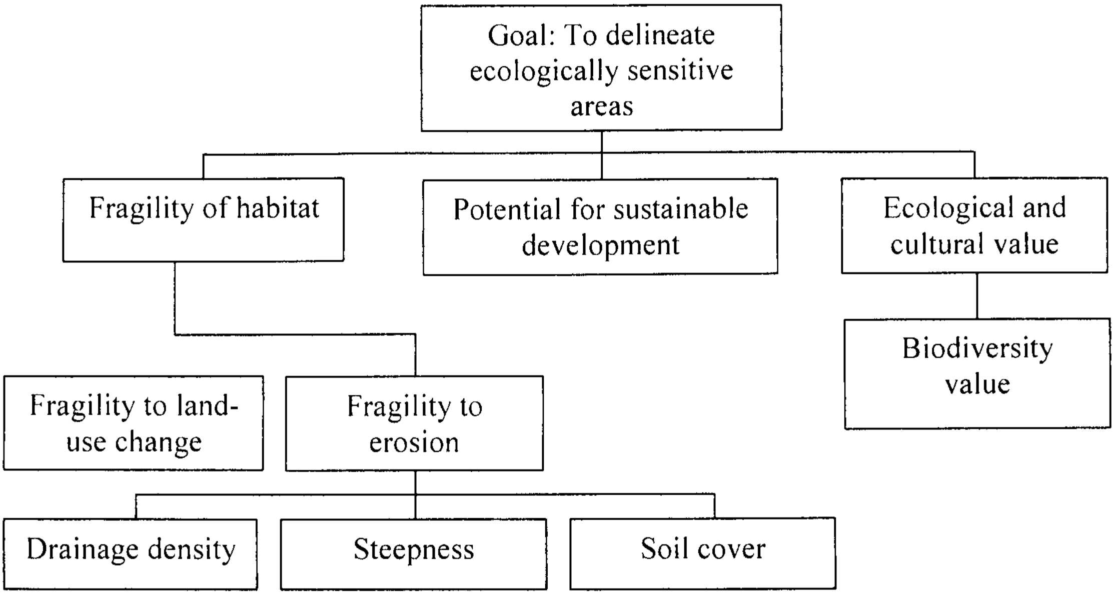
After the selection of a goal and the criteria to achieve it, the goal and criteria are integrated in a diagrammatic multilevel model called hierarchy. This model is the cornerstone of the Analytic Hierarchy Process procedures and organizes all the different elements, which are involved in a problem in a structure shaped like a tree, in which each element of the tree is known as node (Saaty, 1990). The goal of the problem is located at the upper level. Subsequent levels include criteria; attributes assigned to each criterion and at the lower level, the alternatives to achieve the goal (Saaty, 1994).

The use of hierarchies brings some advantages to decision-making processes. According to Saaty (1990) and Ridgley (1995) the principal advantages are:

1) They are structures that allow modelling complex problems by disaggregating them into subsystems or factors of decision, assembling partial and global solutions
2) Hierarchies are flexible and can be structured and adapted to spatial, temporal or uncertain situations.
3) Hierarchies provide detailed information of alternative solutions, showing the weight that different criteria have to achieve the goal of the problem.
4) They allow shaping a problem based on structures that are assembled according to terms of importance, preference or probability.
5) Hierarchies allow a feedback process based on the evaluation of the different alternatives. This evaluation process employs the same criteria and attributes that were used to construct the alternatives. The feedback procedure eases the implementation of a so-called back-forward planning process (Saaty, 1994).

The hierarchy proposed for Ecologically Sensitive Areas delineation is shown in the Figure 3.2.

Figure 3.2 Hierarchy model to delineate ecologically sensitive areas



3.3.2 Involving experts in decision making employing the Analytic Hierarchy Process

To date, the delineation of ecologically sensitive areas has been an expert's task. The employment of value-loaded concepts for delineating them and usually incomplete ecological information has led to the consultation of experts. Here, experts means a person with academic or real-life experience with the delineated problem. However, how can experts become involved in a process to delineate ecologically sensitive areas?

In terms of group decision-making, the Analytic Hierarchy Process also provides a framework for group participation in decision-making and problem solving. The conceptualisation of any problem, using this analytical process, requires the consideration of ideas, judgements and facts accepted by others as essential aspects of the problem. Group participation is viewed as the way to shape unstructured reality through bargaining and compromise. Furthermore, the Analytic Hierarchy Process incorporates judgements and personal values in a logical way, making it possible to include any kind of information scientifically or intuitively derived. Group participation requires imagination, experience and knowledge to structure the hierarchy of a problem, and logic, intuition, and experience to provide judgements (Saaty, 1994).

Another important property is that the Analytic Hierarchy Process is iterative. It allows a complex problem to be defined and sound judgements to be developed in a progressive form. Iterations in the Analytic Hierarchy Process are like hypotheses making and testing; the progressive refinement of each hypothesis leads to a better understanding of the system (Saaty, 1994).

This thesis shows, as an example in chapter six, a strategy to involve experts in a problem related to the contribution of different soil covers to soil erosion. This is a classical problem characterised by insufficient ecological data

3.3.3 Weighting criteria

One of the most controversial steps when the Analytic Hierarchy Process is applied for a group of experts, is establishing a measurement of the relative importance of criteria, e.g. three criteria are taken into account in the delineation of ecologically sensitive areas in relation to susceptibility to erosion: soil cover, soil depth/drainage density and steepness. However, the contribution of each criterion to explain erosion is a controversial point that can be handled using group-weighting procedures.

This procedure starts after the hierarchy has been built. The guide question is: Which criteria are most important? In order to avoid an endless discussion, a strategy called the balls-basket game is proposed. Each expert has 100 imaginary balls and each selected criterion is a basket; thus, each expert has to divide his/her imaginary balls between the different available baskets (selected criteria). Subsequently, two approaches can be followed: calculating an average value for each criterion under unbiased conditions or under biased conditions. Calculating each criteria's proportional value under unbiased conditions is simply to determine a rounded average value of each criterion based on the different values assigned by the group of experts. This average value divided by 100 is the proportional measurement of the importance of each criterion. On the other hand, calculating the criteria's proportional value under biased conditions is the same procedure described above, but removing the highest and lowest values assigned to each criteria in the calculation of average. These results are the basic values of the hierarchy, where the goal value is 1.00 and the different criteria have proportional values, which add to a number around 1.00.

Once the criteria and their relative importance are set, the expert group can compare the different alternatives between themselves. In the Analytic Hierarchy Process this is called pairwise comparison (Saaty, 1994). EXPERT CHOICE is a software package recommended to perform the pairwise comparisons easily. It also calculates the degree of consistency in the judgements and the proportional preference values of each alternative, which are subsequently employed in GIS procedures based on multi-objective, multi-criteria decision-making in land-use.

3.3.4 Landscape/ecosystem database: primary and secondary data, landscape metrics and space and temporal dynamics

This step consists of quantifying spatial patterns employing available spatial data (regional thematic data), image processing/Remote Sensing technology and GIS technology. Available regional thematic data and the results of image processing/Remote Sensing are the main primary data sources to be employed to produce secondary data using GIS technology. For the delineation of ecologically sensitive areas, the more important primary sources are bedrock geology, climate, elevation (DTM or DEM models), hydrography, land use/land cover and soil and transportation networks. Image processing/Remote Sensing technology is applied mainly to get current and past land use/land cover patterns.

GIS technology is applied to the delineation of ecologically sensitive areas for producing secondary data from primary data. Slope maps are produced from elevation points, contour maps from point data and watershed network maps from hydrological and elevation data. GIS technology also permits quantifying landscape patterns and spatial relationships such as shape, connectivity or diversity of landscape patches; and the quantifying of temporal changes as land use conversion. As an outstanding point, GIS procedures permit the integration of secondary data and the results from the Analytic Hierarchy Process into a multi-objective, multi-criteria decision making procedures pertaining land-use.

The main outcome of this step is a set of information in the form of maps that represent the spatial characteristics of the different landscape and ecosystem patterns, including actual and potential ecologically sensitive areas.

3.4 Diagnosis phase

Ecosystem/landscape diagnosis is based upon the results of the analysis phase and represents the application of the selected criteria to produce a diagnostic answering the following questions: In terms of the protection of ecologically sensitive areas, is the biodiversity of the ecosystem/landscape being well protected? If not, where is it not being well protected and why? In other words, the identification of ecosystem/landscape dysfunctions and land-use conflicts, related to biodiversity protection.

Diagnosis applied to the delineation of ecologically sensitive areas has, as its primary objective, that of determining the capability of ecosystems/landscapes to meet the requirements to protect biodiversity and to define standards or indicators to assess the existing ecologically sensitive areas. The complete diagnostic is a synthesis of the application of the selected criteria to evaluate an ecosystem/landscape. As an important result of this diagnostic, two synthetic maps may be considered, a map of potential ecologically sensitive areas and a map of threatened ecologically sensitive areas.

The first map represents the spatial representation of those areas that are valuable biodiversity segments of the ecosystem/landscapes, such as well-conserved localities, already protected territories and others. This map summarizes the ecological significance of the ecosystem/landscape. This significance is an interpreted quality characterized by a set of unique natural structures. The second map is a spatial synthesis of factors such as erosion and land-use change patterns that threat the biodiversity of the territory. It summarizes negative factors related to identifying the fragility of some areas caused by human influence. Attention is focused on the vulnerability to human activities of the ecosystem/landscape. Thus, impact of human activities is characterised by spatial representation of impact sources (point, line, area), as well as negative distant influence transfer from remote localities, such as air and water pollution.

In other respects, the second map summarizes negative factors related to identifying the fragility of some areas caused by human influence. Attention is focused on the vulnerability to human activities of the ecosystem/landscape. Thus, impact of human activities is characterised by spatial representation of impact sources (point, line, area), as well as negative distant influence transfer from remote localities, such as air and water pollution.

Diagnosis also implies the identification of negative and positive factors in connection with the protection of ecologically sensitive areas. On the one hand, negative factors may result from conflicts of interests into the ecosystem/landscape, and on the other hand, favourable factors are generally expressed as interests of different stakeholders on nature conservation, protection of natural resources and human health. This part of the diagnostic is attempted in the problem statement step during the focus phase.

3.5 Prognosis phase

This phase is for the development of possible visions and proposals of how the ecosystem/landscape could change to meet goals. In addition, it implies the assurance that the directions of the proposed changes effectively lead towards more sustainable conditions.

In a strategy based on the delineation of ecologically sensitive areas, the goal is to solve problems related to biodiversity conservation. Their solution, according to the network principle, generally encompasses all aspects linked to alternatives of spatial organization to achieve an optimal degree of biodiversity. The aim is to create a functional network of ecologically sensitive areas within an ecosystem/landscape, composed of biocentres, biocorridors, buffer zones and other particular features like road networks. This network of ecologically sensitive areas usually integrates three basic proposals: a) proposals aimed at creating new space elements on the ecosystem/landscape, such as biocorridors; b) proposals protecting existing and proposed ecologically sensitive areas and c) proposals eliminating disturbance factors from the ecosystem/landscape, such as agricultural impacts, land-use change, air and water pollution and so on.

Ecosystem/landscape prognosis also includes the evaluation of planning scenarios. This evaluation could be carried out through the use of GIS technology or employing the Analytic Hierarchy Process. The employment of GIS technology is mainly focused on space simulations of different land-use alternatives and their future consequences, while, the Analytical Hierarchy Process procedures imply the iterative process of contrasting the different alternatives with respect to the achievement of the goal they were supposed to attain.

3.6 Syntheresis phase

According to Botequilha and Ahern (2002) the syntheresis phase is where the actual plan is designed and implemented, here plans and actions, including public participation, are defined in order to prevent future negative impacts in the landscape and to assure their sustainable functioning. It also includes the monitoring of the on-going processes and changes, the evaluation of the changes occurring as a consequence of the proposed plan and feedback into the planning process. In assessing the efficiency of the plan it is useful to consider implementation, monitoring and feedback as an integrated decision making process. Often it is also helpful to revaluate goals and allow changes in the plan according to new findings, thus supporting a more dynamic and iterative planning process. (Lee and Bradshaw, 1998). This process is the corner stone to supporting the adaptive management approach already described.

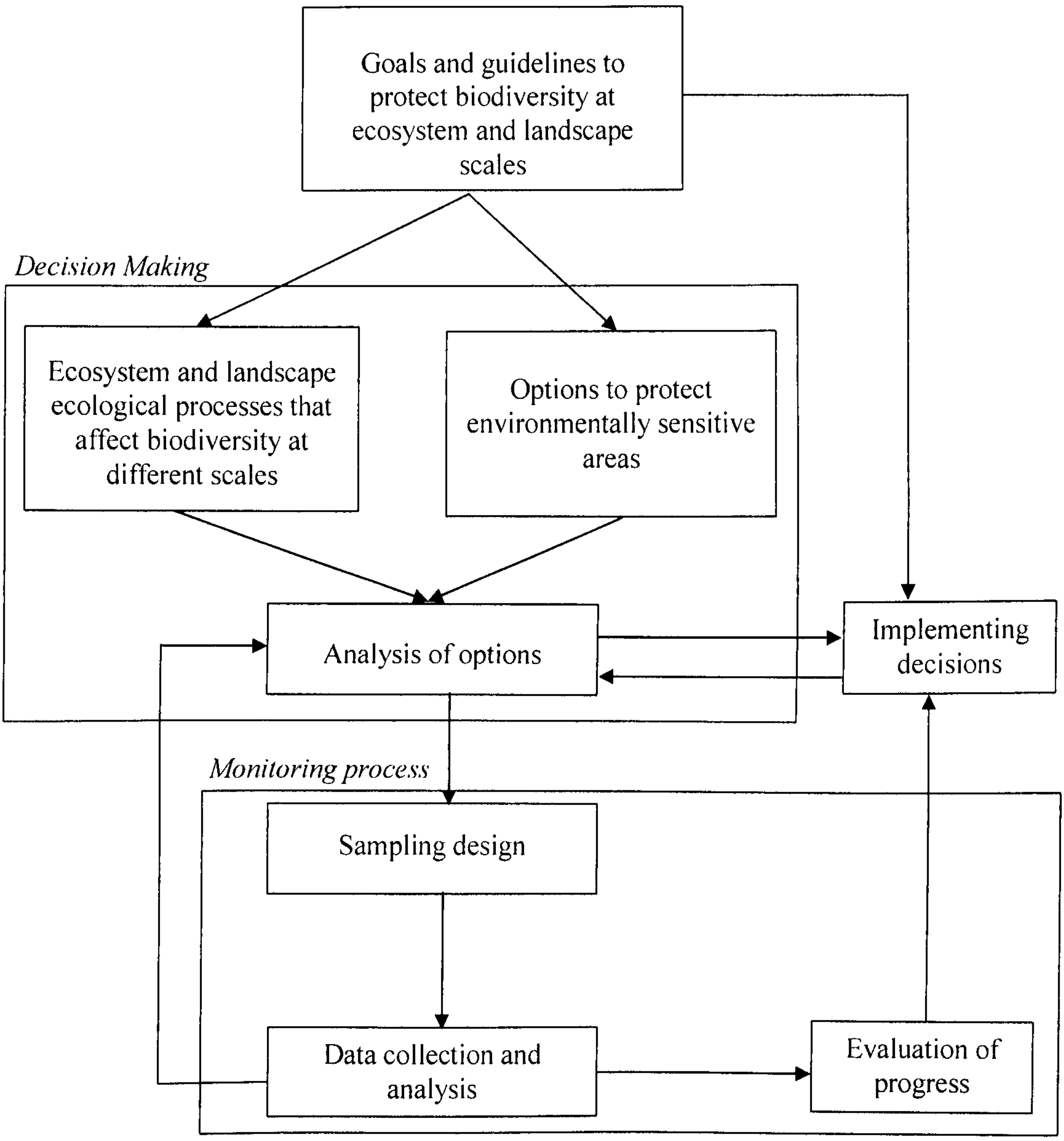
A key aspect in implementation of plans is public participation. Public participation in the planning process is essential to successful planning. According to Decker and Chase (1997) research has shown that people are more likely to accept an issue resolved when they have a voice in the decision-making process. Landscape planners have acknowledged this fact and incorporated participation in different methodologies. Botequilha and Ahern (2002) Yaffee, et al., (1996), Slocombe (1998, 1999) and Golley and Bellot (1999) recommend contemplating public participation early in the planning process. However, this topic is considered in different phase in several ecological-based physical planning methodologies. In their sustainable landscape planning methodology, Botequilha and Ahern (2002) include public participation in the analysis and prognosis phases. In environmental impact assessment methods, usually public participation is considered in the mitigation tasks (prognosis phase) (Morgan, 1998). Rural planning methodology includes public participation in the inventory phase (analysis phase) (Golley and Bellot, 1999). Ahern (1999) in his landscape ecological planning includes the topic in the assessment of ABC (abiotic, biotic and cultural) resources and during the scenario development phase.

This work considers public participation during the implementation of plans at two levels, regional and local. In addition, strategies to each level are proposed. In terms of regional level, the strategy consist in the involvement of federal and estate environmental authorities in facing the regional problems of conservation of nature. This strategy is proposed in order to obtain their support, in terms of financial and human resources to address these problems. It is basically based on the employment of the results of the analysis and prognosis phases to involve environmental authorities in the acknowledgement that the regional threats to biodiversity at regional level are a problem worth of analysis and to intend solving it. At local level, the strategy is based on the involvement of municipal authorities and local stakeholders (communal landowners, private landowners, peasant associations, ranchers associations, environmentalist groups, and primary and high school students) in those activities related with the care, protection and restoration of natural areas at subwatershed and municipality level. Particular consideration should be given to the local threats, at subwatershed level derived from productive activities and urban growth.

The monitoring process is seen also as a key feature of the syntheresis phase. A monitoring process demonstrates active attention to a given environmental issue and its principal is to illuminate decision-making. According to Lee and Bradshaw (1998) effective monitoring should achieve three objectives: (1) to provide an accurate assessment of the status of the resources being managed, (2) to validate that management decisions are correctly interpreted and implemented, and that such decisions achieve desired consequences, and (3) to offer improved insight into how systems operate.

Lee and Bradshaw (1998) support the idea of an integrative decision-making process that provides the appropriate tools to effect accurate translation of scientific information into inference, management decisions, and policy. Figure 3.3 shows a diagram of an alternative integrative decision-making process applied to ecologically sensitive areas planning.

Figure 3.3 An integrative decision making process applied to the protection and planning of ecologically sensitive areas



Source: Adapted from Lee and Bradshaw (1998)

3.7 Conclusions

The multi-functional view of ecosystems and landscapes creates a number of epistemological and operational difficulties, due to the complexity of these systems and the very time consuming task of integrating different views. In addition, multi-functional views imply multi-objective plans; therefore, it is clear that this approach requires appropriate planning instruments to cope with complexity, multi-dimensional views and multi-objectives.

It has been argued that multi-criteria decision-making is an appropriate support to cope with multifunctional views and multi-objective plans for ecosystems and landscapes. This decision-making process permits consideration of the complexity and dynamics of these systems and the social context relative to their management. The integration of a multi-criteria approach applied to ecosystem/landscape planning has been proposed in this chapter. As a consequence, a planning methodology of phases has been proposed: focus, analysis, diagnosis, prognosis and syntheresis

There is a relatively extensive literature on ecosystem management as an ecosystem/ landscape planning experience. However, there is not much research and knowledge about how to develop a methodology that is consistent with its goals. In particular, a methodology about how to integrate multi-functional views and multi-objectives in ecosystem based management, how to delineate areas to protect biodiversity under multiple considerations and how to integrate a practical methodology.

Considering this scant knowledge about ecosystem-based management planning processes, there is no doubt that a methodology of planning is essential to support ecosystem-based management projects and associated strategies as the delineation of ecologically sensitive areas. Bearing in mind that this methodology requires a multiplicity of implementation processes, this chapter has developed an integrated methodology considering the following key aspects: complex problem analysis, Analytic Hierarchical Process as a form of multi-criteria decision analysis and Remote Sensing and GIS technology.

The following chapters will investigate the application of this methodology. For this purpose a concrete example for a research strategy in ecosystem-based management planning has been selected: the delineation of ecologically sensitive areas and its operative practice in a specific mountain region.

Chapter 4. Supporting a case study: The Iztaccihuatl-Popocatepetl volcanoes region at Mexico.

4.1 Introduction

The goal of this chapter is to introduce the case study that was selected to validate the planning methodology, as designed and described in chapter 3. This chapter is driven by a fundamental academic purpose: integrating landscape and ecosystems theory and practice in a realistic ecosystem management planning approach.

As a brief background, it is important to mention that ecosystem management is a landscape planning approach of which there are many case studies in the world. More than six thousand projects in the USA alone were identified in 1995, distributed over a broad range of schemes and projects (Yaffee et al., 1996). However, few of them focused on an ecosystem-based approach, in a regional or geographical context (Yaffee, 1999). Ecosystem-based management has only been applied in but a few real-life cases worldwide. Slocombe (1998) reported case studies in Canada, Australia, South Africa and the USA.

However, there is little knowledge of real-life cases in developing countries, with different social, economic and cultural context. Despite the abundance of key recommendations derived from these real-life applications, little emphasis is given to the development of a particular planning methodology. Generally, ecosystem-based management has been characterised by focusing important efforts on generating information, but few have reached the point in which this information is used as a source for decision-making. This research recognises the need for an appropriate methodology to be applied in ecosystem-based management projects. It also recognises the need for good quality information, but it is a position of this author that such information should be practical, particularly if resources are limited.

Although ecosystem-based management seeks to be a scientifically well-supported landscape planning approach, there are practical obstacles that must be overcome. Among the most important is the mismatch between ecosystem/landscape theory and practice, and that between natural and arbitrary management units. Until now, few efforts have been made to face these inconsistencies in an integrated way. From a research design viewpoint, case studies seem to be an interesting way of exploring different methodologies that seek to integrate ecosystem/landscape theory and practice into naturally defined management units. For these reasons, this author has chosen a case study as his research design. Moreover, a case study design was selected for general purposes:

1) To apply the ecosystem-based management approach, with some emphasis on an associated strategy, the delineation of ecologically sensitive areas.
2) To look for a real-life application in a developing country.
3) To validate and give emphasis to a designed planning methodology.
4) To integrate ecosystem/landscape theory and practice into natural management units.

This chapter introduces the case study that will be investigated extensively in chapters 5 and 6. It is organised in four parts. The first is dedicated to justify the choice of a case study. Its aims are: to establish the reasons to chose the case study as a research strategy; and to link the research strategy and the case study to the proposed planning methodology. The second part provides a brief background of the Iztaccihuatl-Popocatepetl region. Its aim is to give a comprehensive regional context needed for planning. The third part explains the reasons behind the selection of the Iztaccihuatl-Popocatepetl volcanoes region as a case study. It employs two main criteria to justify this selection. Its purpose is to give support to the preference of this volcanic region. Finally, the fourth part describes the general guidelines for an ecosystem-based management planning approach to be applied.

4.2 Case study as the selected research strategy

From its inception, this thesis considered testing the designed planning methodology in a real-life case, in order to identify practical problems related to its implementation. Therefore, a case study research strategy was selected to examine the feasibility of applying the methodology in a real-life ecosystem based management planning situation.

The case study-based research strategy can have certain disadvantages, mainly that there are difficulties in providing a basis for scientific generalisation. It was selected, considering the alternative that a false or a true hypothesis could be identified with the results from one case. Furthermore, case study method represents a practical solution to the problem of useful hypothesis that are rejected. This problem has been recognised as the main concern of the holistic approach. In addition, this author provides evidence to support the hypothesis that the Iztaccihuatl-Popocatepetl volcanic region is a typical example of fragile mountain ecosystems. In addition, it is hypothesised that its complex problems and management challenges are similar to those occurring in other mountain ecosystems around the world.

4.2.1 Linking the research strategy to the proposed planning methodology

Other advantage of the case study research strategy include the fact that it can cope with the tasks related to suggesting a planning methodology. These advantages in order of importance include:

1) It could be designed to test or illustrate a theoretical point and the case is conceptualised as an instance of a type. Therefore, case studies can be used to test hypotheses, particularly to examine a single instance that shows if the hypothesis is true or false. That is the circumstance that is relevant to the appropriateness of the proposed methodology.
2) The aim is not just to develop knowledge, but also to search for a remedy to problems similar to those present in the case: as occurs in a planning methodology.
3) As a consequence of the last point, there is a close relationship between a case study and the attempts to solve practical problems, as happens in a landscape planning methodology.
4) It permits dealing with the subtleties and intricacies of complex/wicked problems. It has been recognised that problems related to the Ecosystem based management approach are complex and wicked.
5) It allows the adoption of holistic research rather than one based on isolated factors, as is usual in a methodology based on multi-criteria analysis.
6) It admits the use of a variety of research methods and sources of data, which is just the situation of the methodology proposed for this research.
7) It investigates a phenomenon as it naturally occurs and concentrates efforts on one research site.

4.2.2 Linking the case study to the proposed planning methodology

For this thesis, the application of the planning methodology to a case study is as important as was its design. The planning methodology and the case study are strongly related, because the outcomes of the former become the working objectives in the latter. In other words, the desired outcomes of each phase are made the work objectives to test the possibilities of the methodology in a real-life case. The relationships between planning phases, outcomes and work objectives are shown in Table 4.1

Table 4.1 Relationships between planning methodology and case study

Planning phase	Outcomes	Work objectives for the case study
Focus	Goals and objectives of the cosystem-based management project	Setting goals and objectives for the application of an ecosystem-based management project focused on the delineation of ecologically sensitive areas
	Geographical units definition	Defining geographical units and applying them to the watershed network
	Geographical limits	Delineating the limits of the region under study
	Criteria selection	Selecting appropriate criteria to delineate ecologically sensitive areas
Analysis	Hierarchy construction	Constructing a hierarchy with the selected criteria
	Weighting criteria	Implementing mechanisms for weighting criteria
	Landscape/ecosystem database	Building a landscape/ecosystem database
	Enabling rate of land use change in a period of 7 years	Estimating land-use rates of change
Diagnosis	Priority vector calculation	Employing the expert choice software for calculating a priority vector to be applied to the process of delineation of ecologically sensitive areas.
	Delineation of ecologically sensitive areas based on biodiversity value	Delineating and mapping ecologically sensitive areas according their biodiversity value.
	Delineation of ecologically sensitive areas based on erosion risk.	Delineating and mapping ecologically sensitive areas according to erosion risk.
	Delineation of ecologically sensitive areas based on land-use change risk.	Delineating and mapping ecologically sensitive areas according to land-use change risk.
	Social context analysis: threats to, and opportunities for, biodiversity protection.	Constructing the diagrammatic model of regional threatens to biodiversity protection

Prognosis	Design of a network of ecologically sensitive areas within an cosystem/landscape	Proposing a regional network of ecologically sensitive areas
	Evaluation of regional potential to achieve sustainable development	Evaluating the regional area-related and planning potential for sustainable development
	Design of a plan to achieve regional sustainability	Designing a general plan for the case study
	Construction of scenarios	Not considered in this thesis
	Design of maps for different scenarios	Not considered in this thesis
Syntheresis	Selection of criteria and indicators	Not considered in this thesis
	Design of the monitoring process	Not considered in this thesis
	Assessment of ecosystem-based management projects	Not considered in this thesis

4.3 Selecting an ecosystem/landscape: The Iztaccihuatl-Popocatepetl region

In order to test the designed planning methodology in a real-life context, the Iztaccihuatl-Popocatepetl region of Mexico was selected as an ecosystem/landscape. Two sets of criteria were employed on this selection. One set was related to the pragmatic basis, including considerations of convenience and another was related to the basis of suitability for the purposes of this research.

4.3.1 Considerations of convenience: personal, institutional and academic interests

Particular interests of the author of this thesis. There was a personal interest and a matter of convenience in applying this methodology to a case study located in Mexico, where the author has been and will be involved in environmental planning. This author regards the Iztaccihuatl-Popocatepetl volcanic region as a research challenge, because it permits the development of a case study characterised by wicked problems that are related to the protection of biodiversity in a hard, social, economic and cultural context. In addition, from an ecosystem/landscape planning perspective, the Iztaccihuatl-Popocatepetl area is an opportunity to face many of the common obstacles of ecosystem-based management planning.

Institutional interests. The Autonomous Metropolitan University at Mexico, where this author is currently working as a lecturer, has other wide-ranging regional projects that include this volcanic region. There are strong relationships between this research and an institutional research programme called the Metropolitan Studies Program, focused on urbanization processes in the countryside, the town-countryside relationships, multifunctional land-use planning, considering ecological and economic criteria all using an interdisciplinary research.

Research interests. The Autonomous Metropolitan University has been involved in developing basic inventorying developing and formulating planning proposals in this region since 1994. First, this region was selected because it is one of the ten most important national parks in Mexico. Thus, there was a particular interest from the Environmental Ministry and the World Bank in the development of a management plan for this national park. The Autonomous Metropolitan University was selected as the institution for developing this plan, which was concluded in 1995. This project was a starting point for further research and planning projects in this region.

4.3.2 Landscape/ecosystem suitability aspects: as a typical instance and as a test site for the methodology

The landscape/ecosystem suitability aspects of this case study will be presented from four different viewpoints: the global, the ecological, the regional and the environmental planning. In order to develop a holistic approach, a particular emphasis will be made on the complex problems and the context involved in the global, the ecological and the regional and environmental planning perspectives.

From the global point of view, according of the criteria enumerated in the chapter 13 of the Agenda 21 the Iztaccihuatl-Popocatepetl region could be considered a mountain ecosystem of a fragile nature. This view highlights the problems relative to conservation, management and recovering of mountain ecosystems as fragile ecosystems. It also provides an opportunity to emphasize the ecological deterioration of these areas around the world. In addition, it permits setting in context the modest contribution this thesis makes to facing this problem in a small region of Mexico.

From the regional viewpoint the case study region is the focus. It describes the regional problem of landscape fragmentation and its relationship with human activities and interests. This viewpoint also includes a discussion of how the regional forest land has been and is being threatened by uncontrolled degradation and conversion to other types of land uses, influenced by increasing regional needs for urban development and the low opportunity cost of other land uses (agriculture, livestock, forestry, conservation). Additionally, particular consideration is given to the way in which forestland is suffering severe impacts derived from agricultural expansion and environmentally harmful mismanagement. This mismanagement is characterised by a lack of adequate forest-fire control, anti-poaching measures, unsustainable commercial logging and overgrazing. This viewpoint also includes a discussion of how landscape fragmentation gives rise to habitat loss and has detrimental effects on biodiversity. A special consideration is given to the phenomenon of loss of control on hydrological and biogeochemical processes, and how both simultaneously damage the ecosystem's capacity to withstand natural and human perturbations. Ecologists have named this lack of response capacity of the whole ecosystem to internal and external perturbations, a loss of resilience and homeorresis of the ecosystem (reviewed in greater depth in chapter 2).

Finally, from the environmental planning viewpoint presents a perspective that reflects the requirement of a methodology suited to facing complex environmental problems related to fragile ecosystems (Slocombe, 1992). In addition, ecosystem-based management is introduced as an appropriate environmental planning approach to cope with the regional problems of the Iztaccihuatl-Popocatepetl volcanoes region. Particular emphasis is given to the problems related to the implementation of an ecosystem-based management approach and to the necessity of assigning different weights to different aspects of the problem, for a proper start of an environmentally sustainable planning process.

Summing up, these four viewpoints permit the research topic of this thesis to be located in relation to other context issues. Altogether, it is seen to be directly related to the complex problems surrounding the planning efforts to conserve fragile ecosystems that lead the way in achieving environmental sustainability. In addition, these viewpoints also help to define guidelines for both, defining and then locating those areas that are threatened or are worthy of conservation, namely: the ecologically sensitive areas.

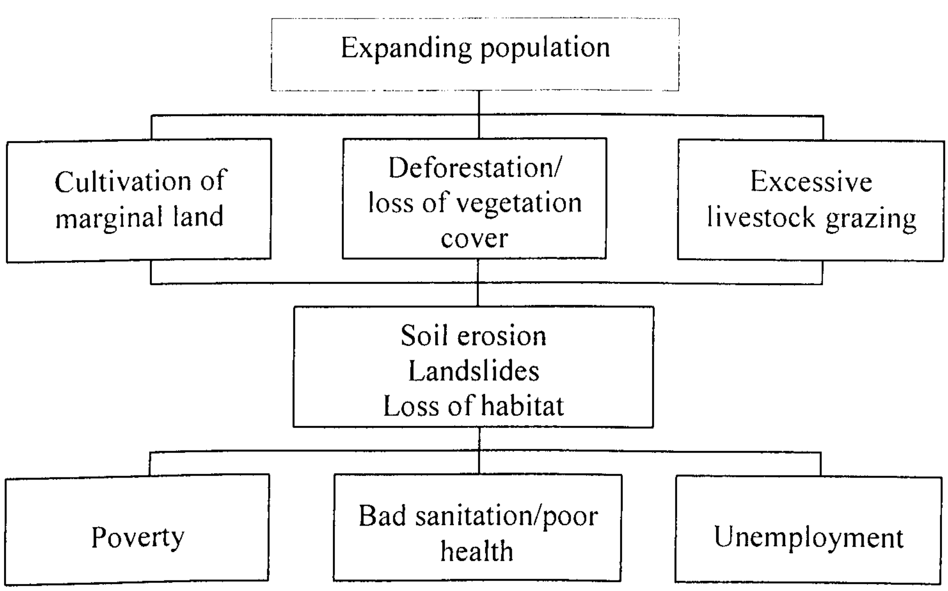
Fragile mountain- ecosystems perspective

From this perspective, the Iztaccihuatl-Popocatepetl mountain region-planning problem is seen as part of a wider international concern for the management of fragile ecosystems. Fragile ecosystems are considered those that are very sensitive to various forms of perturbation or disturbance. Besides mountain ecosystems, fragile ecosystems also include arid lands, polar areas, freshwater wetlands, intertidal wetlands, rainforests, coral reefs and alpine areas.

Mountain areas are recognized as some of the most important types of ecosystems in the world. Nearly half the world's population is affected in various ways by mountain ecology and the degradation of mountain watershed areas. Conservative estimates calculate that about 10 per cent of the Earth's population live in mountain areas with high slopes, while about 40 per cent of this population occupy the adjacent medium and lower watershed areas (Agenda 21, 1991). However, according to this document, there are serious problems of ecological deterioration. Most of the mountain-ecosystems of the Earth are threatened mainly by cultivation of marginal lands, excessive livestock grazing, deforestation and loss of vegetation cover due to expanding population. This ecological deterioration has caused an increase in the susceptibility of such areas to accelerated soil erosion, landslides and rapid loss of habitat and genetic diversity. On the human side, a common characteristic is that there is often widespread poverty among mountain inhabitants and a loss of indigenous knowledge caused by frequent migration movements. As a synergic result, most of the global mountain areas are experiencing environmental degradation.

In particular, soil erosion is the main result of mountain ecosystem degradation. Soil erosion can have a devastating impact on the regional soil capital and on vast numbers of rural people who depend on rain-fed agriculture in the mountain and hillside areas. Moreover, soil erosion affects the most productive irrigated areas located in the lower watershed. Floods and mud flows damage many commercial crops and reduce the life span of water reservoirs and dams. On the other hand, the ecological impacts caused by nutrient bank loss have severe social impacts: poverty, unemployment, poor health and bad sanitation are widespread (Figure 4.1)

Figure 4.1 Mountain ecosystems degradation

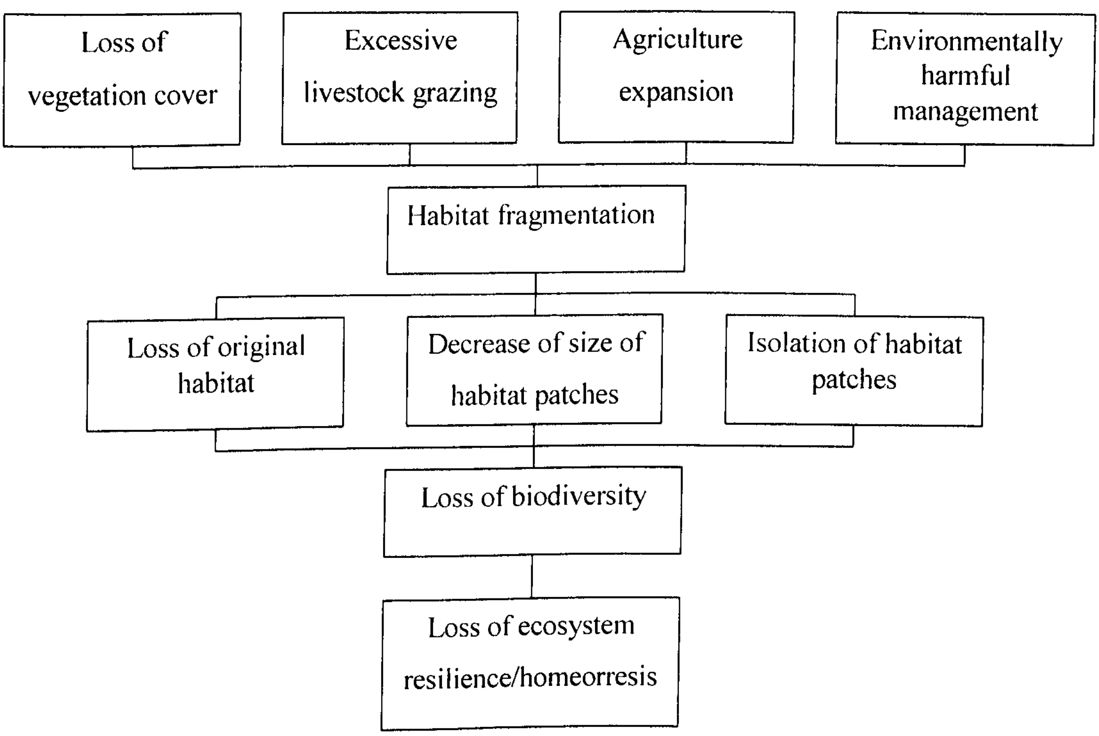


Ecological perspective

From an ecological perspective, the ecologically complex problem is centred on ecosystem/landscape degradation. This is explained by the fragmentation caused by the loss of vegetation cover, often generated by excessive livestock grazing, agricultural expansion and environmentally harmful management. Frequently this environmental mismatch is characterised by a lack of adequate forest-fire control, lack of anti-poaching measures, poor planned transportation infrastructure and unsustainable commercial logging.

Today, habitat fragmentation is believed to be one of the most urgent challenges environmental planners face. Fragmentation of habitats refers to the separation of ecosystem/ landscape elements into smaller parts. Thus, the process of habitat fragmentation has several negative effects on wildlife that include the loss of the original habitat, a decrease in the size of habitat patches and an increasing isolation of these patches. These impacts have immediate effects upon populations of wild flora and fauna, because they reduce their breeding capacity and therefore, their fitness abilities, potentially giving rise to local extinctions of some species or varieties. From an ecosystem viewpoint, habitat fragmentation implies biodiversity damage and a loss of organisms involved in essential ecological processes. This loss of species has simultaneous effects seen in the loss of control on an ecosystem's essential processes like hydrological and biogeochemical cycles, along with a further lack of resilience and homeorresis of the entire ecosystem (Figure 4.2)

Figure 4.2 Habitat fragmentation and biodiversity loss



Regional perspective

The Iztaccihuatl-Popocatepetl volcanic region shares serious problems of ecological deterioration and fragmentation that characterise most mountain areas around the world. The volcanoes region is directly threatened by cultivation of marginal lands, excessive livestock grazing, deforestation and a constant loss of vegetation cover.

From an ecological-economic viewpoint, the Iztaccihuatl-Popocatepetl area is an important regional source of water, energy, recreation, forest and agricultural products, as well as being one of the most relevant regional storehouses of biological diversity and endangered species.

Taking into account the expansion of local population, which is the major threat to fragile mountain ecosystems, this volcanic region is not an exception. An outstanding feature of the Iztaccihuatl-Popocatepetl region is that it is a mountain barrier between two of the valleys in Central Mexico, which are displaying explosive population growth: the Mexico and the Puebla valleys.

This explosive population growth has increased the regional demand for resources, mainly soil and water that are associated with urban growth. These demands threaten the watershed-ecosystems located on this mountain region. As a consequence of urban soil demands, regional forests have been and are being threatened by uncontrolled degradation and conversion to other types of land uses, mainly agriculture or urban soil. There is a local soil change chain, where the currently active or abandoned crop fields are transformed into urban areas and new crop fields are developed on former forestlands. In addition, regional forests are also suffering severe impacts derived from agricultural expansion and environmentally harmful management, such as a lack of adequate forest-fire control and anti-poaching measures; illegal and unsustainable commercial logging; overgrazing, etc. (Chavez et al., 1996).

In order to develop an environmentally sustainable approach to deal with the Iztaccihuatl-Popocatepetl region, the complexity of these problems must be recognised. Conservation of the region's natural capital is being endangered by at least six critical factors:

1. The pattern of land-use change and its consequences. Uncontrolled urban growth and expanding farming land use patterns have depleted forestlands. This decline in forested area implies severe losses in terms of the regional natural capital. Until now the Iztaccihuatl-Popocatepetl region has suffered a loss of forest areas that has caused a corresponding loss of biological diversity, damage to wildlife habitats and a general degradation of its watersheds. This environmental

degradation, caused by land use change, has had an impact on socialdevelopment. From a social point of view, the region also suffers deterioration of the quality of life of its inhabitants and a reduction of their options for development. Poverty, unemployment and poor sanitation are common problems found in regional rural areas. In fact, a major social consequence of environmental degradation is that this region expels migrants to the nearest urban areas and to the USA. This migration has cultural impacts too. It gives rise to a considerable erosion of the indigenous knowledge of local resources, traditional agricultural traits and long established livestock practices.

2. The urban areas growth rate in a regional context. The Iztaccihuatl-Popocatepetl volcanic area is located in a region with one of the fastest urban growth rates in the world: the megalopolis of Middle Mexico. This mountain region is found between two urban pathways that surround it, Chalco-Cuautla on its western and southern sides and Puebla-Atlixco, to the east. Both of them have two municipalities with a high urban area growth rate: Chalco and Puebla, respectively.

3. The continuing population and economic growth. The trends of population and economic growth in the megalopolis of Middle Mexico (Mexico City and the municipalities around it) appear unlikely to change in the near future. According to demographic and economic data projected by the Metropolitan Research Programme, at Metropolitan University, the Mexican Valley, the main sub-region of the megalopolis had 26 744 867 inhabitants in the year 2 000 and will have 31 512 667 inhabitants in the year 2 010, and 35 825 622 inhabitants in the year 2 020. Economic development is estimated to have the same growth rate (Ramirez, 1997). Thus, the future regional scenario is one of more urban and industrial growth, decreasing natural capital and a landscape with large grey areas (urban), a few "brown areas" (agriculture) and very few "green moles" (natural vegetation cover).

4. Regional economic activities not integrated with the environment. Agriculture, animal husbandry, mining, forestry and recreational services have been undertaken without considering the impacts on natural resources and environmental services. As a consequence, there is an increasing regional shortage of resources (mainly water and soil) and an increase in the pollution of water, soil and the air.

5. Low institutional capacity to foster environmental quality and conservation. In Mexico, the Environmental Ministry has a low decision making profile and it is subordinated to the Ministry of Economics. This implies little political awareness

about topics related to the environment and a limited local and federal capacity to foster the application of environmental law. A common concern is the finding that natural heritage conservation is a topic to which references are rarely made in the regional and local development plans.

6. Lack of local and regional awareness of the social consequences of environmental risks derived from environmental degradation. This is another common issue found in the volcanoes region. It is perceived to be a result of the predominant application of economic criteria in land use decision-making and a strong regional influence of urban life style. This point also has a synergic effect on regional patterns of land use change. In reality, the predominant economic criteria are unfavourable to conservation, forestry and agricultural activities. The actual opportunity costs for urban uses make these activities non-competitive

Environmental planning perspective

In order to find the solution to complex problems related to environmental sustainability, as those described above, the design of appropriate planning methodologies is required. The proposed methodology of this thesis was designed so that these kind of complex problems could be analysed and alternative solutions to them could be constructed. For this reason, it was decided that an ecosystem/landscape planning approach should be applied to the Iztaccihuatl-Popocatepetl volcanoes area. Thus, first of all it is important to recognize that any regional planning effort to achieve environmental sustainability implies the need to confront complex and wicked problems. The problems described above, epistemologically have all the characteristics of a "wicked" problem. They are tricky, complex and thorny. In addition, their solution implies the need to face ambiguities, conflicts, internal inconsistencies, lack of organised approaches, institutional confusion and lack of scientific understanding of management consequences (Holling, 1996).

Accordingly, from an ecosystem/landscape planning perspective, the Iztaccihuatl-Popocatepetl volcanoes area exemplifies many of the common obstacles and problems associated with ecosystem-based management planning, which include the following:

1) Regional development societal goals, preferences and values are numerous, ambiguous and often conflicting.
2) Legal federal and municipal mandates related to land-use change regulations are complex, unclear and at times contradictory.
3) Regional and municipal, urban and nature conservation policy directions are missing, ambiguous or incomplete with a tendency to shift rapidly in response to political pressure.

4) Federal agencies and municipalities do not have a well-defined and widely accepted decision making process. Decisions and decision-making processes are usually based on methods of trial and error and on local pragmatic necessities.
5) There is not an available and widely accepted method for producing consensus among often conflicting stakeholders, or improving collaborative decision making process between decision makers and stakeholders.

Many regional land-use decisions are made on a basis of missing and uncertain data and often incomplete scientific knowledge.

Despite the fact that wicked problems often give rise to distorted visions of reality, strategies should be designed to cope with them. One of the most common involves the weighting of the relative importance of different issues before the problem is tackled. This author acknowledges the immense importance behind the efforts to state initial objectives and weight problems as the starting point of any planning process. This strategy permits focusing on specific problems and their solution, hoping to add successive solutions to achieve a global solution. Applying this premise to the case study, it is recognised that the delineation of ecologically sensitive areas is not enough to solve the conservation of nature problems in the Iztaccihuatl-Popocatepetl region. However, it allows those areas that should be protected, in order to achieve regional environmental sustainability to be highlighted.

Additionally, it is recognized here, that regional environmental sustainability is just an isolated good desire if it is not confronted with the needs of a social and economic development in the volcanoes area. This multi-functional vision on regional ecosystems and landscapes is intended to lead towards an integration of regional sustainable development targets in land-use planning and to the implementation of collaborative strategies to achieve them. However, on many occasions these processes require a starting point. This thesis supports the idea that the delineation of ecologically sensitive areas seems to be a good initial point from which to start the process.

4.4 A general background of the Iztaccihuatl-Popocatepetl region

This section seeks to provide a broad background associated with the Iztaccihuatl-Popocatepetl region and issues related to environmental policy in Mexico. The development of this section takes into account different contexts to be considered for the improvement of the frame of reference for the case study. Thus, different perspectives have been adopted in considering the case study area. These include a conservation of nature's context, a geographical position, a hydrological framework, a perspective of climatic conditions, a biological situation and a legal and planning frame of reference.

All of these are considered to be necessary supports for an ecosystem-based management planning approach and for an ecologically sensitive areas delineation strategy. Each perspective is individually stated. The conservation of nature's context emphasises the regional potentialities and problems related to biodiversity conservation. The geographical position defines the location and relevant features of the region. The hydrological framework underscores the importance of hydrological zones and regions; both of them key aspects for delimiting the different territorial units under study. The prevalent regional climatic conditions are described in order to illustrate the environmental heterogeneity of the Iztaccihuatl-Popocatepetl region. In the meantime, the regional biological situation is introduced, based on the main vegetation features. Here the main vegetation types and more conspicuous species are enumerated. Finally, a legal and planning frame of reference related to environmental policy in Mexico is described briefly from a historical perspective. Particular emphasis is given to the main factors and guidelines to take into account during the environmental planning design.

4.4.1 The conservation of nature's context

Mexico is a mountainous country. More than a half of its surface is part of, or influenced by, mountain ecosystems. The Iztaccihuatl-Popocatepetl area is part of a mountain chain in Central Mexico. This mountain chain, which crosses from west to east, named the Eje Neovolcanico (Neo-volcanic axis) is very famous for its active volcanoes. Part of this axis is the Sierra Nevada where the Iztaccihuatl-Popocatepetl region is located. There are two outstanding features related to Sierra Nevada: it is a mountain barrier between two of the valleys of Central Mexico in which there is an explosive population growth, the Mexico and Puebla Basins. It also has a considerable importance in terms of its regional biodiversity.

The potential and problems for its conservation paradoxically are related to the geographical location of this area in Mexico. On the one hand, its natural conditions permit a high degree of biodiversity, due to the area's long, biogeographical history and complex topography. On the other hand, it has conditions that are appropriate for human settlements. Since the time of the Aztec, the Mexican Basin has been the most populated region in Mexico. The main impact of human settlements on regional biodiversity is the fact that wildlife has been restricted to what remains of natural areas and as a consequence, some subspecies and species are either endangered or close to extinction.

This severe impact is regionally important because some 44 % of the 2071 species registered in the Mexican Basin can be found in the Sierra Nevada area, as well as more than 60% of the main species that are located along the Eje Neovolcanico biogeographical province (Chavez, et al., 1995). As indicated above, this mountain chain crosses Mexico from the

Pacific to the Atlantic Ocean, in a NW to SE direction. In biogeographical terms, it is a natural barrier between the two main biogeographical regions in America: the Neartic Region and the Neotropical Region. In fact, this phenomenon explains why the Eje Neovolcanico biogeographical province is considered to be a transition province. This also explains why it contains so many endemic species of animals and plants.

The relatively high altitude is another important factor that induces high biodiversity values in the Eje Neovolcanico biogeographical province. As an example, the Sierra Nevada region is located between 2 000 and 5 500 meters above sea level. This altitude explains the presence of two of the temperate biomes in Mexico, which includes a major number of species, the forest pine biome and the oak forest biome (Rzedowsky, 1991). Likewise, this altitude permits the presence of two further biomes with a great number of endemic species, the alpine vegetation biome and the wet mountain forest biome.

From a physical planning point of view, it is important to draw attention to the fact that the Iztaccihuatl-Popocatepetl volcanoes region was decreed a National Park in 1935. Firstly, the boundaries were determined with reference to the elevation contour at 3 000 meters above sea level and included a surface area of about 59 513 ha. In 1948, the boundaries were raised to the 3 600 meters contour, reducing the total area of the park to 37 350 ha.

4.4.2 Geographical position

The Iztaccihuatl-Popocatepetl volcanic region forms the upper watershed of three important valleys in the central region of Mexico: Valle de Mexico, where Mexico City is located and its associated urban area, the most populous region in the country, Puebla Valley, an important industrial and agricultural region. This is also a heavily populated region. It includes also the Cuautla Valley, another important agricultural region. This mountain region is part of three Mexican states: Mexico, Puebla and Morelos. The area under study is about 1 473 square kilometres (see map 4.1).

4.4.3 Hydrological framework

Hydrological altitude zones

The hydrological resources of the volcanoes region are supported by the melting of glaciers and the abundant precipitation over the Iztaccihuatl and Popocatepetl volcanoes. There are two different types of watercourses, perennial and intermittent. The perennial watercourses are present all year round and the water from glacier melting and spring-waters feed them. The temporal water flows carry water only during the rainy season.

Most hydrological resources of this area are typical of mountain regions and they vary widely in altitude (Robles, 1944). This variation is reflected in different types of areas, based on the origin of the water and on geomorphological history. Five different zone types can be distinguished: glacier, glacier-pluvial erosion, fluvial erosion, intensive erosion and deposit.

The glacier zone ranges from the 4 500 meters contour line to the summit of the volcanoes (more than 5 000 meters above sea level). This is the zone of permanent snow and glaciers and where many micro-watersheds have their origin.

The glacier-pluvial soil erosion zone is located between the 4 000 and 4 500 meter contour lines. This is the zone where most of the spring-waters originate and where rainfall water flows away, because the thin soil cover is easily saturated. The fluvial soil erosion zone is found between the 3 450 and 4 000 meter contour lines. This is the zone with the most severe soil erosion because of the steep slopes and abundant watercourses and waterfalls.

The intense soil erosion zone is also found between the 2 500 and 3 450 meters. This zone is characterised by strong soil erosion due to the large volume of water flowing through watercourses and over the steep slopes.

The deposit zone is located between the 2 300 and 2 500 meter contour lines. It is the zone in contact with the valleys. This zone presents an accumulation of sediments forming alluvial fans from 4 to 10 kilometres wide. In this zone, water is employed for agriculture, municipal needs and energy production. It is in this type of areas that regional dams are generally located.

Hydrological regions

The volcanoes area is a division that separates, and partially gives rise, to two of the largest basins in middle Mexico: the Panuco river basin and the Balsas river basin. The first drains into the Atlantic Ocean while the Balsas river basin drains into the Pacific Ocean (INEGI, 1985).

The Iztaccihuatl-Popocatepetl region is a part of the upper watersheds of these basins. Thus, following the Balsas river basin four watersheds can be found: Balsas-Santo Tomás, Huautla- Tetlanapa and Atoyac-San Martín Texmelucan. In contrast, the Pánuco basin includes only the sub-watershed Texcoco-Zumpango (Table 4.2)

Table 4.2 Main watersheds in the Iztaccihuatl-Popocatepetl region

Basin	Watershed	Main sub-watersheds	Surface (ha)
Balsas	Atoyac-San Martín Texmelucan	Atoyac San Martín	164 085.4
	Tetlanapa	Alseseca Apol Atila	196 044
	Huautla	Without sub-watersheds	555 897.6
	Balsas-Santo Tomás	Without sub-watersheds	58 939
Panuco	Texcoco-Zumpango	La Compania Amacameca	58 939
Total			1 473 364

Inside the Texcoco-Zumpango watershed, there are two main rivers with their respective water-flow areas: La Compania and Amecameca river sub-watersheds. The watercourses of the west side of the Iztaccihuatl and Popocatepetl volcanoes feed these sub-watersheds. La Compania river sub-watershed is located north west of Iztaccihuatl and is fed by water from this volcano and from the Rio Frio Mountains. On the other hand, the Amecameca river joins watercourses from the west side of Iztacccihuatl and from the north west of the Popocatepetl volcano.

The watershed Atoyac-San Martín Texmelucan includes the San Martin river sub-watershed and the Atoyac river sub-watershed. The San Martin sub-watershed is fed by the water flows that arise from the glaciers on the north side of the Iztaccihuatl, while the Atoyac river sub-watershed is fed by the water flows from the glaciers on the east side of this volcano. Tetlanapa watershed is the largest in the region (see table 4.1). This watershed contains three main sub-watersheds: the Alseseca, the Apol and the Atila sub-watershed. These three rivers are all tributaries of the Nexapa river watershed that flows from north to south on the east side of the volcanoes. Each one is fed by different water-flows: Alseseca river sub-watershed gathers the water-flows from the glaciers on the east side of Iztaccihuat, while the Apol river sub-watershed concentrates water-flows from glaciers Southeast of the Iztaccihuatl and from the northeast side of Popocatepetl. Last, the glaciers south of Popocatepetl feed the Atila river sub-watershed.

The Huautla watershed is provided by water flows from the south side of Popocatepetl volcano. Contrasting with those previously mentioned, this is not a typical river. It has ravines that drain into the Cuautla river. The Grande ravine is the most important and it originates near the town of Yecapixtla, running to the South and being fed by the watercourses along its course.

The Balsas-Santo Tomás watershed is supplied by water-flows originated by the glaciers on the southeast side of Popocatepetl. Its most notable feature is Nexpayantla ravine, the deepest ravine in the region (about 500 m in depth). This ravine concentrates the main water-flows of this watershed and also drains into Cuautla river.

4.4.4 Climate conditions

The Iztaccihuatl-Popocatepetl region presents five climate types. According to the Köeppen classification, modified by Garcia (Garcia, 1968), these climate types are: wet temperate with summer rains, sub-wet temperate with summer rains, wet semi-cold with summer rains, semi-cold with summer rains, cold and very cold. A brief description of each climate type found in this mountain region is shown in table 4.3.

Table 4.3 Climate types in the Iztaccihuatl-Popocatepetl volcanic region

Climate type	Average annual temperature (°C)	Total annual precipitation (mm)	Main characteristics
Wet temperate	17.2	1 885.2	Isothermal, Ganges
Sub-wet temperate with summer rains	13.2	1 092.6	Isothermal, Ganges
Wet semi-cold with summer rains	7.7	1 186.8	Isothermal, Ganges
Semi-cold with summer rains	10.4	1 074.3	Isothermal, Ganges
Cold and very cold	-2	-	-

4.4.5 Biological situation

Of the biological conditions of the area of study, this section highlights only the vegetation features because of two main reasons. Although the region has a rich animal biodiversity, this thesis is concerned with the landscape scale, at which interest is directed to surfaces over tens or hundreds of square kilometres. Most of the reported animal species have habitats of the order of tens of hectares or less. This work supports the hypothesis that conservation efforts must be focused on the protection of habitat for different species. This means that if the places for feeding, hiding, breeding, etc. are protected, as a consequence the species are protected. Therefore, the vegetation features are considered here to be the most important, because of their role in the regulation of essential ecological processes and as the habitat for animal species.

Vegetation traits

The Iztaccihuatl-Popocatepetl region has a rich biodiversity of plants. The estimated number of plant species is about 914 distributed in 370 genera and 89 families.

These 914 species are part of the following vegetation communities or types: pine forest, fir forest, oak forest, grassland and secondary vegetation patches.

The pine forest vegetation type is widely distributed in the region. This kind of forest is distributed between the 2 500 and 4 100 meter levels. The predominant tree species are *Pinus hartwegii, Pinus montesumae, Pinus leyophilla, Pinus rudis, Pinus pseudostrobus, Pinus teocote and Pinus ayacahuite.*

The fir forest is restricted to ravines from 2 700 to 3 500 meters of altitude. The dominant tree species is *Abies religiosa.*

Oak forest is widely distributed too. It is found between the 2 250 and 3 100 meter levels. The dominant tree species are *Quercus rugosa, Quercus crassipes and Quercus laurina.*

There are two communities of grasslands: high mountain and induced. The former is a community located from 4 000 to 4 500 meters above sea level. The dominant species of grass are *Agrostis tolucensis, Eriginium sp, Arenaria broydes, Calamagostris tolucensis, Cirsium sp., Festuca livida and Muhllenbergia sp.* Induced grasslands are secondary communities derived from the destruction of forests. They are located from 2 700 to 4 300 meters above sea level. *Muhlenbergia macroula, Festuca toloucensis, Festuca amplisima and Calamagostris tolucensis* are the dominant grass species.

4.4.6 Legal frame of reference of biodiversity conservation in Mexico: Physical planning in Mexico.

The beginning

The first legislative measure about territorial and environmental planning in Mexico was the General Planning Law of the Mexican Republic, published in 1930. This law established, in general terms, the commitment of the Mexican Government to consider the conservation of natural resources during the development planning of Mexico. However, in this general planning law, natural resources protection was only considered to be a legal objective. It did not acquire normative importance until 1946, when the Mexican Conservation of Water and Soil Law was established (INE, 2000).

The 1970s

At the beginning of the 1970s the first law that relates specifically to environmental planning was approved, The Federal Law of Prevention and Control of Pollution. As a consequence, the Environment Improvement Department was created, as an ad hoc institution with responsibility for environmental conservation and restoration.

In 1976, physical planning was established as an instrument of land use regulation in the Human Settlements General Law. This law defines the responsibilities of different government levels in terms of decision-making related to land use (INE, 2000).

The 1980s

In 1982, the Ministry of Urban Development and Ecology was founded. This state department was given responsibility for the physical planning, public infrastructure planning and natural resource management. It also assumed control of protected areas, ecological physical planning and environmental impact assessment. Likewise, the Federal Law of Environmental Protection was published in the same year. This law recognised ecological physical planning as the main medium for nation-wide territorial planning in Mexico (INE, 2000).

In 1988, the General Law of Ecological Equilibrium and Environmental Protection was approved. This law, with its addenda in 1996 is the main legal instrument for environmental policy in Mexico. In terms of physical planning, it establishes that land use planning ought to be based on potential land use (INE, 2000).

The 1990s

In 1992, the Ministry of Urban Development and Ecology was transformed into the Ministry of Social Development. As a part of this ministry were created the National Institute of Ecology and the Office of the Federal Procurator for Environmental Protection as autonomous institutions. Since this date, the National Institute of Ecology has been in charge of the formulation, implementation and assessment of Mexican ecological and environmental policy. In addition, it develops ecological physical planning at a nation-wide scale, in a way coordinated with federal, state and municipal levels and social and private sectors.

In 1994, the Ministry of Environment, Natural Resources and Fisheries was created, in order to concentrate in one ministry the responsibilities for the development and application of environmental laws and standards at a nation-wide scale. Since this date, this ministry has been developing policies related to the rational management of water, fisheries, coasts, wildlife, forests, air and environment (INE, 2000).

Current environmental policies in Mexico

Since 1995, sustainable development has been adopted as the target for the socio-economic development planning in Mexico. The analysis of complex environmental problems and physical planning are tackled under a comprehensive approach that includes economic, social and environmental views.

The 1995-2000 National Development Plan includes in its principles: the achievement of equilibrium among economic growth, environmental protection and quality of life improvement, through the rational management of natural resources and environmental carrying capacity. As part of this plan, the 1995-2000 Environment Program considers ecological physical planning as the main environmental policy instrument to face regional development planning. It identifies the appropriate areas for urban and industrial development, nature conservancy and ecological restoration. It is considered as well the main technical aid supporting decision making about local, regional and national development (INE, 2000). The 2001-2005 National Development Plan has maintained the same environmental policy.

Legal support for physical planning

Physical planning has a legal framework in articles 26 and 27 of the Political Constitution of the Mexican United States; articles 23, 24, 29, 31 and 32 of the Planning Law; in the National Development Plan and the General Law of Ecological Equilibrium and Environmental Protection.

The General Law of Ecological Equilibrium and Environmental Protection defines ecological physical planning as an instrument for environmental policy. Its main objective is related to the regulation or inducement of appropriate land use or productive activities. This is based on the purposes of environmental protection, on the sustainable use of natural resources and on the analysis of the impact of resource mismanagement its and potential for use. This law establishes five basic factors to be taken into account in ecological physical planning (Table 4.5)

Table 4.4 Factors to be taken into account in ecological physical planning in Mexico

FACTORS	
I.	The nature and characteristics of current ecosystems at a nation-wide scale, including exclusive maritime zones.
II.	The potential use of each zone or region based on its natural resources, population distribution and predominant economic activities.
III.	The impact on ecosystem equilibrium caused by urban development, economic activities and natural disturbances.
IV.	The needed equilibrium between human settlements and their surroundings.
V.	The environmental impact of new human settlements, roads and other infrastructure constructions

Source: INE (2000)

Also, in order to guide land use decision-making and the development of policies for the preservation, protection, restoration and management of natural resources, the General Law of Ecological Equilibrium and Environmental Protection establishes five main guidelines for ecological physical planning (INE, 2000):

1) To improve the certainty of land use, based on a legal framework and consensus building.
2) To establish the criteria and strategies for the identification of relevant ecological processes that ought to be maintained in order to achieve sustainable development.
3) To regulate and foster appropriate land uses and productive activities based on the state and potential of natural resources.
4) To promote ecosystem restoration in a frame of reference related to the maintenance of productive activities.

4.5 Conclusions

This chapter has presented a case study research strategy as a way of exploring ecosystem-based management approaches. Emphasis was made on the features of this research strategy that support holistic and flexible characteristics of an ecosystem-based management project. Consequently, this case study is considered an appropriate research strategy to test the proposed methodology, because it allows the adoption of holistic approaches and admits the use of a variety of research methods and sources of data, permitting the test of a possibly true hypothesis.

On the other hand, in this chapter's particular efforts were given to demonstrate that the Iztaccihuatl-Popocatepetl volcanoes region is a typical example of a fragile mountain ecosystem. Also, that its complex problems and management challenges are similar to those faced in other mountain ecosystems around the world. The case study at the Iztaccihuatl-Popocatepetl region was considered from global, ecological and local perspectives and it was concluded that the region is an appropriate area on which to test the proposed methodology.

This chapter also displayed a strong relationship between planning methodology and the case study. The strong relationship between the outcomes of the planning methodology and the work objectives in the case study was emphasized. As a consequence, the potentialities of the designed methodology, when applied to an ecosystem based management planning case, have been demonstrated.

Likewise, this chapter established the considerations of suitability for the purposes of this research. Emphasis was made on:

1. The different interests that explain the choice of this volcanoes region: particular interest of the author, together with institutional and research concerns.
2. The suitability of the landscape/ecosystem for a holistic approach.
3. The complex problems and contexts involved from the global, ecological, regional and environmental planning perspectives.
4. The fragile nature of the Iztaccihuatl-Popocatepetl region as a mountain ecosystem.
5. A broad background associated with the Iztaccihuatl-Popocatepetl region and issues related to environmental policy in Mexico, contemplated as necessary supports for an Ecosystem based management planning approach and for an ecologically sensitive areas delineation strategy.

As a consequence, it was pointed out that the Iztaccihuatl-Popocatepetl case study is a typical and appropriate instance to test the designed methodology in-site.

Chapter 5. Results of the application of the designed methodology in the Iztaccihuatl-Popocatepetl volcanic region case study

5.1 Introduction

The goal of this chapter is to describe how the procedures discussed earlier were applied in practice. The main aim of this chapter is to demonstrate the potential of the methodology to enable the integration of a number of procedures in pursuing different objectives in a realistic ecosystem management planning approach.

This chapter presents the main results of the application of the designed methodology, previously described in general terms in chapter 4. The results are ordered accordingly to the different phases of this methodology. However, as it was indicated in chapter 4, results were only included for the phases of focus, analysis, diagnosis, and partial results for the phase of prognosis. The syntheresis phase was partially considered.

The presentation of results is organised according to a problem-solving approach. The objective question is included prior to the procedures that were carried out, followed by description and analysis of results. Particular emphasis is given to the rationale behind the procedures employed. For this reason, the main criteria that give rise to the selection of procedures are mentioned. A problem-solving approach was selected because it simultaneously involves the description of the problems, the procedures and the results. In this chapter many of the results shown are the procedures themselves.

The methodology was designed as a general one that can be applied in different situations. However, what this presentation of results indicates is that it is necessary to adapt the methods and procedures to reflect specific circumstances. As a consequence, parts of the results are the procedures employed to address these problems and the logic behind their selection. In this respect, the integration of different procedures into the methodology serves to accomplish two fundamental characteristics of a holistic approach: to be flexible and to include different viewpoints and procedures.

This chapter is arranged in four sections according to the phases of the applied methodology: focus, analysis, diagnosis and prognosis. Unlike previous chapters where the different sections were organised around aims, different sections of this chapter are structured about objective questions as a consequence of the application of a problem-solving approach.

The procedures and results displayed in the focus phase section were driven by the following four questions that reflect the objectives of this phase:

1. How can goals be set such that they are not so general nor so specific as to make them difficult to apply in a different case study?
2. How can areas be geographically delineated that are appropriate for an ecosystem-based management approach while their boundaries take into account geographical, ecological, economic, social and cultural criteria?
3. How can appropriate areas be delineated for regional conservation concerns while saving time and money during the phases of analysis, synthesis and prognosis?
4. Which are the most appropriate criteria to delineate ecologically sensitive areas?

Therefore, this section tackles and displays results related to setting goals and objectives in an ecosystem-based management project, defining geographical units through a watershed network approach, delineation of appropriate geographical units for research purposes and selecting the most fitting criteria to delineate ecologically sensitive areas.

In the analysis section, the procedures used to answer these questions are described and the results of this application discussed. The questions that reflect the objectives of this phase are:

1. How can criteria and attributes be integrated into a hierarchical model that reflects a holistic view and the synergy among them?
2. Do criteria/attributes contribute in a similar way to explain the upper level of he hierarchy? If not, how can these different contributions be estimated?
3. How can a GIS database be constructed that is appropriate for the delineation of ecologically sensitive areas, taking into account all criteria/attributes previously described, as well as their relative priorities?
4. How can information from the 1993 and 2000 vegetation cover satellite images be employed in order to estimate regional land-use change during that period?

As a consequence, this section is involved with situations and displaying results related to the construction of a hierarchy with selected criteria, implementing mechanisms for weighting criteria and attributes, building a landscape/ecosystem database and estimating regional land-use change during the period 1993-2000.

The third section is structured around five questions relative to the diagnosis phase.

1. How can the weighting results derived from the application of the Analytic Hierarchy Process procedures be integrated into the delineation of ecologically sensitive areas?

2. How can ecologically sensitive areas be delineated based on biodiversity criteria?
3. How can ecologically sensitive areas be delineated taking into account the three weighted sets of data related to erosion susceptibility to land use, steepness and drainage density?
4. How can ecologically sensitive areas be delineated taking into account data relative to land-use change patterns?
5. How can regional threats to biodiversity protection be defined from policy-making and decision-making perspectives?

Following these questions, this section examines situations and displays results that incorporate the expert choice results into the delineation of ecologically sensitive areas, based on the criteria of biodiversity, landscape fragility and land-use change risk, estimating regional social context having to do with threats to biodiversity protection.

The fourth section is structured around three questions related to the prognosis phase:

1. How can it be determined if the ecologically sensitive areas of the Iztaccihuatl-Popocatepetl volcanoes region have potential for environmental sustainability and sustainable development?
2. How can a network be defined of regional ecologically sensitive areas in the volcanoes region?
3. How can a strategy be constructed to confront the regional threats to biodiversity conservation in a context of environmental sustainability and sustainable development?

Taking into account these questions, this section outlines the prospects for environmental sustainability at a regional scale; it is also concerned with the establishment of a regional network of ecologically sensitive areas and with the construction of a strategy to confront regional threats to biodiversity conservation in a context of environmental sustainability and sustainable development.

Conclusions are finally presented in a general form. This presentation highlights only the main results. The next chapter draws conclusions about the strengths, weaknesses and potential of the general methodology and the different procedures that were carried out.

5.2 Focus phase results

5.2.1 Goal setting procedure

The problem: Undoubtedly, the greatest and most important challenge in ecosystem-based management is identifying goals, because it is common to confuse goals with obstacles (Slocombe, 1998). According to this author, setting goals in an ecosystem-based management project is a complex task. Usually, they should be normative, based on principles, integrative, complex, dynamic, transdisciplinary, applicable, participatory, understandable and adaptive. A simplified explanation of each one of these characteristics is compiled in Figure 5.1.

Table 5.1 Characteristics of goals in an ecosystem-based management project

Characteristic	Explanation
Normative	Reflect specific values and limits
Based on Principles	Reflect "higher values", ethical principles and rules
Integrative	Reflect a wide range of interests, goals and objectives
Complex	Work with, not artificially reduce, complexity
Dynamic	Accept and recognise the inevitability of change
Transdisciplinary	Synthesise a wide range of information and knowledge
Applicable	Be applicable to a wide range of ecosystem types and conditions
Participatory	Involve people and actors
Understandable	Be explainable and operational in a consistent way to different people and groups
Adaptive	Be inherently tentative and evolving as conditions and knowledge change

Source: Slocombe (1998)

The strategy to tackle the problem: To face the complex task of goal setting in an ecosystem-based management project, a four step procedure was designed: targeting, literature support, definition of the viewpoint of the planner and goal proposal.

Targeting step

The aim of this step is to focus on the goal setting procedure to take into account normative, principled, integrative and complex characteristics. For this case study, importance was given to goals related to the conservation and protection of ecologically sensitive areas within a general context of achievement environmental sustainability.

The results:

This step was reached through the application of a hierarchical model as described previously in figure 3.1 (Section 3.2)

As a consequence of using this hierarchy, it was decided to focus only on goals related to the conservation of natural capital in order to give focus to a particular goal related to achieve environmental sustainability.

Literature support step

The aim of this step was to assemble a set of appropriate examples in the literature, in support of the choice of the goals specified at each stage. Particular emphasis was made on regional conservation of natural capital and the criteria set out in Figure 5.1

The results:

This step was accomplished through an analysis of literature on diverse topics about environmental planning and policy, including goals, purposes and land use planning viewpoints in the international and the Mexican environmental management policies as well as the academic landscape planning context.

Agenda 21 (UNCED, 1992) was the main source consulted for obtaining the information related to international environmental management policy. This document was considered in setting the broad context on what should be done in the case study and describes in a general way the main international environmental concerns and general policies used to address them. The literature review was focused on two chapters of this reference: Chapter 13: Managing the Fragile Ecosystems: Sustainable Mountain Development and chapter 15: Conservation of Biological Diversity. The main goals that are identified in these chapters that are relevant to an ecosystem-based management project are summarised in table 5.2.

Table 5.2 Main goals related to a Ecosystem-based management planning project from Agenda 21

Fragile ecosystems protection related	Biodiversity protection related
To undertake a survey of the different forms of soils, forest, water use, crop, plant and animal resources of mountain ecosystems.	To establish appropriate natural reserves in representative species-rich sites and areas.
To generate and maintain database and information systems to facilitate the integrated management and environmental assessment of mountain ecosystems.	To promote the rehabilitation and restoration of damaged ecosystems and the recovery of threatened and endangered species.
To identify hazardous areas that are most vulnerable to erosion, floods, landslide and other natural hazards.	To take action for the maintenance of biological diversity through the in situ conservation of ecosystems and natural habitats.
To improve coordination of regional efforts to protect fragile mountain ecosystems through the consideration of appropriate mechanisms, including regional, legal and other instruments.	To promote and encourage understanding of the importance of the measures required for the conservation of biological diversity and the sustainable use of biological resources at all policy-making and decision-making levels.
To promote integrated watershed development programmes for conserving, upgrading and using the natural resource base of land, water, plant, animal and human resources.	To promote environmentally sound and sustainable development in areas adjacent to protected areas with a view to furthering protection of these areas.
To develop appropriate land-use planning and management for both arable and non-arable land in mountain-fed watershed areas to prevent soil erosion.	Take measures to encourage a greater understanding and appreciation of the value of biological diversity, as manifested both in its component parts and in the ecosystem services provided.

Source: Agenda 21 (UNCED, 1992) modified by the author.

As can be seen, all of them are broad-scope goals that could only be considered a reference point in a general context, but they reflect the international concerns about fragile ecosystems and biodiversity protection. It seems as well that they need a logical ordering because they are expressed as a list of issues to be accomplished and some of them seem to be part of a higher level. However, such ordering is not presented here.

The Mexican environmental management policy review was based on the analysis of Mexican laws related to environmental planning. This review was given in chapter 4. The results are summarised in table 5.3.

Table 5.3 Guidelines to ecological physical planning in Mexico

1	Regional biodiversity conservation is a federal concern in Mexico. Therefore, landscape scale alternatives to protect and maintain the biodiversity of Iztaccihuatl-Popocatepetl region should be discussed and constructed within the top level of management of the Federal Environment Ministry of Mexico.
2	Integrated watershed-ecosystem management is both a federal and state concern. Regulating alternatives to cope with land use change patterns, water shortage, Ecologically Sensitive Areas protection should be developed within the top level of management of the Federal Environmental Ministry of Mexico and the top level of management of Environmental, Rural and Urban Development Ministries of Puebla, Mexico and Morelos states.
3	Appropriate land zoning and land management is a concern of multistakeholders. The elaboration of these tasks should be a main concern of the top level of management of Environmental, Rural and Urban Development Ministries of Puebla, Mexico and Morelos states, municipality staffs and landowners.

Source INE (2000) modified by the author.

This indicates that according to the ecological physical planning law reference in Mexico, ecosystem-based management projects and ecologically sensitive areas protection goals need to reflect the interests of many stakeholders.

The academic landscape planning context was taken into account by reflecting the three main schools of thought in landscape planning, in the opinion of the author,: greenways planning, ecological landscape planning and ecosystem management. Our approach focused on a form of ecosystem-based management. This analysis focuses mainly on the ideas on landscape planning associated with these schools of thought, their planning purposes and type of goals. The results are shown in table 5.4.

Table 5.4 Academic landscape planning context for goal setting

Planning schools of thought	Purpose	Type of goals	Main ideas related to landscape planning
Greenways planning	To regain public access to natural areas through the planning, designing and management of a multipurpose landscape	Biodiversity related Water resource related Recreational and cultural related Urban development control related	Landscape as a linear-network spatial configuration Linked and multifunctional landscapes as planning targets Planning consistency with sustainable development
Ecological landscape planning	To develop ecological principles to achieve optimum land use and environmentally friendly technology	Biodiversity related Water resource related Natural and cultural resources related Urban development-technology control related Man's environment preservation related	Landscape as the defined territory unit to be planned Multi-functional landscapes under environmental carrying capacity thresholds as planning targets Planning consistency with sustainable development
Ecosystem management	To manage areas at various scales, in order to preserve services and natural resources from ecosystems	Biodiversity related Ecosystem dynamics-equilibrium related Adaptive management related	Sustainability as a precondition for management Broad spatial and temporal scales Collaborative decision building Organisational change Adaptive management

Ecosystem-base management	To manage the activities within the ecosystem to protect native integrity over the long term, dealing with sufficiently large spatial areas, whether they are regions, greater ecosystems or landscapes.	Biodiversity related Ecosystem dynamics-equilibrium related Adaptive management related Ecosystem services and natural resource preservation related	Landscapes as large spatial areas (regions, greater ecosystems or landscapes) Planning success comes through the maintenance or restoration of ecological functions associated with those landscape units Defines the ecosystem naturally, e.g. bioregionally, instead of arbitrarily Recognizes goals and taking an active, management orientation; Uses an anticipatory, flexible, research and planning process Recognizes systemic limits to action---defining and seeking sustainability

Sources: Slocombe, 1993, 1998; Grumbine, 1994; Kay, and Schneider, 1994; Fabos and Ahern, 1995; Fabos 1995; Ahern, 1995; Christensen, et al., 1996; Miklos, 1996; Zigari, 1996; Yaffee, 1999.

The examination of results from academic origin proved to be the richest source for ideas to be applied in goal setting. Some of them are worthy of particular comment in terms of common concepts. It seems to be that the concepts of multi-functional, multi-purpose landscape-regions are a basic idea for setting goals at a regional planning level. Also, that this basic idea of regional planning should be consistent with sustainable development. As a consequence of sustainability being a precondition for management, broad ranges of ideas arise for goal setting. The most important idea seems to be the need to plan at broad spatial and temporal scales, the improve need of collaborative decision building and the initiation of organisational change and adaptive management (Grumbine, 1994; Kay, and Schneider, 1994; Christensen, et al., 1996; Slocombe, 1993, 1998, Yaffee, 1999).

Summarising the results of this step, it seems to be clear that the goal setting for this case study has to reflect the international concern on fragile ecosystems and biodiversity protection. Also the possibility should be considered of designing the system using a scheme that involves multistakeholders. Finally, the goal setting process has to take into account issues related to its consistency with sustainable development, such as multifunctional broad regions, collaborative decision building, organisational change and adaptive management.

Defining the viewpoint of the planner

The aim of this step was to identify the role and the related viewpoint of a landscape/ regional planner who is seeking to address the development versus conservation complex problem in the Iztaccihuatl-Popocatepetl volcanoes region.

The results.

Considering the need to focus on the diverse roles that a planner could play, as analyst, promoter or catalyser, and builder of plans, it was decided to propose a role of planner based on two activities: designing conservation-development plans at different temporal and spatial scales and enhancing the involvement of multistakeholders, at different organisational scales to achieve them.

Trying to pursue this role the author seeks to integrate issues considered in the guidelines for physical planning in Mexico and the academic landscape planning context described in Tables 5.3 and 5.4. On the contrary, the general goals from Agenda 21, displayed in Table 5.2 were only considered to be of secondary importance and are not accommodated explicitly.

Defining the viewpoint of the planner.

The aim of this step was to identify the role and the viewpoint of a landscape/regional planner who is seeking to address the complex problem of development and conservation in the Iztaccihuatl-Popocatepetl volcanoes region

The results:

It was decided to focus on the role of plan builder. Thus, emphasis was given to two activities: designing conservation-development plans at different temporal and spatial scales and enhancing the involvement of multistakeholders, to implement this at different organisational scales.

First of all, it is important to make clear here, that the author assumes the role of the planner as already defined. Therefore, it is suggested that there is a need for a landscape plan based on ecologically sensitive areas that could play the role of a trigger mechanism. The main idea is to design a plan to involve the different Mexican Government agencies in a regional effort to protect the Iztaccihuatl-Popocatepetl volcanoes landscape. This purpose is based on two premises:

1. Yaffee et al. (1995) reported that the success of ecosystem management projects has been to a great extent associated with government initiatives, which often means that they have received funds and technical support.
2. The responsibility and duty of federal and state government in Mexico for the set of issues relevant to this case study, namely fragile mountain ecosystems protection, regional biodiversity conservation, ecologically sensitive areas protection and integrated watershed-ecosystem management.

Also, this author supports the idea that the landscape/regional planning approach should be guided by the following planning principles:

1. Planning should be consistent with sustainable development and environmental sustainability as a precondition for management.
2. Landscape as a defined territory unit (considering large spatial areas, such as a regions or greater watershed-ecosystems) to be planned, recognising that planning success comes through the maintenance or restoration of the ecological functions associated with those landscape units.
3. Linked and multi-functional landscapes should have environmental carrying capacity thresholds as planning targets.
4. A planning process that encourages collaborative decision building, organisational change and adaptive management.

Goal proposal

The aim of this step was to integrate the planner's viewpoint in goals that were, neither so general that they would become meaningless nor so specific that it would difficult to generalise the results for their application elsewhere. In this particular emphasis is given to the method.

The results:

Three general goals were selected and a hierarchical approach was applied in order to establish the organised relationships between them. Thus, the goals were arranged as Figure 5.1 shows:

Figure 5.1 Selected goals for the Iztaccihuatl-Popocatepetl volcanoes region case study

General goal: To improve coordination of regional efforts at all policy and decision-making levels, for promoting, encouraging and understanding the importance of the measures required to protect the Iztaccihuatl-Popocatepetl volcanoes region/landscape and for the conservation of its biological diversity.

Sub-goal 1: To promote integrated watershed management programmes for conserving, upgrading and using the regional natural resources base.

Sub-goal 2: To encourage the development of a planning culture among multistakeholders and municipality based on promoting appropriate land-use planning and management in the volcanoes region

5.2.2 Defining geographical units through a watershed network approach

The problem: How can areas be geographically delineated that are appropriate for an ecosystem-based management approach so that the boundaries take into account geographical, ecological, economic, social and cultural criteria?

The results:

A watershed network approach was adopted in this case study.

This procedure was accomplished through a division of the Iztaccihuatl-Popocatepetl region into basins, watersheds and sub-watersheds. The reasons for the use of a watershed network have been explained in chapter 3. However, a brief summary of the main criteria that justify the employment of the watershed network approach from a holistic viewpoint is given in Table 5.5

Table 5.5 Main criteria that justify the employment of the watershed network approach

Criterion	Watershed characteristic
Functionality	The watershed is a functional region established by physical boundaries and water interrelationships.
Biophysical linkage	The watershed network approach is appropriate for evaluating the different biophysical linkages between upland and downstream.
Holism	The watershed network approach permits holistic views, which enable planners and managers to consider many facets of the management of watershed-ecosystems and natural resources.
Environmental impact	Land-use activities and upland disturbances often result in a series of environmental impacts that can be readily examined within the watershed network context.
Economics	The watershed network approach has a strong economic logic. Many of the externalities involved in alternative land management practices on an individual parcel are internalised when the watershed is managed as a unit.
Socio-cultural	The watershed network approach provides a framework for analysing the effects of human interactions with the environment. The environmental impacts within the watersheds operate as feed back loops to consider changes in the cultural system.
Management Compatibility	The watershed approach can be integrated with or be a part of programs including forestry, soil conservation, rural and community development and farming systems.

Source: Adapted from Steiner et al. (2000)

As a summary of the above criteria, in terms of landscape planning, a watershed network provides a holistic framework to understand a place, because it reveals interconnections, so that relationships between biophysical and socio-cultural processes can be revealed. It is also a guide to improve planning efforts and intergovernmental coordination and management of ecosystem-based projects, such as the conservation and protection of regional ecologically sensitive areas.

The watershed network approach applied in the case study allowed the delimitation of the basins of which the Iztaccihuatl-Popocatepetl region is a part, as the watersheds that were formed from their glaciers and associated watercourses. For the process of delineation, a set of maps, scale 1:250 000 was employed of the basins and watershed limits and regional hydrology (INEGI, 1995). This set of maps was digitised using geographical information systems software: ILWIS 2.1. The results were already displayed in chapter 4 when the hydrology of the region was described. The distribution of the watersheds is displayed in Maps 4.1 and 5.1.

5.2.3 Delineating the limits of the region under study.

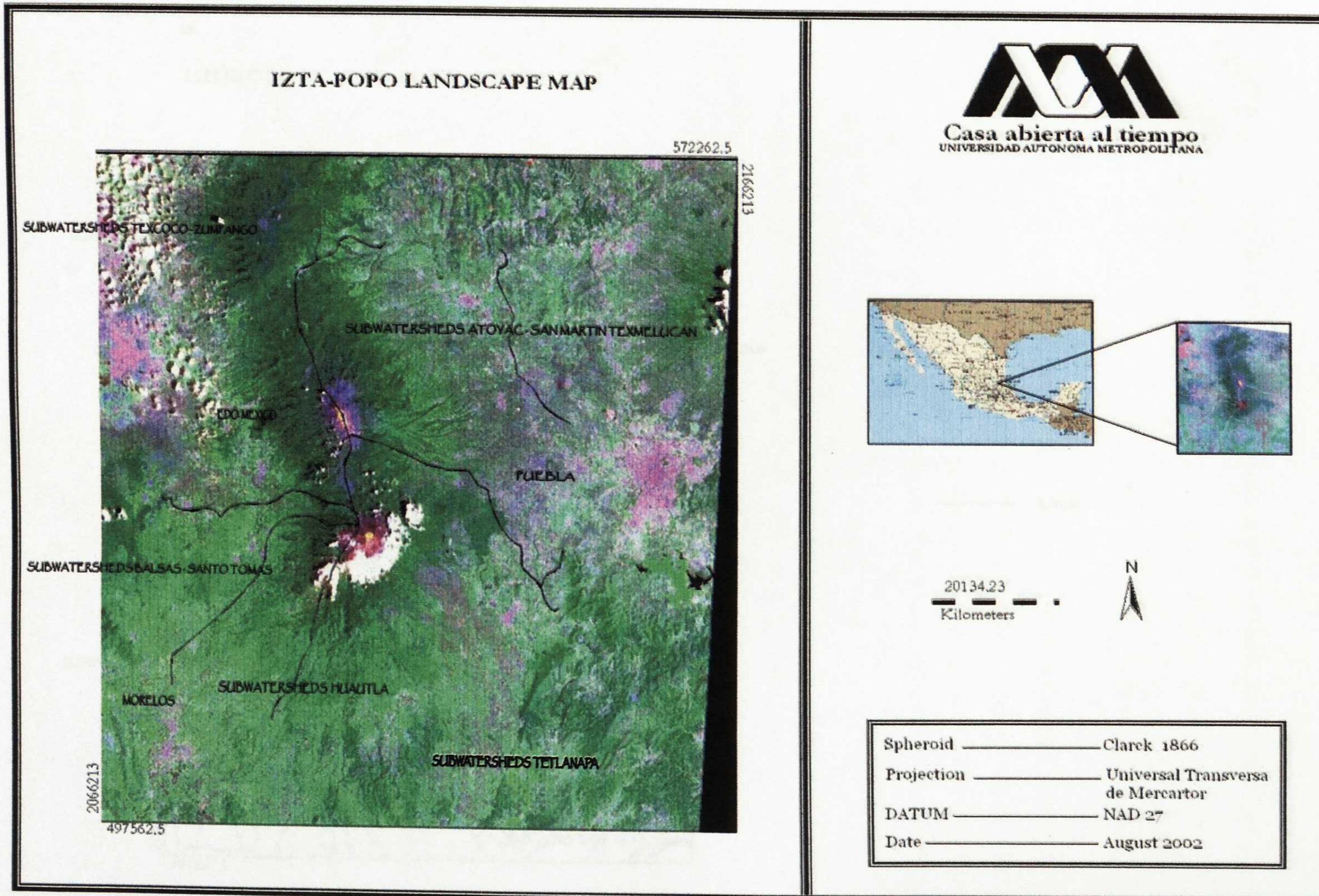
The problem: How to delineate an appropriate area for regional conservation concerns while saving time and money during the phases of analysis, synthesis and prognosis.

The results:

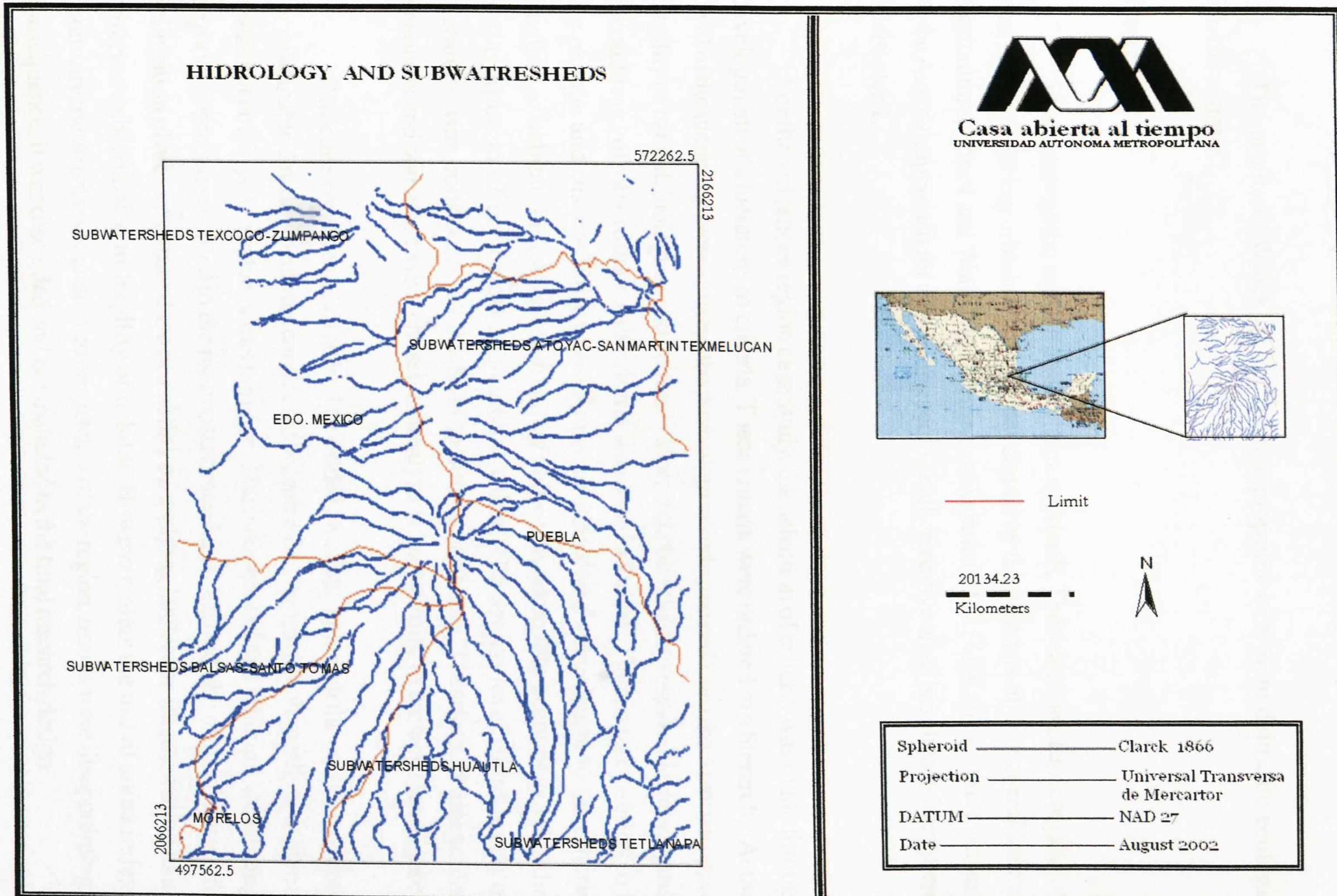
This task was carried out employing two criteria: a matter of convenience and hydrological altitude zoning. A matter of convenience criterion is related to two aspects; one of them was the appropriateness of nature conservation and another associated with the convenience of considering a small area to save time and money. This last point, implied making a decision about the size of the area under study. The alternative was: include the whole area, which means the analysis of a region of about 14 733 Km^2, or a smaller region including only the upper watersheds. It was finally chosen to analyse only the upper watersheds, because this was consistent with the idea of appropriateness for nature conservation and with a small area.

The problem of the delineation of the upper watersheds was tackled utilising the hydrological altitude zoning criterion. This criterion is based on the origin of water and on geomorphological genetics. According to this criterion, the volcanoes region includes five zones: glacier zone, glacier-pluvial erosion zone, fluvial erosion zone, intensive erosion zone and deposit zone as described in chapter 4. As a result of the application of this criterion, it was decided to include in the upper watersheds only the glacier zone, glacier-pluvial erosion zone, fluvial erosion zone, and the intensive erosion zone. This implied choosing the area above the 2 500 meters sea level. For this purpose, a digital terrain model using a set of topographic maps of the region was developed (INEGI, 1995). This set of maps was digitised using a geographical information system: ILWIS 2.1. The digitisation procedure was made including contour lines at 100 meter intervals. The limits of this area under study are illustrated in Map 5.2 and amount to around 6 259 Km^2.

Although this procedure accomplished the proposals to reduce the area under



Map 4.1 The Subwatersheds of the Iztaccihuatl-Popocatepetl region.



Map. 5.1 Hidrology and subwatersheds of the Iztaccihuatl-Popocatepetl region.

study and focus on the regional conservation problem, it also limited the landscape/ regional perspective needed for the prognosis phase.

5.2.4 Selecting appropriate criteria to delineate ecologically sensitive areas

The problem: Which are the most appropriate criteria to delineate ecologically sensitive areas?

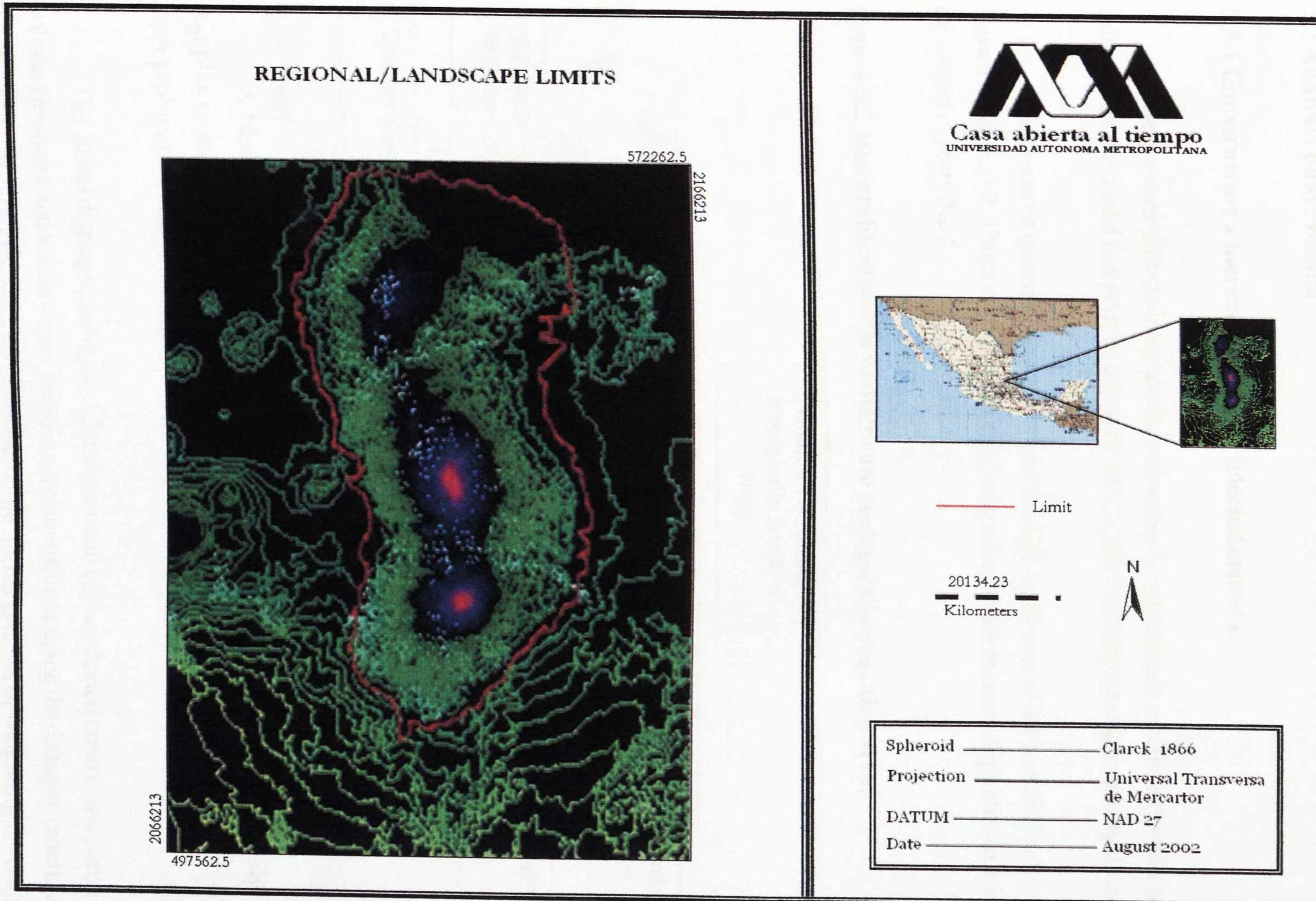
The results:

This involved the use of a multicriteria approach. The selection of appropriate criteria was based on the key criteria catalogue developed by the planners of the Federal Ministry of Agriculture, Forest and Water Management of Austria (BMLFUW circa, 2000). An analysis of the Austrian approach for delineating ecologically sensitive areas has already been presented in chapter 1.

For the volcanoes region case study, the selection of criteria was made through the development of a hierarchy of criteria. These criteria were ordered in a hierarchy. At the first level of the hierarchy were situated the three main criteria derived from the Austrian approach: fragility of habitat, biological and cultural value, and potential for sustainable development. A second level of subordinate sub-criteria was also included. Thus, susceptibility to land-use change and susceptibility to erosion were considered subordinate to the criterion of fragility of habitat. Likewise, biodiversity value was taken into account as subordinated to the criterion of ecological and cultural value. The lowest level (third level) of the hierarchy was considered as the level to situate attributes. Therefore, drainage density, steepness and soil cover were chosen to analyse susceptibility to erosion (see Figure 5.2).

Particular considerations should be made here. First, although the criterion of potential for sustainable development was considered valuable for choosing ecologically sensitive areas, it was not employed to achieve this purpose. The indicators of this criterion were thought to be more appropriately used in the prognosis procedures. Second, the original design for the delineation of areas examined the possibility of applying landscape fragmentation as a third criterion subordinated to fragility of habitat. However, after the use of some indexes of connectiveness in the vegetation cover patches of the region, results were disappointing. As a consequence, it was discarded and not included in the final research design.

As it can be seen, conservation concerns predominated in the selection of criteria. Mainly those threats associated to fragility of habitat and biodiversity value. Particular



Map 5.2 The limits of the area under study.

emphasis was also made on the ecosystem-based concerns of erosion and vegetation cover loss.

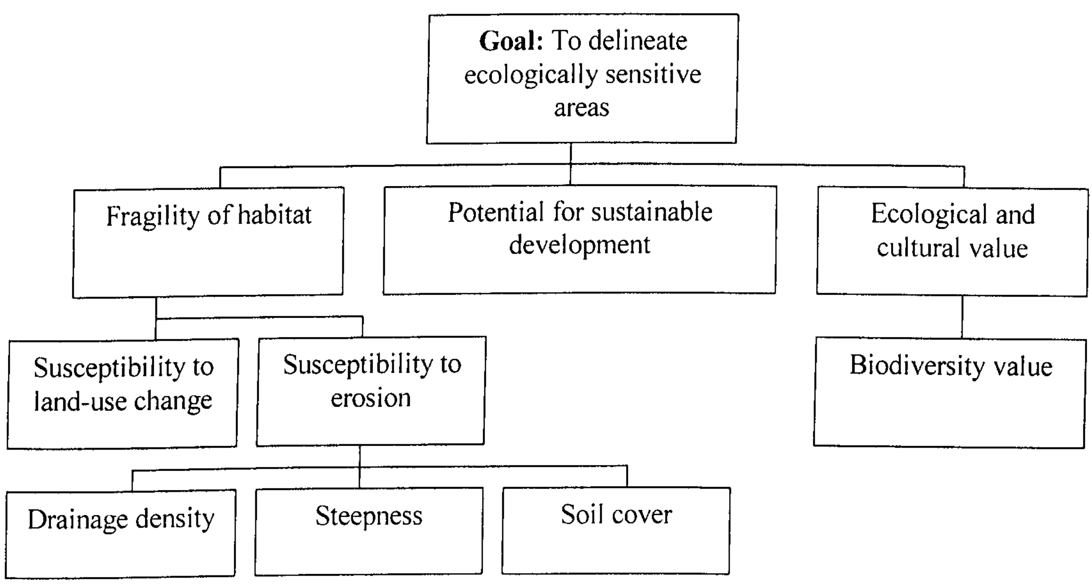
5.3 Analysis phase results

5.3.1 Constructing a hierarchy with the selected criteria.

The problem: How to integrate the main criteria, subordinate criteria and attributes in a diagrammatic model that permits a holistic view and reflects the synergies among them.

This research question was answered through the design of the hierarchical model shown in figure 5.2. This model was designed according to the relationships among criteria described in point 5.2.5

Figure 5.2 Hierarchical model to delineate ecologically sensitive areas



A hierarchy as a model was chosen because of its advantages for analysing complex problems and displaying the synergies among different components involved in such problems. These characteristics were already reviewed in chapter 2.

The model displayed in Figure 5.2 integrates all of the selected criteria and permits a holistic viewpoint and a clear image of the interrelationships among the different criteria and the attributes. This model provides the basis for the further process of weighting the criteria and the attributes.

5.3.2 Implementing mechanisms for weighting criteria and attributes.

The problem: How can all criteria/attributes contribute in a similar way to explain the upper level in the hierarchy? If not, how can their different contributions be estimated?

The results:

The above research questions are classical in the Analytical Hierarchy Process and they are the key for developing the main procedures of this analytical process. The Analytical Hierarchy Process and related expert choice processes have already been reviewed in chapter 2. For this case study, these procedures were applied to weight the attributes related to the erosion susceptibility criterion.

The choice of Analytical Hierarchy Process procedures for this purpose was due to the need of a viewpoint by experts, about the different contributions of steepness, land-use cover (pine forest, fir forest, urban soil cover etc.) and drainage density in the erosion process. In terms of erosion susceptibility, there are generally not enough empirical data to estimate the role the different criteria-attributes play in the control of soil erosion. This lack of information is a common obstacle to defining and delineating areas under different values of erosion susceptibility. This obstacle is often overcome by consulting experts, and for this case study, a consultation was designed in order to calculate relative priorities using an expert choice procedure. Accordingly, an expert choice procedure was followed to assess susceptibility to erosion. The procedure was carried out through 6 steps: design of the procedure, selection of experts, selection of the basic information to be given to the experts, establishing and explaining the procedure, processing the raw data.

Designing the expert choice procedure

The aim of this step was to design an expert choice procedure under the restrictions of the experts' willingness to participate.

The procedure was designed in order to obtain a relative weight for the different attributes used to assess susceptibility to erosion, and to determine the relative weights of different soil covers with respect to their contribution to this criterion. The premise for this weighting exercise is that this set of attributes does not contribute equally to the criterion. The original design had contemplated an expert pairwise comparison method using the fundamental scale for pairwise comparisons designed by Saaty (1995), showed in table 5.6. The experts had direct access to the EXPERT CHOICE 9 software, in order to facilitate the pairwise comparisons and were continually informed about the consistency of their judgments. Finally, the experts would supply a preference vector as data for a later calculation of average priorities. However, this procedure was modified because in a previous test with some colleagues at the Metropolitan University, the use of the EXPERT CHOICE 9 software was too complicated for the experts and they were not willing to spend the amount of time required. Thus, a "dominance gradient" was invented in order to obtain raw data for the average priority calculation through the employment of EXPERT CHOICE 9 software. Two premises led the design of the "dominance gradient": 1) saving time and easing the participation of experts, and 2) maintaining a high degree of consistency in the judgments of experts.

It is important to stress here the importance the consistency of judgments has in pairwise comparisons. First, the value of consistency measures the degree of coherence in the judgments during a pairwise comparison exercise. This means that a good decision cannot be supported by judgments with a low consistency value, which seems to reflect random choices. Second, in pairwise comparisons, coherence is not a problem when only two attributes are compared, yet as the number of attributes increases, as so does the number of pairwise comparisons does so too, and as a consequence, the probability of losing judgment consistency rises too.

The "dominance gradient" seeks to maintain this consistency based on a linear arrangement of the attributes. This arrangement is based on the fundamental scale for pairwise comparison of Saaty (1995). It is constructed by locating the numbers of the Saaty's scale in sequence (see Table 5.6). Then, the most extreme criteria/attributes with respect to the achievement of an objective are situated at the ends of the scale, i.e.1 and 9. For example, in this case, different soil covers (natural vegetation cover, grasslands, agricultural lands and urban-bared soil cover) were compared with respect to their contribution to susceptibility to erosion. Thus, natural vegetation cover was located at number 1 of the scale, as the class with the lesser contribution. In contrast, the urban-bare soil cover was situated at number 9, as the category with the most important contribution.

Afterwards, the rest of the criteria/attributes were arranged along the line, according to a classical nearest-neighbour exercise. This placing the remainder of the sub-criteria/attributes in line with their most similar soil cover. Following the example already cited, agricultural land cover is more similar to an urban-bare soil cover than a natural vegetation cover, thus it was generally located at number 7 of the scale

Subsequently, the results of the different "dominance gradients" derived from the experts were employed as raw data for two procedures. First, to define an "average dominance gradient", calculating the average values for each land cover class and then rounding them off. Second, to use this "average dominance gradient" as the source for a pairwise comparison exercise in order to calculate the priorities vector and the degree of consistency with the of EXPERT CHOICE 9 software.

Table 5.6 Fundamental scale for paiwise comparisons.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgment strongly favour one activity over another
7	Very strong importance	An activity is favoured very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is the highest possible order of affirmation

Source: Saaty (1995)

Selection of experts

The aim of this step was to integrate a set of experts. The criterion that led this choice was that they should be familiar with the problem or situation in question

For this case study, a set of six academic experts from Mexico City, related to hydrology and forest ecosystems ecology were invited to carry out the expert choice procedure. They were willing to participate but over a short-time period.

Selection of the basic information to be given to the experts

The aim of this step was to provide the experts with the minimal, but most significant information to support their judgements.

The selection of basic information was guided by two criteria: briefness and purpose.

Decision-making was thus over a selection of some key extracts of the classical work on patterns and processes in a forested ecosystem by Bormann and Likens (1979). Particular emphasis was given to a table that shows the relationship between different land-uses and their derived loss of soil. In terms of the Analytical Hierarchy Process only the fundamental scale was selected (see Table 5.6) and the relationship between the numerical and the nominal scale was explained to the experts. Finally, a brief explanation of the rationale behind the selected criteria (soil cover, steepness and hydrological density) was also included.

Establishing and explaining the procedure

The aim of this step was to design a format that could facilitate the expert choice exercise.

For this purpose, a meeting format was designed, including the characteristics of the session, its objectives and aims, and the procedures to be employed. A session was booked and the basic information and the meeting format were sent two weeks in advance. It was designed as a short time session because of the time of the experts. The following basic key questions were used for the experts to focus on: Which criteria or attribute has a major contribution on erosion? Which criteria or attribute has a minor contribution on erosion? How would you arrange, in order of importance, the remaining sub-criteria or attributes in terms of their contribution to soil erosion?

Also, the procedure of using the "dominance gradient" was explained in detail. Originally, it was planned as an individual exercise, but experts ended up working as a team. Thus, they drew the "dominance gradient" on a blackboard and constructed a consensus view of the arrangement of the different degrees of contribution to erosion susceptibility.

Processing raw data

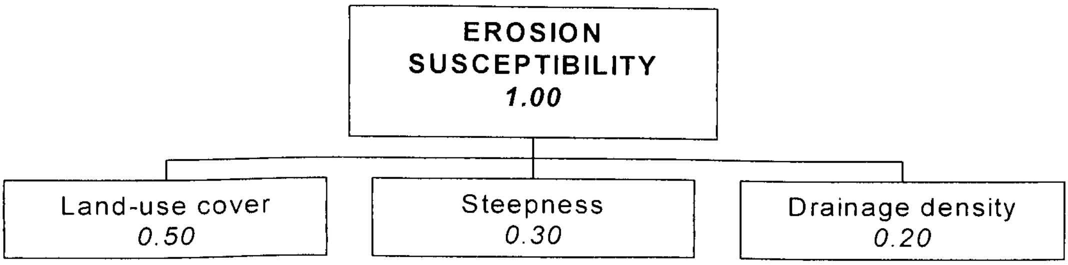
The aim of this step was to calculate the judgment consistency value and the priorities vector. Thus, the calculation was achieved through pairwise comparisons using the EXPERT CHOICE 9 software. The consensus built about the "dominance gradient", already described, saved time and work in the "average dominance gradient" calculation.

The pairwise comparisons were facilitated through the use of the "dominance gradient", because the calculation of the priorities of each sub-criteria or attribute was based on the difference between the numbers in the fundamental scale. For example, the priorities difference, in terms of contribution to erosion susceptibility, between bare-urban cover, located at number 9 and natural vegetation cover situated at number 1 was 8 units.

In addition, the results of the employment of the "dominance gradient" gave place a high value of the consistency of the judgments of the experts, above 98 %.

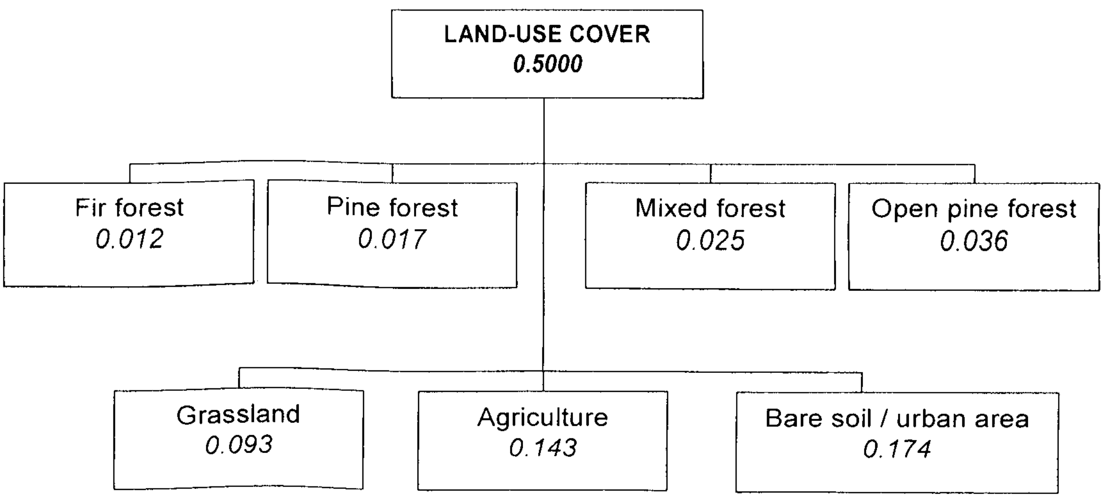
The priorities vector was calculated next. This vector describes the standardized proportional values of the different criteria or attributes. For this case, the "ideal synthesis" procedure to calculate the eigenvector was selected. The values of this eigenvector (priorities vector) are fundamental for weighting data layers derived from applying GIS procedures. The values of calculated vectors are shown in figures 5.3, 5.4, 5.5 and 5.6. In each case the weights associated with individual criteria, add up to the weight associated with the criterion at the high level.

Figure 5.3 Priorities of contributions to susceptibility of erosion from land cover, steepness and drainage density



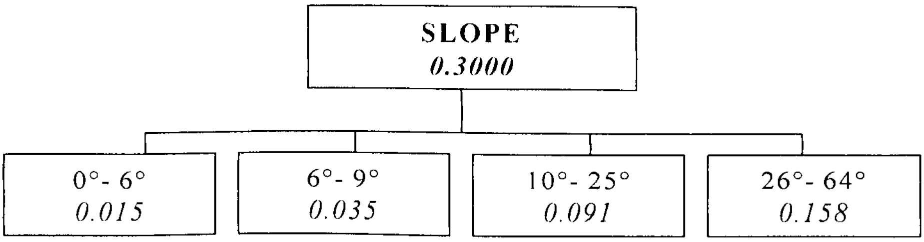
The most remarkable aspect of this figure is the importance that experts gave to land-use cover. It accounts for half the set of criteria employed to assess susceptibility to erosion. This fact had a significant influence on further results. It is important to stress here the influence that the table of loss of soil under different land-uses, provided as basic information, had on the judgements of the experts.

Figure 5.4 Priorities of contributions to susceptibility of erosion from different land-use cover types



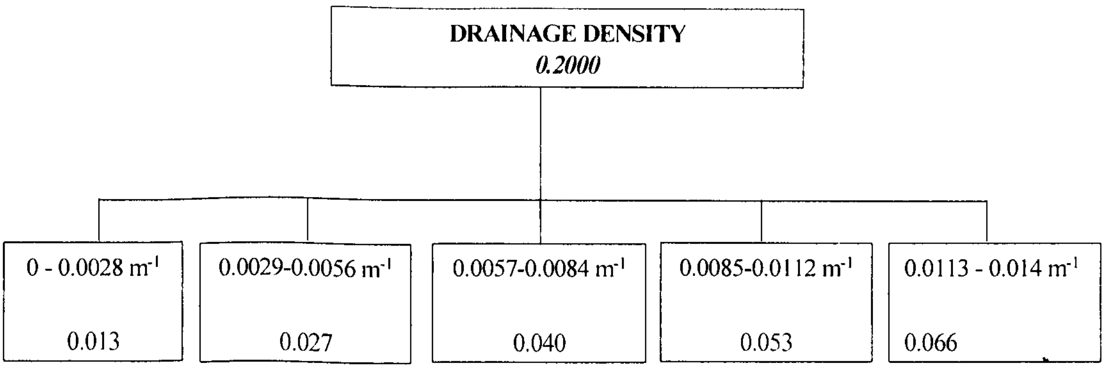
The results of this table show the enormous differences, as given by the experts, between natural areas and those influenced by human activities. This difference is almost of logarithmic order. Here again, the influences that human land-uses have on loss of soil explain these results.

Figure 5.5 Priorities of contributions to susceptibility of erosion for different steepness ranges



These results do not show a significant pattern and they follow an almost linear relationship. This is probably explained because the experts were familiar with the scale proposed by van Zuidman (1986) to relate steepness ranges and a nominal scale that relates to erosion susceptibility (see table 5.6).

Figure 5.6 Priorities of contributions to susceptibility of erosion for different drainage density ranges



The results follow a linear relationship, because it was assumed that there was such a relation between drainage density and the degree of contribution to erosion susceptibility. Also, it is explained by previous knowledge of the experts of a relationship between the different ranges of drainage density and a nominal scale of susceptibility to erosion (see table 5.6).

5.3.3 Building a landscape/ecosystem database

The problem: How to construct a data base appropriate for the delineation of ecologically sensitive areas, considering all criteria/attributes previously described as well as their relative priorities.

The results:

In order to tackle this research question a GIS-based procedure was designed to construct a database of the Iztaccihuatl-Popocatepetl region. This procedure had three main steps: entering information into a GIS, selecting the appropriate GIS procedures and deriving secondary data. The aim of this step is to choose the main data sources to be accessed by the GIS software.

The sources of primary information employed to build the spatial database were:

Selecting information for a GIS

1. A topographic map, scale 1:50 000 with a UTM projection (INEGI, 1996).
2. A hydrological map, scale 1:50 000 with a UTM projection (INEGI, 1996).
3. A basin and watersheds limits map, scale 1:250 000 with a UTM projection (INEGI, 1996).
4. Two LANDSAT TM satellite images, taken during the summer season in 1993 and 2000, both with a resolution of 30 m.

Selecting the appropriate GIS procedures

The aim of this step was to choose the basic GIS procedures to be employed in the construction of the database of the volcanoes region. The GIS procedures and different GIS software employed to construct the database were:

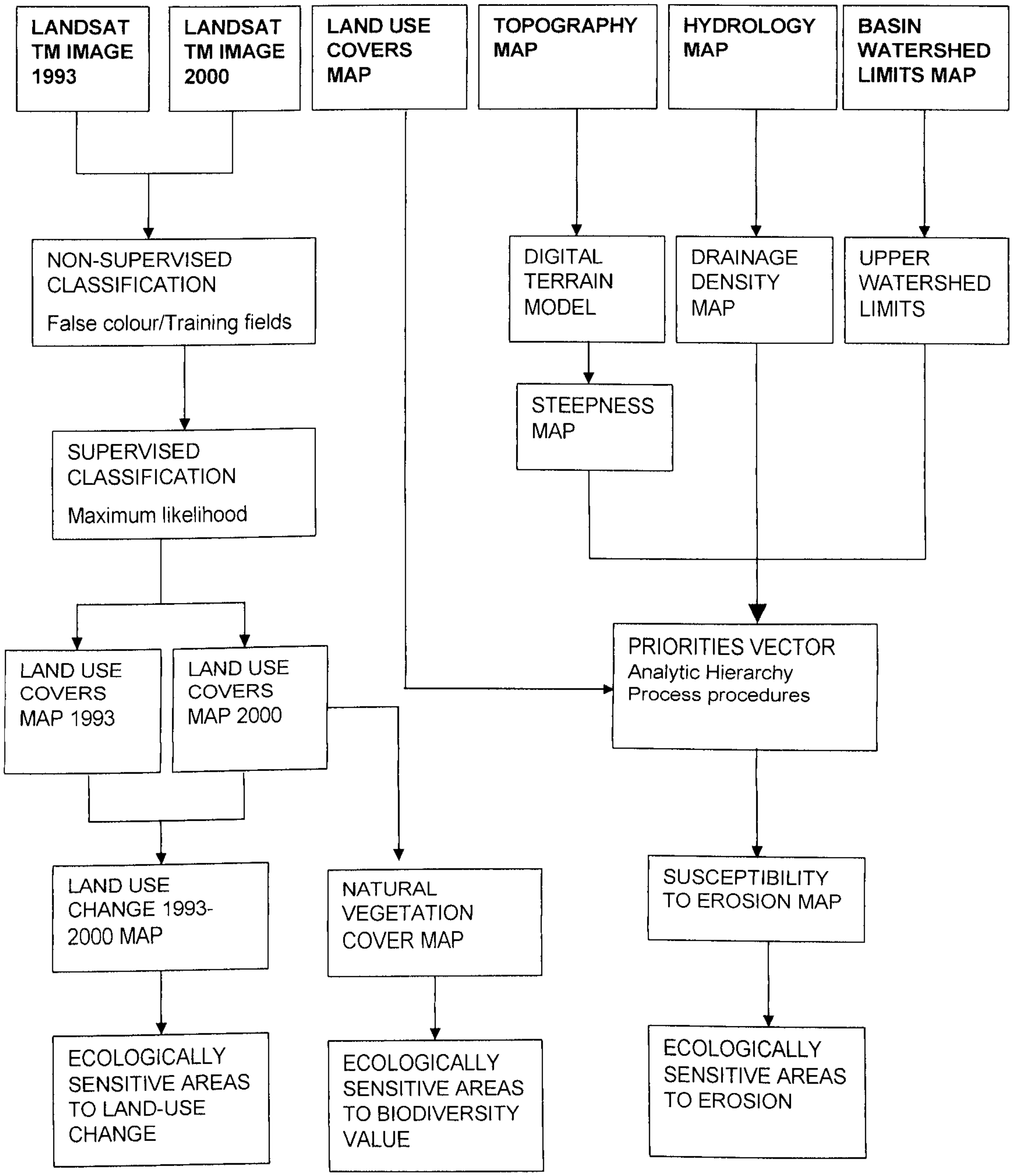
1. Digitisation. For accessing and correcting primary data the GIS software ILWIS 2.1 was employed.
2. Analysis and modelling of spatial data. For analysis, modelling and transformation of spatial data the GIS software IDRISI 32 was used.
3. Map editing. For map editing the software ARCVIEW 2.0 was utilised.

Deriving secondary data

The aim of this step was to process primary information in order to delineate ecologically sensitive areas in the Iztaccihuatl-Popocatepetl volcanoes region.

The description of the entire process for gathering the different data layers, or cartographic model, is showed in figure 5.7.

Figure 5.7 Cartographic model



A brief description of each procedure is given as follows:

1. Digital terrain model. The digital terrain model was obtained employing the topographic map, described above. The contour lines were digitised at 100 meter intervals. This data layer was the basis for the derivation of the steepness classes data layer.
2. Steepness classes data layer. This map was the result of the application of an equation for estimating slopes, to the digital terrain map. The slope is calculated as a tangent of an imaginary line between the lowest and highest height values. For each pixel, the estimation of the slope was based on the following equation

   Where:

Tan_slope	Tangent-slope
Right	Height value of the right píxel
Left	Height value of the left píxel
Res	Map scale
Top	Height value of the pixel above
Bottom	Height value of the pixel low

Subsequently, are resulting multiple slopes class map was classified through the application of a cluster analysis, which enabled steepness to be related to susceptibility to erosion, following van Zuidman (1986). The ranking of steepnesses is shown in Table 5.7.

Table 5.7 Relationship between steepness rank and erosion susceptibility

Steepness class	Erosion susceptibility
0-6	Insignificant
7-9	Moderate
10-25	Strong
26-64	Very strong

Source: Adapted from van Zuidman (1986)

The main result was a steepness class data layer.

3. *Land use and vegetation cover map.* In order to obtain this map, a classification procedure was applied to the LANDSAT TM images. This procedure mixed two approaches: hard and fuzzy classifications.

An initial procedure was to correct for geographical reference the satellite LANDSAT. The hard approach was based on the use of a non-supervised classification. This classification consisted of the application of a cluster analysis, employing a combination of bands 4, 5 and 7 of the satellite images. The result was an image composed of 15 categories of land use cover over which false colour was applied.

Afterwards, these land use categories were corroborated with "ground truth" information from previously existing data on soil cover and a series of field trips to the area under study. The result was the definition of spectral signatures of different land use classes and the development of "training fields" for a supervised classification.

This supervised classification provides a basis for the fuzzy approach. First, a fuzzy classification was applied in order to improve the land use classification previously obtained. It consisted of an analysis of maximum likelihood, based on the development of different data layers to improve the differentiation among land cover categories. For this research, a NDVI (Normalized Difference Vegetation Index) data layer plane and other three false colour images were developed.

Later, these data layers were overlaid, in a selective way, onto the previous 15-class classification employing the GIS software IDRISI 32. The result was the identification and location of 11 land-use classes from both satellite images.

For the 1993 and 2000 LANDSAT TM satellite image the following classes were identified. Fir forest, pine forest, open pine forest, mixed forest, grassland, agricultural lands, urban cover, bare soil, clouds, water and snow. Finally, these land-use categories were arranged into 7 classes to estimate land-use change in the period from 1993 to 2000. These classes were: fir forest, pine forest, open pine forest, mixed forest, grassland, agriculture lands and urban-bare soil. The result was the 1993 and 2000 vegetation cover class data layers.

4. *Drainage density classes data layer.* This map was constructed based on a hydrological map, at a scale of 1:50 000 with a UTM projection (INEGI, 1996). The permanent and temporal watercourses of the area under study were digitised. This data layer was captured in a vector format.

The drainage density was estimated as follows. First, a regular 100 m grid was created and overlaid on the hydrology map using AUTOCAD. Afterwards, this data layer was printed and the length was measured of the different watercourse segments in each 100 x 100 m square cell. The result was a drainage density data set, which was input into the GIS software IDRISI 32.

Finally, this data layer was classified through the application of a cluster analysis employing five drainage density classes and their respective relationship with a nominal scale based on the fundamental scale of Saaty (1985) (see Table 5.8).

Table 5.8 Relationship between drainage density and erosion susceptibility

Drainage density rank (m/ha)	Erosion susceptibility
0-0.0028	Insignificant
0.0029-0.0056	Moderate
0.0057-0.0084	Strong
0.0085-0.0112	Very strong
0.0113-0.014	Extremely

The main result was a drainage density class data layer

5.3.4 Estimating regional land-use change during the period 1993-2000

The problem: How to employ the 1993 and 2000 vegetation cover class data layers, in order to estimate regional land-use change during the period 1993-2000.

The results:

The estimation of regional land-use change was calculated through the development of a GIS procedure that gave particular emphasis to the loss of natural vegetation cover. Mainly, this loss occurs from natural vegetation cover to agricultural soil cover and to bare-urban soil cover.

First, the limits of the 5 sub-watersheds (only the upper watersheds) were digitised in a vector format. This data layer was overlaid over the 1993 and 2000 LANDSAT TM satellite images. This procedure was applied in order to analyse each watershed separately.

Second, the 2000 LANDSAT TM satellite image was reclassified, based only on the agricultural soil and bare-urban soil cover classes.

Third, the 1993 LANDSAT TM satellite image was reclassified, based only on the land-use classes related to natural vegetation. The remaining classes were fir forest, pine forest, open pine forest and mixed forest.

Fourth, this new data layer was overlaid over the 2000 LANDSAT TM satellite image to define the areas where there was loss of natural vegetation soil cover. Subsequently, those areas that suffered such a change were delineated.

The result was a new data layer that was titled natural forest vegetation cover change.

Fifth, the surface value and percentage of change were calculated at both the regional and sub-watershed scales. The results are shown in table 5.9.

In contrast, the results in land-use change for each sub-watershed area shown in tables 5.10, 5.11, 5.12, 5.13.and 5.14 respectively.

Table 5.9 Regional land-use change pattern (1993-2000)

Land-use change	**Net change (Km^2)**	**Percentage of change**
Natural vegetation cover to bared soil-urban cover	291.84	4.5%
Natural vegetation cover to agriculture cover	795.95	12.37%
Total	1087.8	16.9 % (rounded)

The results at the regional level, show a loss of about one sixth of the total vegetation cover above the 2 500 meter contour. More that two thirds have become agricultural land and to a lesser degree, urban-bare soil. Field surveys revealed a land change pattern from forest to marginal agriculture as a response to urban growth pressures. On the one hand, high regional migration rates have pressed less profitable agricultural lands to become new urban areas. On the other, as a consequence of agricultural surface loss, forest lands are being transformed into new agricultural areas.

Table 5.10 Texcoco-Zumpango sub-watershed land-use change pattern (1993-2000)

Land-use change	**Net change (Km^2)**	**Percentage of change**
Natural vegetation cover to bared soil-urban cover	231.7	13.8%
Natural vegetation cover to agriculture cover	98.5	5.8%
Total	330.3 (rounded)	19. 6% (rounded)

This sub-watershed is the sub-watershed under the greatest urban growth stress. This is explained because this is the area which is located in the neighbourhood of the urban area of the Mexican Valley. Also, the municipalities with the highest population growth are located here.

Table 5.11 Atoyac-San Martin Texmelucan sub-watershed land-use change pattern (1993-2000)

Land-use change	Net change (Km^2)	Percentage of change
Natural vegetation cover to bared soil-urban cover	45	3 %
Natural vegetation cover to agriculture cover	300	18.3%
Total	345 (rounded)	21 % (rounded)

This is one of the sub-watersheds that displayed more vegetation cover loss. As can be seen in table 5.11 the main change was from natural vegetation to agricultural land. It is explained because the Atoyac-San Martin Texmelucan watershed is one of the regional suppliers of vegetables to the Central Market located at Mexico City. Thus, the need for new agricultural areas is ever growing.

Table 5.12 Tetlanapa sub-watershed land-use change pattern (1993-2000)

Land-use change	Net change (Km^2)	Percentage of change
Natural vegetation cover to bared soil-urban cover	17	1 %
Natural vegetation cover to agriculture cover	352	18 %
Total	369 (rounded)	19 % (rounded)

This was the sub-watershed that has the highest loss of vegetation cover. As can be seen in table 5.12, the main change is also from natural vegetation cover to agricultural cover. As in the case of the previous sub-watershed, this area is under the pressure for new agricultural lands for regional market reasons. A well developed regional peach and plumb market has resulted in many forested areas becoming orchards.

Table 5.13 Huautla sub-watershed land-use change pattern (1993-2000)

Land-use change	Net change (Km^2)	Percentage of change
Natural vegetation cover to bared soil-urban cover	-9.6	-1.8 %
Natural vegetation cover to agriculture cover	18.2	3.2 %
Total	8.6 (rounded)	1.4 % (rounded)

In contrast, Huautla sub-watershed displayed the lowest vegetation cover loss. A curious result is the negative value of change from natural vegetation cover to bare soil-urban cover. This result is explained as a result of the regional reforestation campaigns that focused on the restoration of bare soil. On the other hand, the low pressure on vegetation cover has its main explanation in the fact that the municipalities located in this sub-watershed have the highest rates of outward migration.

Table 5.14 Balsas-Santo Tomas sub-watershed land-use change pattern (1993-2000)

Land-use change	Net change (Km^2)	Percentage of change
Natural vegetation cover to bared soil-urban cover	8.2	1.4 %
Natural vegetation cover to agriculture cover	27.2	4.6 %
Total	35.4 (rounded)	6 % (rounded)

Finally, the Balsas-Santo Tomas sub-watershed, despite the low values in vegetation cover loss, has a relatively high degree of change. This sub-watershed occupies almost 1% of the whole area under study. Thus, in this context, 35.4 Km^2 is a huge area. Also, the explanation of this high level of change is related to strong urban growth on former agricultural lands and consequent need for new crop growing areas.

The results of land use change patterns at the regional and sub-watershed levels can be summarised in a general statement to this effect: The loss of vegetation cover is the main threat to conservation in the volcanoes area. A subsequent analysis of the watershed areas will show the severity of this threat.

5.4 Diagnosis phase results

5.4.1 Incorporating the expert choice results in the process of delineation of Ecologically Sensitive Areas

The problem: How to integrate the weighting results derived from the application of Analytical Hierarchy Process procedures into the delineation of ecologically sensitive areas?

The results:

The values of each eigenvector (priorities vector) were the fundamental result that was used in weighting data layers applying GIS procedures. This vector describes the relative weight values of land cover, steepness and drainage density criteria. The relative weight is displayed in figure 5.8. The values of the eigenvector were incorporated to the data base with a routine in IDRISI 32.

Figure 5.8 Vector of relative weight values of land cover, steepness and drainage density criteria

Contribution of susceptibility to erosion: 1.0		
Land cover	**Steepness**	**Drainage density**
0.50	0.30	0.20

Later, this vector was employed to weight the land-use data layer (Figure 5.9).

Figure 5.9 Priorities vector of the contribution of soil-cover classes to susceptibility to erosion

Total contribution of soil cover to erosion susceptibility: 0.5					
Fir forest	**Pine forest**	**Mixed forest**	**Grassland**	**Agriculture**	**Bare soil / urban area**
0.012	*0.017*	*0.025*	*0.093*	*0.143*	*0.174*

As a result, a new weighted data layer was created, that displayed the erosion susceptibility due to soil cover. This data layer was constructed through a GIS assignment routine. The different weight values of each soil cover were assigned to the soil cover data layer.

Subsequently, a second weighted data layer was created that showed erosion susceptibility based on drainage density. This data layer was also built through an assignment GIS routine, in order to include the priority values for each steepness class (shown in figure 5.10), as delineated in the corresponding data layer.

Figure. 5.10 Priorities vector of the contribution of steepness classes to susceptibility to erosion

Total contribution of steepness: 0.3			
0°-6°	**7°-9°**	**10°-25°**	**26°-64°**
0.015	*0.035*	*0.091*	*0.158*

Finally, a third weighted data layer was constructed that exhibited erosion susceptibility based on drainage density. This data layer was once more developed through a GIS assignment routine, in order to include the priority values for the different drainage density classes (shown in figure 5.11).

Figure 5.11 Priorities vector of the contribution of steepness classes to susceptibility to erosion

Total contribution of drainage density:0.2				
0 - 0.0028 m^{-1}	**0.0029 - 0.0056 m^{-1}**	**0.0057 – 0.0084 m^{-1}**	**0.0085 - 0.0112 m^{-1}**	**0.0113 - 0.014 m^{-1}**
0.013	*0.027*	*0.045*	*0.053*	*0.066*

Summarising, three new weighted data layers were obtained. These layers integrated the weighting exercise results into data layers of a GIS data base. These provide the basis for the subsequent GIS procedures to delineate areas ecologically sensitive to erosion.

5.4.2 Delineation of Ecologically Sensitive Areas based on a biodiversity criterion.

The problem: How to delineate Ecologically Sensitive Areas based on biodiversity criteria.

The results:

This research question was answered by designing a GIS procedure based on the year 2000 vegetation cover data layer. This procedure was as follows:

1. Re-classification of satellite image for the year 2000. The aim of this step was to create a recent data layer which included only the natural vegetation cover. For this reason, the LANDSAT TM satellite image was re-classified based on diversity of vegetation type. Thus, from this satellite image a new data layer was derived. This new plane of information only included the classes of forested vegetation: fir forest, pine forest, open pine forest, mixed forest. Grasslands were discarded, despite the fact that some grass associations are a natural vegetation type. The criteria behind this decision were biological and technical. The biological criterion was that natural grasslands are associated to open pine forest, a class already taken into account; and also, the distribution of natural alpine grasslands is reduced to a few areas above the 4 000 meters above sea level. The technical criterion was related to the difficulties associated with distinguishing natural grasslands from those induced by human activities (clear-cutting and grazing activities). It was not possible to refine the satellite image classification in order to identify both grassland classes. Furthermore, the use of an omission-commission analysis to support this task would have been highly time and money consuming, due to the dispersion pattern of grasslands in the upper-watersheds of the volcanoes region.

2. Application of a heterogeneity index over the data layer of the forest vegetation types. The aim of this step was to select those areas with a high diversity value. As a consequence, the application of a heterogeneity index based on the measurement of uncertainty was selected. Then, the so-called Simpson's index was chosen, because of its characteristic of being more sensitive to class types than to their relative proportions (for an in depth revision of heterogeneity indexes and their application to diversity measurement see Pielou, 1995). This index is described below. Finally, the application of this index was achieved through the use of a routine developed for the IDRISI 32 GIS software

3. Defining the appropriate square-size for the application of the heterogeneity index. The aim of this step was to find the appropriate square size for the application of the diversity index under low variance criteria. The routine was ran employing different sizes already defined in the software. They were squares of 3, 5 and 7 pixels per side. For this study, each pixel has a resolution of 50 m per side. Subsequently, every routine run was analysed through a standard deviation and variance dispersion analysis in order to select the square-size with a low value of dispersion. Eventually, a square of 7 pixels per side was chosen.

4. Selecting the index ranks with biological meaning. The aim of this step was to select the ranges of the diversity index with biological meaning. This selection was made through a trial and error procedure. First, only positive values were considered based on two criteria: biological and spatial meaning. On the one hand, negative values of the index could not have a biological meaning; and on the other, test runs with negative values give rise to meaningless spatial distributions. Afterwards, the dispersion patterns of the positive values of the diversity index were examined through a histogram analysis. As a result, 4 value ranks were defined in bits (binary units) from 0.1 bits to 0.33 bits, from 0.331 bits to 0. 73 bits, from 0.731 bits to 0.1.13 bits, and from 1.131 bits to 2.0 bits (the maximum value of heterogeneity for four items under the condition of evenness, or even probability). Subsequently, a new test run was executed in order to analyse the scattering pattern derived from the application of these ranks. Finally, after a new dispersion-histogram analysis it was decided to consider only two ranks: from 0.731 bits to 0.1.13 bits, and from 1.131 bits to 2.0 bits. This decision was supported by the fact that they were the ranks with the highest values of heterogeneity, and therefore, they also expressed the highest values of vegetation type diversity. Thus, applying only those two ranks, a new data layer with only two categories was produced. It was labelled the diversity data layer.

5. Delineation of the ecologically sensitive areas according to biodiversity value. The aim of this step was to delineate in the diversity data layer those areas with the highest diversity value. This delineation was made through two procedures. First, the data layer containing the limits of the area under study and the limits of the five sub-watersheds was overlaid over the diversity data layer. Second, the areas with the highest values of heterogeneity were delineated considering the entire volcanoes region and the different sub-watersheds. They were labelled Biodiversity Ecologically Sensitive Areas and Regional Biocentres. They are displayed at the regional and sub-watershed scales in map 5.3, this map shows those areas that could be considered of great ecological value because of their richness of vegetation types or habitats.

It is important to highlight that the most important biocentres were located in protected areas. The main biocentres are located inside the Iztaccihuatl-Popocatepetl National Park. They are concentrated mainly in the west, southwest, south and southeast portions of the volcanoes region. However, other important areas are situated to the north and northeast of the region (see Map 5.3). On the other hand, there exist other biocentres located to the north of the volcanoes area, as is shown in Map 5.3. These biodiversity sensitive areas seem more fragmented than those of the volcanoes area. They are included in the Zoquiapan National Park. A relevant result of this research is the diagnosis that this national park is suffering problems of fragmentation, in terms of the scattered pattern of its biodiversity sensitive areas. This problem will be considered in subsequent research focusing only on this park.

Finally, from a landscape perspective, there are other mountain biocentres but these are isolated and far from the volcanoes area. Thus, although they could be taken into account in a broad scale study, they were not considered here.

5.4.3 Delineating the map of ecologically sensitive areas under the criterion of landscape fragility.

The problem: How to delineate ecologically sensitive areas taking into account the three weighted data layers of erosion susceptibility to land cover, steepness and drainage density described in subheading 5.3.1

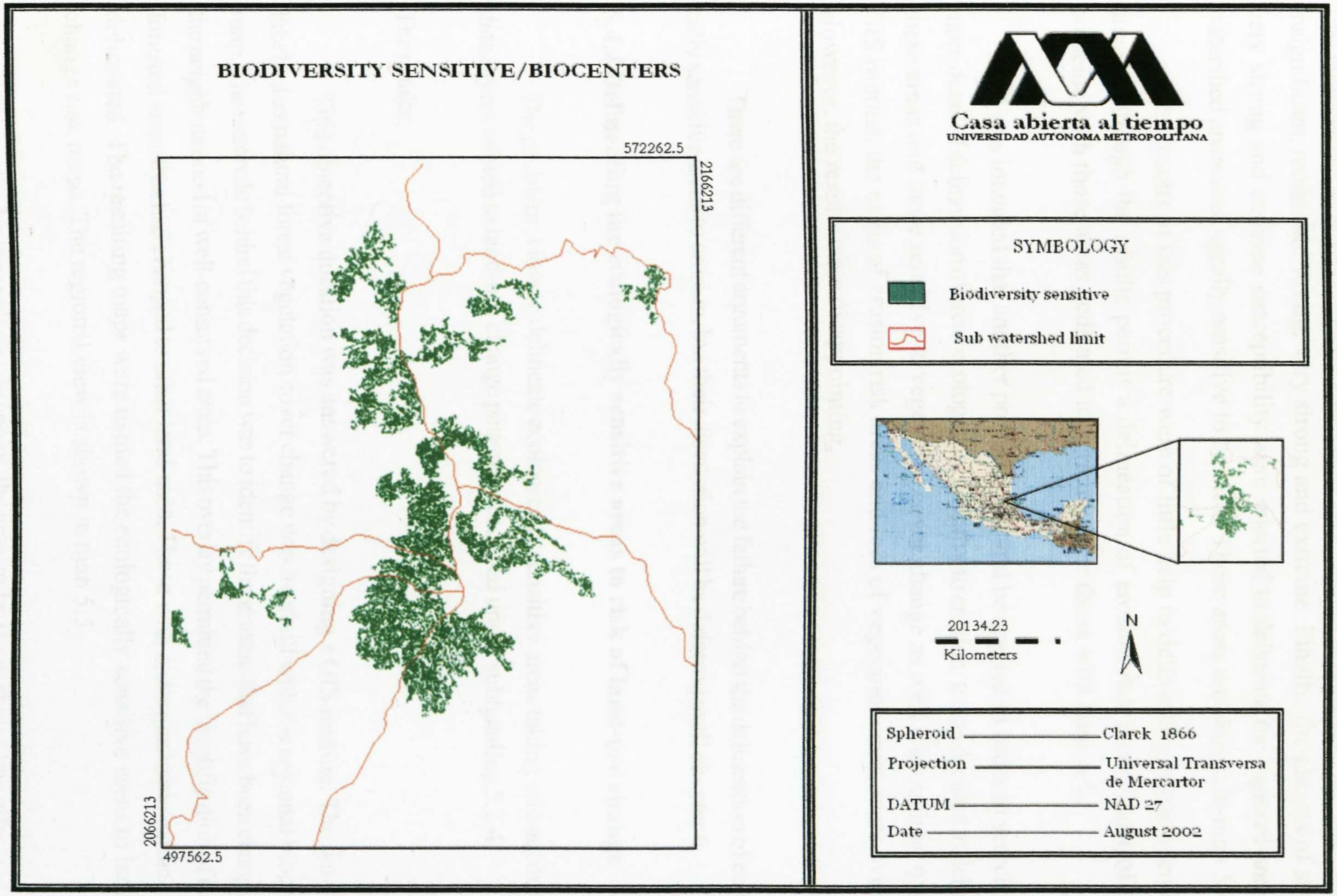
The results:

This map was delineated through an overlay GIS routine, where the weighted data layers that displayed erosion susceptibilities due to soil cover, steepness and drainage density were overlaid in order to delineate a synthesis data layer. This data layer was labelled areas ecologically sensitive to erosion risk.

The overlay process was carried out under a weighted decision rule. For this, the basic equation employed by Barredo and Bosques (1995) was modified. This equation is shown here as:

$$C = \Sigma w_i x_i$$

Where:
C = Total susceptibility to erosion
w_i = Weight of criterion/attribute i
x_i = Surface value into the criterion/attribute i



Map 5.3 Biodiversity sensitive areas/biocentres of the Iztaccihuatl-Popocatepetl region.

Subsequent to the overlay procedure, a reclassification process was carried out, in order to reduce the number of classes. For this, a dispersion analysis based on histograms was applied. The nominal scale of the fundamental scale of Saaty (1985) was additionally applied to produce a data layer based on five erosion susceptibility classes: insignificant, moderate, strong, very strong and extreme. Finally, the classes of strong, very strong and extreme susceptibility were selected to delineate the regional and sub-watershed areas ecologically sensitive to erosion. These areas are shown in map 5.4.

The results of this procedure were of little help in delineating erosion sensitive areas. Although the results permit a delineation of erosion risk areas, most of them coincide with those areas dedicated to agriculture or those with bare-soil.

It was intended that another procedure should be applied in order to search for a more detailed delineation of areas ecologically sensitive to erosion. It was decided to delineate these areas and those sensitive to vegetation cover change as well. Through an overlay GIS routine, the maps of erosion risk areas and loss of vegetation areas were overlaid. However, the results were disappointing.

There are different arguments to explain the failure behind the delineation of ecologically sensitive areas to erosion, but their discussion will be deferred until chapter 6.

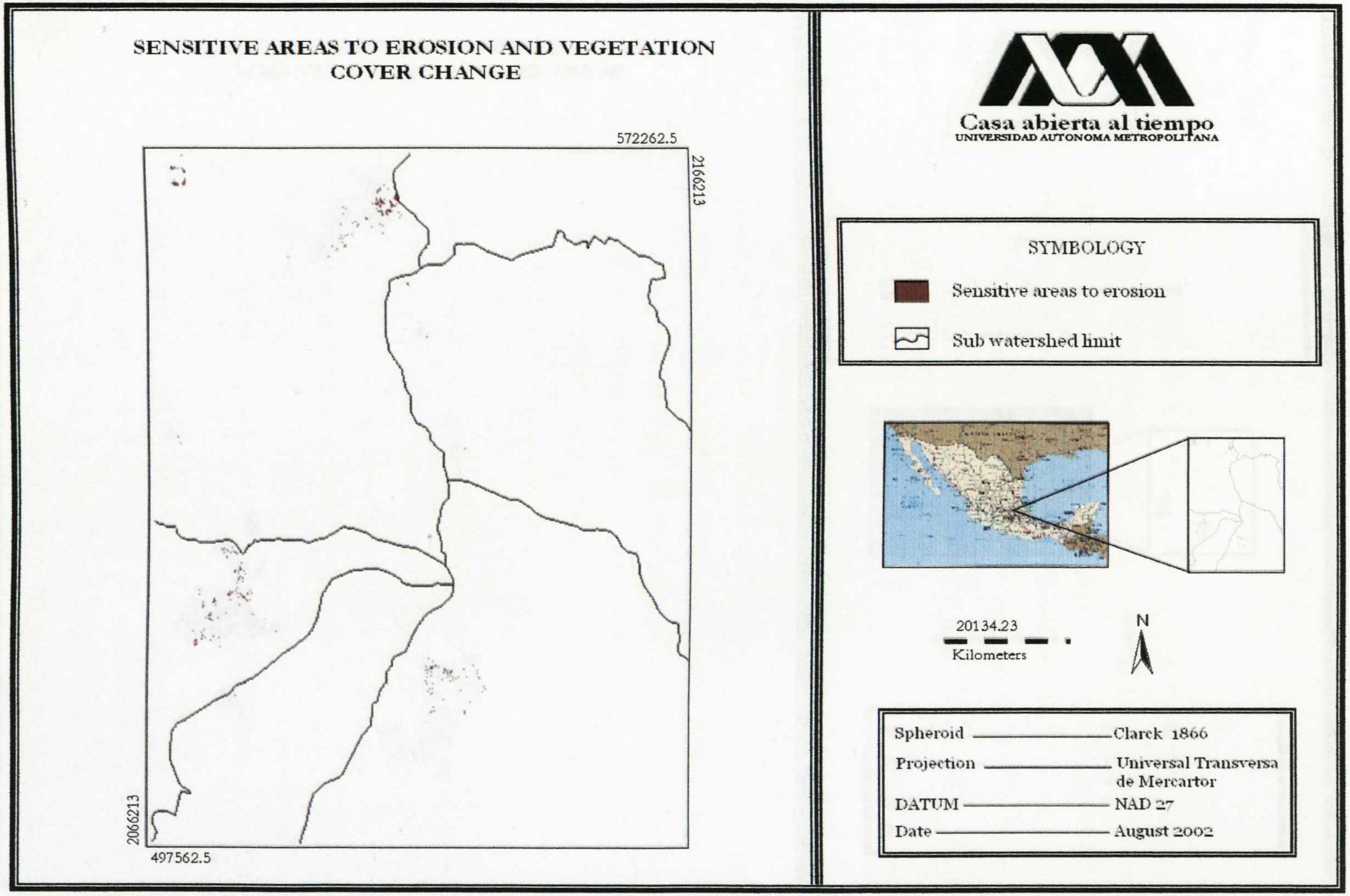
5.4.4 Delineating the ecologically sensitive areas to risk of land-use change

The problem: How to delineate ecologically sensitive areas taking into account the data layers related to land-use change patterns described under subheading 5.2.4

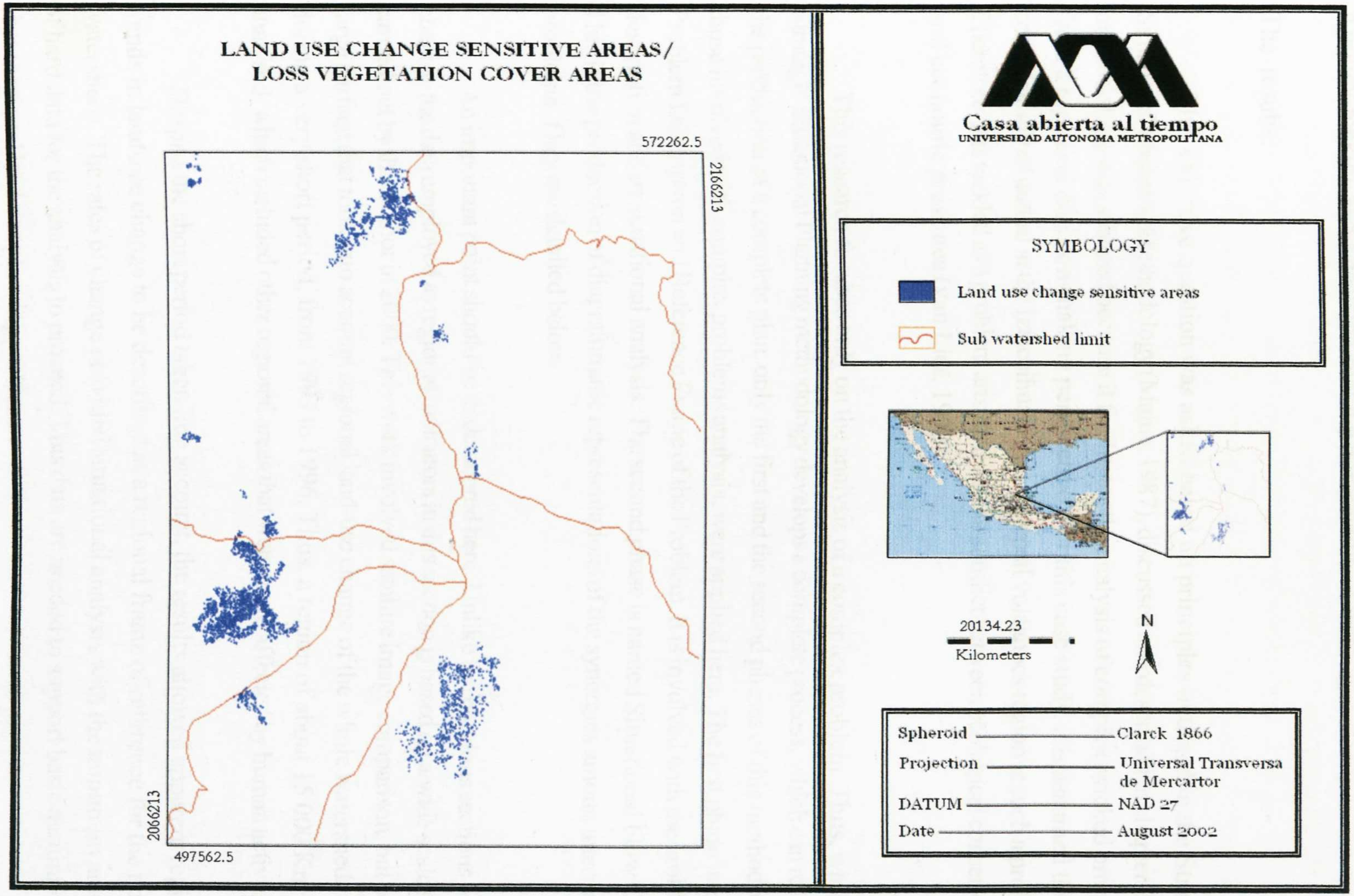
The results:

This objective question was answered by designing a GIS routine. The data layer labelled as natural forest vegetation cover change was overlaid with the regional biocentres map. The rationale behind this decision was to identify those areas that have been changing in the neighbourhood of well-conserved areas. This overlay permitted the identification of natural forested areas that had changed to other land-uses. Those with distinguishable surface were delineated. The resulting maps were named the ecologically sensitive areas to land-use change risk maps. The regional view is shown in map 5.5.

From a landscape analysis viewpoint, the area under study shows few effects to land-use change risk. However, at the sub-watershed scale, there is a important threat in the loss of vegetation cover at Tetlanapa sub-watershed. To a lesser degree, another threat can be identified at the sub-watershed of Atoyac-San Martin Texmelucan.



Map 5.4 Ecologically sensitive areas to erosion of the Iztaccihuatl-Popocatepetl



Map. 5.5 Land use change sensitive areas of the Iztaccihuatl-Popocatepetl region.

5.4.5 Estimating political context analysis: threats to biodiversity protection

The problem: How to define the regional threats to biodiversity protection from a policy-making and a decision-making perspective.

The results:

This objective question was asked based on principles outlined in the Strategic Situational Planning Methodology (Matus, 1987), discussed and described in chapter 2. The methodology was selected because it facilitates the analysis of complex-wicked problems from a top-level decision-making perspective. For this case study, it is assumed that the conservation of nature in the Iztaccihuatl-Popocatepetl volcanoes region is such a problem. Therefore, it is tackled as a problem arising from the conflict between ecological conservation and economic pressures (van Lier, 1998).

This research focuses only on the analysis of a complex problem. Thus, while the Strategic Situational Planning methodology develops a complete process, which can result in the production of a complete plan, only the first and the second phases of this methodology, those involved with complex problems analysis, were applied here. The first phase is called Problem Description and Reference Frame of the Problem. It is involved with the problem's description and its situational analysis. The second phase is named Situational Flow Chart. This is the production of diagrammatic representations of the synergies among interrelated problems. They are detailed below.

An important point should be underscored here. Unlike the previous sections of this chapter, the data employed as regional indicators in this section is based on a wide scale study carried out by this author in 2000. This work involved satellite image comparison, but over a large surface that took into account regional land-use change of the whole watersheds area, during a very short period, from 1993 to 1996. Thus, a region of about 15 000 Km^2 was analysed, which included other regional areas that were more affected by human activities.

Despite the short period taken into account, the results allowed apparent regional trends in land-use change to be described as a regional frame of reference for the upper-watersheds. The rates of change provided situational analysis with the minimum amount of hard data for the analysis to proceed. This data are needed to support basic assumptions about regional land-use planning problems.

Description and Reference Frame of the Problem

This section summarizes the relevance of the case study, previously discussed in section 4.4 of chapter 4.

The aim in this phase is to establish a systematic description of the regional threats to biodiversity protection as a complex problem. The basic assumption is that complex problems are quasi-structured or poorly structured, i.e., it is not possible to know all the elements that originate the problem, nor all the relationships among variables that are involved in it.

However, a targeting exercise was carried out in order to determine if regional biodiversity protection as a complex problem was a situation worthy of being analysed. This was to establish if this problem had meaning for any social actors that need to confront it and who want to solve it. It also implied to describe the actor's rationale behind the worthiness of the selected problem.

The basic strategy for problem analysis was to describe this problem as systematically and accurately as possible. Particular emphasis was made on the identification of a target problem. This target was chosen from a set of problems related to the conflict between ecological conservation and economic pressures. After this selection, the remaining problems were considered parts of the context of the one selected.

The results of preparing the Description and Reference Frame of the Problem are shown in Figure 5.12. This phase was developed through the following steps:

1. Description of the macro-problem of which the selected problem is a part. This provides a succinct description of the macro problem. As was established before, it was chosen to tackle a complex-wicked problem related to the conflict between ecological conservation and economic pressures, described as a Conservation-Development Planning Crisis in the Megalopolis of the Central Region of Mexico (see Figure 5.12).
2. The main result of the exercise of targeting was the description of the problem to be analysed. This implied the definition of a target problem from the complex mess that gave rise to the conservation-development planning crisis (see Figure 5.12).
3. Description of the most important related problems. This implies a selection of other problems related to the target. The leading idea was to identify those problems that could have a direct effect on the target problem, or that could be produced by this problem. This can be called the nearest environment of the problem (see Figure 5.12).
4. Description of the rationale behind the selection of the problem. Here were described the reasons that support the target problem as a worthy situation to be

analysed. Usually, the reasons are identified from a social actor or actors who need to confront it and who want to solve it. For this case study, the author identified the reasons (see Figure 5.12).

5. Description of the main political actors involved in causing, tolerating or facing the target problem, i.e., all the social actors involved in the creation, maintenance and solution of the target problem (see Figure 5.12).
6. Selection of problem descriptors indicators. Here, the main indicators related to of the target problem were defined. The rationale behind a selection of indicators is the need to choose outstanding features of the problem that highlight its importance and help future analyses and monitoring of alternative solutions. For this case study were selected different land-use change rates (see Figure 5.12).

Figure 5.12 Description and reference frame of the selected problem

Description of the macro-problem of which the selected problem is a part Conservation-development planning crisis in the megalopolis of the Middle Region of Mexico
Description of the complex problem to be analysed Land-use change patterns in the Iztaccihuatl-Popocatepetl volcanoes region
Description of the most important related problems 1.Undefined conservation and development policies and programs at a national level. 2.Undefined conservation and development policies and programs at the national, state and municipal levels. 3.High regional demand for urban land-use. 4.Low profitability and support for productive land-use activities. 5.Low presence and action capacity of the state and municipal land-use planning sector. 6.Excessive tolerance and corruption in regional land use decision making 7.Low regional managing and organisational capabilities. 8.Regional historical trends of accumulation of economic and political power.
Description of the rationale behind the selection of the problem Until now the Iztaccihuatl-Popocatepetl region has suffered a loss of forest areas that has caused a loss of biological diversity, damage to wildlife habitats and a general degradation of its watersheds. This volcanic area is located in a region with one of the fastest urban growth rates in the world: the megalopolis of Middle Mexico. Like the rest of the natural areas of the country, the volcanoes region is affected by the low institutional capability for fostering environmental quality and conservation, and the lack of local and regional awareness of the social consequences of environmental risks derived from environmental degradation
Description of the main social actors involved in the target problem 1.Federal Environmental Ministry of Mexico 2.Environmental, Rural and Urban Development Ministries of Puebla, Mexico and Morelos states. 3.Municipality staffs 4.Landowners 5.Legal and illegal house builders
Selection of problem descriptors Ratio of increase in eroded areas Ratio of loss of regional vegetation cover Ratio of growth of regional urban areas

Situational Flow Chart phase.

The goal of this phase is to develop a cause-effect explanatory network about the target problem: Land-use change patterns in the Iztaccihuatl-Popocatepetl region. The construction of this diagrammatic model follows the logic of flow models and of a hierarchical arrangement of interrelated problems.

The diagrammatic model was constructed considering three main parts: a vector of indicators of the problem, causes and consequences (see Figure 5.13). In a subsequent part, this diagrammatic model is simplified in order to determine the main problems to be faced and the interrelationships among them. This new diagrammatic model was labelled as "main problems tree and its critical nodes" (consistent with the classical idea about searching for the root problem or problems).

Defining the vector of descriptors of the problem

For this research, the vector of indicators of the problem displays a set of estimated values, which support the assumption that there is a disadvantageous land-use pattern change in the volcanoes region. It contains the hard data derived from the comparison of regional satellite images, already described. For this case study, it contains broad estimated values of the rate of increase of eroded areas, regional vegetation cover loss rate and regional urban growth rate (see Figures 5.12 and 5.13).

Defining the causes of the problem

This phase used a list of interrelated problems that have been enlisted by the author since 1995, when he was coordinating a management plan to the Iztaccihuatl – Popocatepetl National Park. The sources for this list of problems are diverse. It includes mainly personal communications from local stakeholders (municipality authorities, elderly people, communal authorities, and so on) and results of local, regional or expert workshops discussing regional conservation problems or urban growth control. However, the selection of the problems included in this research reflex only the personal view of the author and it is not the result of a consensus.

The causes were identified considering three sets of problems. One of them was identified as the assumed answers to the question of how to explain the land-use changes described by the indicators. This set includes direct causes and may be called flows (main factors) according to the Strategic Situational Planning methodology (see Figure 5.13). It includes as principal causes high operational capability for legal and illegal house builders, farmers giving up farm productive activities, low regional farm productivity and low regional income.

Other two sets of problems were a result of an arrangement of the related problems already described in Figure 5.13. They were ordered according to generality and interrelationship criteria. For this case study, a first of this sets was recognised as being composed of more general problems. More general problems were considered to be: undefined conservation and development policies and programs at a national level; undefined conservation and development policies and programs at the state and municipal level; and regional historical trends in the accumulation of economic and political power. This set was named "causes related to rules" (laws, rules, policies or approaches).

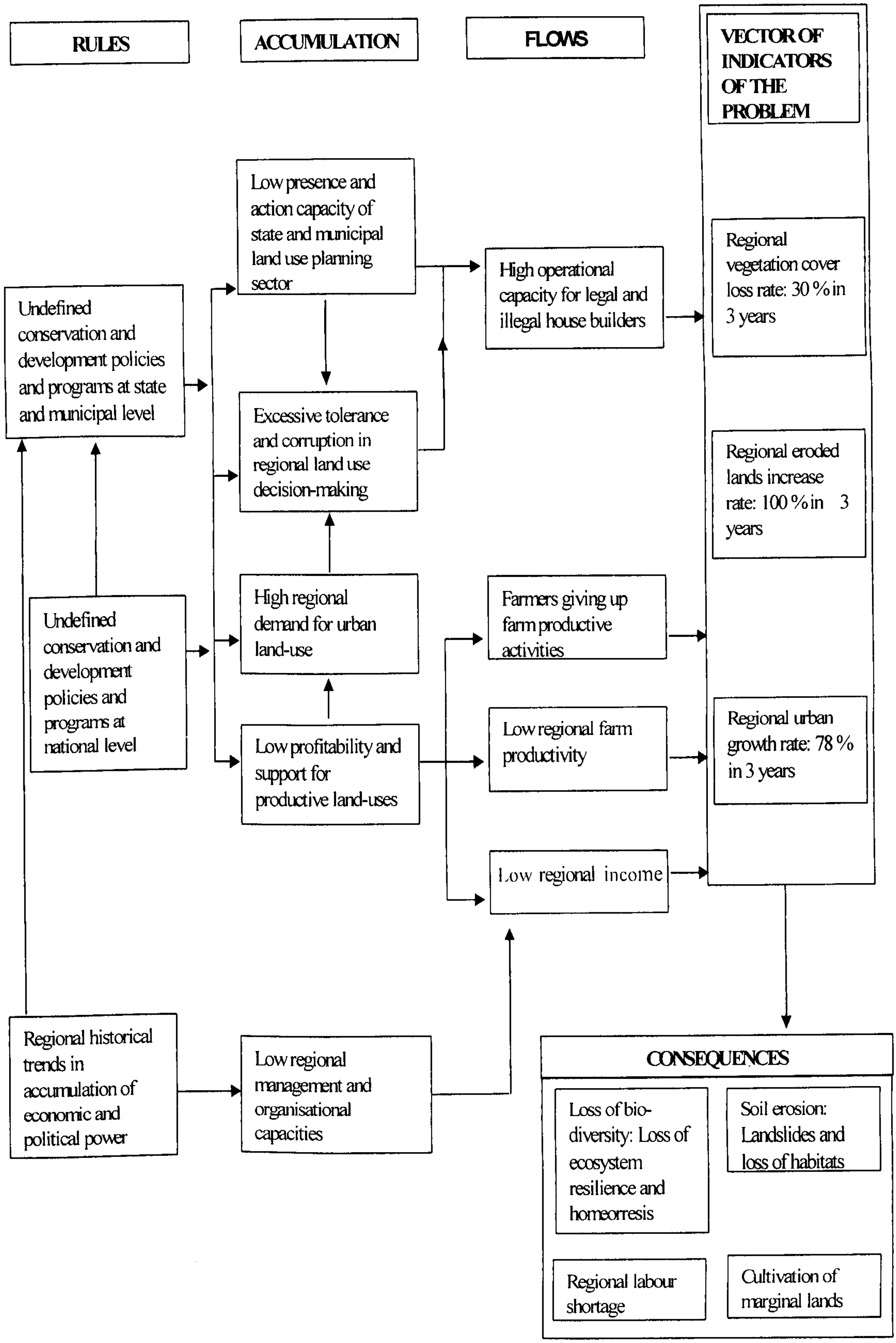
The remaining set is made up of less general problems. It was labelled "accumulative causes" (persistent unsolved problems). It includes problems like high regional demand for urban land-use, low profitability and support for productive land-use activities, low presence and action capability of the sector in charge of state and municipal land use planning, excessive tolerance and corruption in regional land use decision-making, and low regional managing and organisational capabilities. The results of the identification of interrelationships between these various problems are shown as a flux diagram displayed in Figure 5.13

Defining the consequences of the problem

This part was constructed considering two ecological effects already reviewed in depth (sections 4.1 and 4.4 of chapter 4) and two social consequences. Soil erosion and loss of biodiversity were considered the main results of land-use change in the region. In contrast, regional labour shortage and cultivation of marginal lands were the main social effects of the disadvantageous alteration of land-use patterns.

As can be seen in the results summarised in Figure 5.13, this approach to analyse complex/wicked problems is a powerful epistemological and heuristic framework. First at all, it allows the common entanglement of problems that constitute complex/wicked problems to be structured logically. In addition, the identification of a generality criterion and the causality interrelationships provide a strong epistemological support to the analysis of these problems. Finally, it is important to highlight the role of the diagrammatic model. The author thinks that it provides support for the use of a holistic approach to the analysis. First, it gives a global view of the problem, and second, it identifies the network that describes the apparent synergies displayed between the main individual problems that constitute the complex/wicked problem.

Figure 5.13 The complete causality network

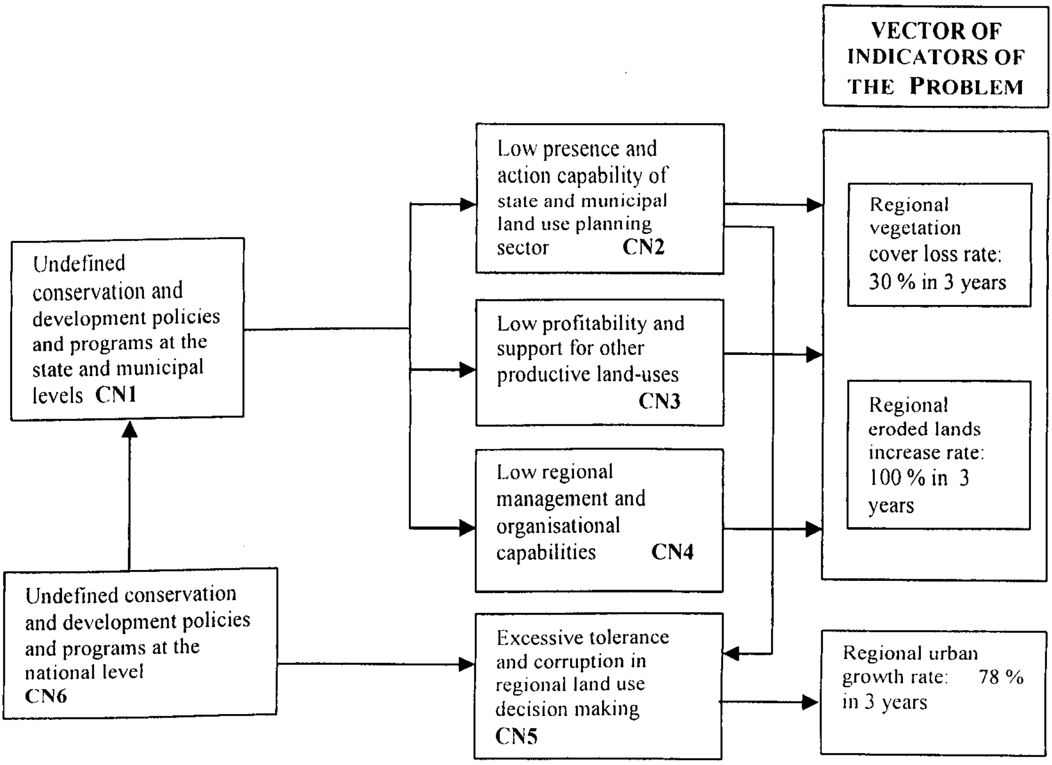


Defining the tree of main problems and its critical nodes

Finally, the causality flow diagrammatic model was simplified in order to determine the main problems to be faced and the interrelationships among them. This new diagrammatic model was called "the tree of main problems". It displays a summarised global view of those problems selected to be faced subsequently (see Figure 5.14). It was built from a selection of those that were considered the main accumulative and rules-related causes of the land-use change problem. For this case study, the guideline followed was to pick up those that showed a strong synergy in the causality flow diagrammatic model. It was also intended to maintain a global view of the interrelated problems (see Figure 5.14)

A weighting process was later identified in order to determine the degree of importance of the chosen problems taken as causes (see Figure 5.14). The guideline for this selection was the degree of synergy of the different accumulative and rules-related causes. These causes were then named "critical nodes" (CN). Thus, the weighting procedure gave rise to an ordered arrangement of these causes, by order of importance. For this purpose, the causes were marked with a notation of CN and their order of importance assigned a consecutive number. The results of this weighting process are shown in figure 5.14.

Figure 5.14 Tree of the main problems related to land-use change patterns in the Iztaccihuatl-Popocatepetl volcanoes region



The problem of "Undefined conservation and development policies and programs at the state and municipal levels" was considered the main cause that is producing the change in land-use patterns in the volcanoes region. It was chosen because of the very strong influence that a lack of a legal and ecological physical planning framework has had on the regulation of land use. Its absence gives rise to land-use decision-making processes in the hands of landlords and of legal and illegal house builders. Till the publication of this thesis, the physical planning in the region was only based in broad bases. It means that the ecological physical planning decision are made on broad classifications of land-use and geographical scales (1:500 000 or 1:250 000). In addition, a main result of expert workshops related to the problem of urban control is the vulnerability of municipality authorities to local or regional economic power. As a consequence, the local and some times state urban growth policy is in the hands of powerful legal or illegal house builders. For this reasons, it is considered that this cause has a direct and strong influence in the remaining causes as can be seen in the figure 5.14.

Low presence and action capability of state and municipal land-use planning sector was chosen as the second cause. A chronic regional problem is the lack of enough human and financial resources to develop and apply the regulatory policies across the region. Actually, from 18 municipalities considered in the area of influence of the region under study, only Puebla, Chipilo, Chalco and Yexapixtla have developed ecological physical planning and urban development projects. The rest have not enough financial and human resources to foster them.

A third important problem is the low profitability and support for other productive land-uses. It is also a chronic regional problem. Usually, there are limited financial resources to improve farm activities but frequently they are oriented to improve technologically dependent farm activities. Many times they disappear at the same time that financial aid ceases or is exhausted.

Low regional managing and organisational capabilities was selected as having a fourth degree of importance. Regionally, there exist incipient organised groups with at least two main purposes: to face the problems related to the distribution and marketing of farm products, and to look for ways to update regional and municipality policies for ecological and social care. However, their level of influence has no regional significance. They are limited to a local or municipal level of influence.

Excessive tolerance and corruption in regional land use decision-making was granted a lower priority. This is the fact that other colleagues consider to be as the most important cause of regional land-use change. This author thinks in an opposite sense and it places it here in the last degree of importance. The rationale is that after the analysis of the causality flow diagrammatic model shown in Figure 5.13, it is considered that this problem requires a synergic solution. Thus, it is proposed that it could only be faced through the improvement of the physical planning activities at the municipal level, the increased presence and action capability of municipal physical planners, the intensification of other productive land-uses, and the raising of local and regional managing and organisational abilities,

5.5 Prognosis phase results

This phase was developed in order to propose a regional scheme addressing the protection of ecologically sensitive areas in an environmentally sustainable context. This scheme was built contemplating three main issues: a prognosis of their potentials for environmental sustainability, a space-based proposition for their protection and a strategy to confront the regional threats for their conservation.

5.5.1 Constructing the prognosis of regional potentials for environmental sustainability

The problem: How to determine if the ecologically sensitive areas of the Iztaccihuatl-Popocatepetl region have potential for environmental sustainability and sustainable development?

The results:

This objective question was tackled searching for the application of instruments that permits to look forward the regional potential for sustainable development. Potential implies utility and it means that the anthropogenic relationship is clearly apparent but research instruments should be constructed to assessing it. These instruments should assess strong and irreversible impacts that threatened biodiversity, which reduce the ecological potential of a region. On the contrary, they should assess high potential as all appropriate economic activities and huge regions with important ecological functions. In this research focus was given to of to ecologically sensitive areas. Thus, it was employed an appropriate instrument to evaluate their potential. It was selected checklist of indicators as instrument. This checklist was developed by BLFUW (circa 2000). The rationale behind this selection is that it was considered as an appropriate tool for a rapid regional assessment based on expert judgement.

The Austrian research team of the Federal Ministry of Agriculture, Forestry and

Water Management (BLFUW, circa 2000) developed this checklist and their indicators. These researchers grouped them under three main criteria: open possibilities for development; planning culture and strategies for the future, special reserve areas for the future. Described in more detail

1. Open possibilities for development. A criterion related to the assessment of those areas where it is still possible to support diverse development. This criterion was selected because particular emphasis is given to the presence of bio-diverse areas and those that have possibilities for a future sustainable use. Following this rationale, four indicators were selected to evaluate this criterion: (a) no dominant utilisation, (b) no/minimal irreversible utilisation, (c) no/minimal utilisation causing significant disturbance, and (d) no/limited designation or precluding utilisation.
2. Planning culture, strategies for the future. This criterion is associated with planning processes that create and keep opened the scope of opportunities for environmental sustainability and sustainable development. The rationale behind the choice of this criterion is related to the importance that different ways of planning and a "planning culture" have on sustainable approaches. Also, there needs to be considered the possible impact of plans and how they could be changed. Four indicators were preferred for assessing this criterion: (a) participatory planning, (b) binding planning, (c) networking planning, and (d) flexible planning.
3. Special reserve areas for the future. This is a criterion associated with the suitability of areas that may be reserves for future development, or areas with natural resources that need to be conserved or developed. The basis for its selection has to do with the concern for sustainable functionality for beneficial effects in future generations. Four indicators were chosen for valuing this criterion: (a) water, (b) recreational areas for future or additional needs, (c) habitats for endangered plants and animals, and (d) buffer zones.

Subsequently, these three criteria and their indicators were arranged in a checklist following that proposed by Austrian researchers (Figures 5.15, 5.16 and 5.17). However, it was adapted to be applied in this case eliminating a third column of the original checklist that relates each indicator with other indicators derived from checklist applied to risk and natural and cultural value criteria (these checklist were not employed in this research). Particular attention was given to the cases where the indicators did not apply. This occurred with the indicators related to planning culture and strategies for the future.

In order to save time, on this occasion an Analytical Hierarchy Approach was not applied to weight the criteria and the indicators. The results are only supported by a simple expert exercise based on a checklist. The results of the assessment for environmental sustainability potential region are shown in three different checklists. They are displayed in Figures 5.15, 5.16 and 5.17.

Figure 5.15 offers a view of the use of the criterion of open possibilities for development. The results point out that this region presents enormous possibilities for environmentally sustainable development. All the indicators related to assess these possibilities are registered as typical in the area. This means the region deserves particular attention in its conservation and future protection. The reasons for this argument are included in the explanations/reason column.

Figure 5.15 The open possibilities for development of the Iztaccihuatl-Popocatepetl volcanoes region

Core indicator	**Explanation/Reasons**	**Typical of the area**	**Locally/part applicable**
No dominant utilisation (intensive farming, forestry, etc.)	The satellite image of August of 2000 of the region shows that there is not any intensive and dominant productive activity at the upper-watersheds level.	X	
No/minimal utilisation causing significant disturbance (minimal erosion, noise, odour)	The satellite image of August of 2000 of the region shows minimal disturbances at the upper-watersheds level.	X	
No/minimal irreversible utilisation (sealing, contamination, construction, fragmentation)	The satellite image of August of 2000 shows that there is not any irreversible utilisation at the upper-watersheds level.	X	
No/limited designation precluding utilisation (nor a small percentage designated as restricted areas)	The majority of the well-conserved vegetation cover of the region is under legal protection as a national park.	X	

The results of the application of planning culture and strategies for the future to the area are displayed in Figure 5.16 Unlike the previous criteria, the absence of a regional planning culture threatens the possibilities of the region for environmental sustainability. The predominance of legal-based binding planning is of little help to the involvement of the different regional stakeholders. In addition, the lack of voluntary commitments and of prosecution action capabilities at the municipal level fosters illegal activities and lack of interest in the conservation area. This time the explanation/reasons column is thin because of the scant regional planning experience.

Figure 5.16 The planning culture and strategies for the future of the Iztaccihuatl-Popocatepetl volcanoes region

Core indicator	Explanation/Reasons	Not applicable	Typical of the area	Locally/part applicable
Participatory planning (participation of those affected)	This planning approach is exceptionally applied. It could be qualified as almost non-existent.	X		
Binding planning (legal binding or voluntary commitment)	Nowadays this approach is partially applied in the region. However the legal-base is predominant.			X
Networking planning (agreed with other planning levels, interdisciplinarily harmonised).	It could be qualified as almost non-existent.	X		
Flexible planning (capable to respond to new situations or findings)	It could be qualified as almost non-exstent.	X		

In contrast, the results of the criterion of the special reserve areas for the future reveal again extraordinary possibilities for environmental sustainability. Once again, the region is qualified to fulfil this role. Particular attention should be paid to the indicators of water, recreational areas for future or additional needs and buffer zones, because they capture the relationship between the protected area and the goods and services that it provides for regional human needs. Again, the logic that supports the previous arguments is set out in the explanation/reasons column.

Figure 5.17 Special areas for the future potentials of the Iztaccihuatl-Popocatepetl volcanoes region

Core indicator	Explanation/Reasons	Typical the area	Locally/part applicable
Water (potable water reservoirs, potential groundwater reservoirs, glaciers)	The Iztaccihuatl-Popocatepetl region is the main regional water reservoir because of its glaciers, groundwater reservoirs and watercourses.	X	
Recreational areas for future or additional needs (areas with suitability for recreational use)	The region is the main regional reservoir for future recreational activities in contact with nature. It offers a wide range of recreational opportunities, from bird watching to hiking.	X	
Habitats for endangered plants and animals	The relatively well-conserved vegetation cover of the Iztaccihuatl-Popocatepetl National Park helps protect endangered plants and animals.	X	
Buffer zones (open, buffer, margin and sparsely populated areas)	Many areas that surround the National Park are open or sparsely populated areas that could be considered as buffer areas for ecological physical planning proposals.	X	

An integrated view, derived from the results of the three checklists, is that the volcanoes region is appropriate for sustainable development. In terms of environmental sustainability, its area-related characteristics of land-use give rise to possibilities for improvement of its conservation and protection. Likewise, its capabilities as a reserve area for the future contribute to the region's suitability promoting sustainable development.

In contrast, the topics related to regional planning culture and strategies for the future seem to be the bottleneck in pursuing the possibilities for regional environmental sustainability or sustainable development. Thus, many of the proposals given in these sections are focused on ways to clear this obstacle.

5.5.2 Proposing a regional network of ecologically sensitive areas.

The problem: How to propose a network of regional ecologically sensitive areas in the region.

The results:

The proposition of a regional network of ecologically sensitive areas was not required in the area under study. The vegetation cover patches, located in the upper-watersheds of the region are strongly linked. In the analysis of map 5.3, it could be observed that the degree of connectivity was absolute. The relatively low fragmentation that this area presents is the factor that explains this strong connectivity and the usefulness of a regional network of ecologically sensitive areas.

However, it is important to explain here why this task was contemplated in the original outline of this thesis, before the area was chosen. This regional network, as an appropriate spatial model for conservation, was selected when a large area could be taken into account. This topic has been previously analysed in this chapter while the rationale behind the employment of a network as a spatial principle has been analysed in depth in chapter 2.

As can be seen in map 5.3, there are possibilities for this network design if other vegetation cover patches outside the area under study are examined. The patches situated to North of the volcanoes offer the best possibility. They are located in another national park, Zoquiapan National Park. In addition, this park presents more severe problems of fragmentation of its vegetation patches. Consequently, a network spatial model could be implemented to improve connectivity among the different vegetation patches leading into Zoquiapan National Park, and between this park and the volcanoes area

Another possibility could be contemplated southwest of the region (see map 5.3). There are vegetation patches that are located on another mountain chain, called Chichinautzin. This mountain chain is the southern limit of the Valley of Mexico. Nowadays, it has vegetation cover patches mainly near the top of the mountains. Thus, a future network model for conservation purposes could be designed. However, it also presents a strong obstacle derived from urban growth. Between Iztaccihuatl-Popocatepetl volcanoes and the Chichinautzin range lies Cuautla Valley, which is one of the areas that presents higher urban growth rates

5.5.3 Constructing a strategy to confront the regional threats to biodiversity conservation in a context of environmental sustainability and sustainable development

The problem: How to construct a strategy to confront the regional threats to biodiversity conservation in a context of environmental sustainability and sustainable development

The results:

This objective question was treated through the development and arrangement of a series of proposals. The general aim was to integrate the results of previous analyses. Mainly, they are those arising from the analysis of regional land use change as a complex/ wicked problem and from the evaluation of regional potentials for sustainable development. On the other hand, the arrangement was given in order to support the proposal from a practical perspective.

It should be said that the rationale behind the development of proposals was to design a series of guidelines. The search for this generality in the proposals was to achieve the main goal of landscape planning: to improve the coordination of regional efforts at all policy and decision-making levels, in order to promote, encourage and understand the importance of the measures required to protect the Iztaccihuatl-Popocatepetl region/landscape and to conserve its biological diversity.

However, a second intention was behind the development of the proposals: their use as a "trigger mechanism" to achieve regional environmental sustainability and to support pathways to sustainable management. This intention is that of supporting proposals to face regional problems that threaten the protection of the and the conservation of its biological diversity.

The development of proposals was attempted in two steps: defining the proposal/ strategies axis and building a scheme of strategical actions.

Defining the proposals/strategic axis

The aim of this step was to develop a series of proposals based on the critical nodes shown in Figure 5.14

This step was attempted through the development of proposals to solve the complex problem related to land-use pattern change in the region. The analysis of this problem has been already treated in this chapter under subheading 5.3.5. The bases for this proposal are the critical nodes in figure 5.14.

These critical nodes were the main issues on which the design of strategic proposals was based. These were established as a possible solution to the problem described at each node. The logic behind the proposals, beside the problems displayed, was the result of assessing the regional potential for environmental sustainability and sustainable development (described in Figures 5.15, 5.16 and 5.17). Particular attention was paid to the lack of a regional planning culture, already stated as the main obstacle to regional sustainable development.

Possible solutions were stated as general proposals and they were titled strategic axes in the Strategic Situational Planning Methodology. For this case study these strategic axes and their associated critical nodes are displayed in figure 5.18.

Figure 5.18 Strategic axis and associated critical nodes

Label	Critical node	Strategic axis
CN1	Undefined conservation and development policies and programs at the state and municipal levels	Supporting the development of a municipality-based planning culture
CN2	Low presence and capability for action of the sector in charge of state and municipal land use planning	Improve municipality staffs responsible of physical and development planning
CN3	Low profitability and support for other productive land-uses	Empowering municipality skills for productive and design of development projects and lobbying for funds
CN4	Low regional management and organisational capabilities	Enhancing organisational capabilities of municipal organisations, government and citizen based, that are involved in environmental care and assessment, and for the establishment of markets for regional products.
CN5	Excessive tolerance and corruption in regional land use decision making	Empowering municipality skills for land-use regulation activities, mainly those related to the vigilance and prosecution of illegal human settlements

The results displayed in Figure 5.18 enable the identification of the central line of the proposed strategy: the development of a municipality-based regional planning culture. Remaining strategic axes hinge from this central line. They are focused on those skills and capabilities that require the improvement at the municipal level to address the problems that threaten regional biodiversity conservation.

Building a scheme of prior actions

The aim of this step was to build schemes of strategic actions that indicate the prior actions to achieve the strategic axis, the proposed stakeholder to be involved and the proposed stakeholder responsible for leading the task force to accomplish the actions.

In order to achieve this aim, a strategic actions scheme was assembled. The rationale was to establish the first version of a working proposal for inter-institutional task forces, as well as a selection of possible stakeholders to integrate these task forces. The selection was based on a criterion about the resources under the control of stakeholders. The selected stakeholders and resources under their control are shown in Figure 5.19.

Figure. 5.19 Selected stakeholders and their resources under control

Stakeholder	Resources under control
National Institute of Ecology	Federal funds, convening capabilities, political will
Federal/StateEnvironmental Prosecutor	Funds, prosecution capabilities, political will
State government planning staff	Federal funds distribution, state funds, planning and convening capabilities, political will
Metropolitan University planning research team	Regional database, coordinating, planningand convening capabilities
Municipality staffs responsible for economic development and ecological physical planning	Federal and state funds distribution, convening capabilities, political will
Local stakeholders involved in environmental protection and productive activities	Convening, and coordinating capabilities, political will

Otherwise, this author thinks that this multi-stakeholder scheme is the best proposal to achieve the propose of improving a regional planning culture. Moreover, it is a proposal for pioneering new organisational procedures to increase targeted commitments among a wide range of stakeholders.

Finally, the whole action scheme was built. For this task, it was designed based on. Strategic Planning Methodology. The scheme includes the critical node that gives rise to the strategic axis and the actions to be developed. These are displayed in Figures 5.20, 5.21, 5.22, 5.23, and 5.24.

Figure 5.20 Strategic actions to support the development of a municipality –based planning culture

Critical node: Undefined conservation and development policies and programmes at the state and municipal levels

Strategic axis: Supporting the development of a planning culture that is municipality-based Regional market improvement National park conservation

STRATEGIC ACTIONS
Pioneering collaborative ways of planning
Improving normative planning
Enhancing network planning
Initiating flexible planning

Figure 5.20 shows the main characteristics of the proposed strategy in its entirety. A series of strategic activities is proposed to improve the capabilities of the municipalities.

Figure 5.21 Strategic actions for improving municipality staffs which are responsible of physical and developing planning

Critical node: Low presence and action capacity of state and municipal land use planning sectors

Strategic axis: Improving the capability of municipality staffs which are responsible of physical and development planning Regional market improvement National park conservation

STRATEGIC ACTIONS
Initiating municipality-based ecological physical and urban planning projects
Action-training for municipal staffs in urban and ecological physical planning
Designing the municipality-based urban and ecological physical plans
Applying the municipal urban and ecological physical plans
Designing appropriate procedures to assess the achievements of the municipal urban and ecological physical plans

Figure 5.21 displays the main aspects of the proposed strategy to improve physical planning capabilities at the municipal level. A series of prior activities is proposed to improve capabilities related to ecological physical and urban planning

Figure 5.22 Strategic actions to improve municipal skills for productive and development projects design and lobbying for funds

Critical node: Low profitability and support for other productive land-uses

Strategic axis: Improving municipal skills for productive and development projects design and lobbying for funds

STRATEGIC ACTIONS
Initiating economic development projects that are municipality-based
Action-training for municipality development staffs in economic development planning
Designing the economic development plan
Searching for state and federal funds for economic development
Applying the municipal economic development plan
Designing appropriate procedures to assess the achievements of the municipal economic development plan

Figure 5.22 presents the main aspects of the strategy proposed to improve the economic planning capacities at the municipal level. A series of strategic activities to improve capabilities related to economic planning is suggested.

Figure 5.23 Strategic actions to enhance organisational capabilities of municipal organisations that are involved in environmental protection and assessment, and in the establishment of regional and external markets for local products

Critical node: Low regional managing and organisational capacities

Strategic axis: Enhancing organisational capabilities of municipal government and citizen based organisations that are involved in environmental protection and assessment, and in the establishment of regional and external markets for local products

STRATEGIC ACTIONS
Originating organisational capabilities for development projects that are municipality-based
Action-training to improve organisational capabilities among municipal staffs and citizen-based organisations
Designing multistakeholders-based plans for environmental protection and assessment, and for the establishment of regional and external markets for local products.
Searching for state and federal funds for the support multistakeholders initiatives
Developing multistakeholders projects related to environmental protection and for the establishment of markets for local products
Designing appropriate procedures to assess the achievements of the multistakeholders plans

Figure 5.23 displays the main aspects of the strategy proposed to improve municipal organisational capabilities. A series of prior activities to improve these capabilities related to organisational development is suggested.

Figure 5.24 Strategic actions to enhance organisational capabilities of municipal government and citizen based organisations involved in environmental protection and assessment, and for the establishment of regional and external markets for local products

Strategic axis: Empowering municipality skills for land-use regulation activities, mainly those related to the vigilance and prosecution of illegal human settlements

Critical node: Excessive tolerance and corruption in regional land use decision-making

STRATEGIC ACTIONS
Fostering municipality skills for land-use regulation activities, mainly those related to the vigilance and prosecution of illegal human settlements
Action-training for municipal in legal land-use regulation and prosecution procedures
Applying legal land-use regulation and prosecution
Designing appropriate procedures to assess the achievements of the applying legal land-use regulation and prosecution

Figure 5.24 presents the main aspects of the strategy proposed to improve land-use regulation. A series of prior activities to improve municipal skills related to legal and prosecution of illegal land-users is suggested

5.6 Syntheresis phase results

The basic idea is to initiate a new planning process for integrating top down and bottom up planning but based on a collaborative perspective, which pursue from the focus phase the participation and involvement of stakeholders and public. Following Selin and Chavez (1995) this thesis results might contribute to initiate a collaborative process. This process would set the antecedents related to the threats to the conservation of the region, and contribute to analyse the conflict between economic development and conservation.

On the other hand, the role of the Metropolitan University as a third party organization or broker is proposed. Its main activities will be related to instigate collaboration, and fostering government agencies to mandate and incentivate collaboration. In addition, the University might help to create common visions by practising a regional leadership. Currently, Metropolitan University is able to practise a strong leadership with legitimate authority and appreciative skills that could mobilize others to participate by using energy and vision. Following Selin and Chavez (1995) the University could guide collaborative processes to determine appropriate kinds of collective actions to create networks with different organizations. The aim is to improve regional and local united relations and assembly diverse subjects around shared projects or promote social transformations. In this context, the Metropolitan University also should play the role of a third party for solving public sector and environmental disputes.

From a practical perspective the idea is to involve stakeholders in land-use planning through state and municipal physical planning projects. Municipality and sub-watershed are proposed as the appropriate levels for this new planning process. The use of this thesis′ results as a trigger mechanism for fostering physical planning at local scale is proposed. As a matter of fact this kind of parallel planning activities have being carried out in the Huautla sub-watershed. Since 2001, our research group has been supporting a collaborative process to develop an environmental plan and the physical planning project in the municipality of Yecapixtla. In addition, research studies aimed to set the antecedents to face a water use conflict in this sub-watershed have been carried out. Profitable productive activities, mainly peach cultivation, have raised conflicts related to the use of fresh water for irrigation and the contamination of streamflows by fertilizers, herbicides and pesticides. Currently, the Metropolitan University is assessing the environmental and social impact of peach cultivation in this subwatershed.

In addition, first contacts have been established to introduce projects related to the management of waste and sewage. Furthermore, some local workshops have been set up to debate general results which pursue the integration of local community views and expectations related to the control of pollution, urban growth, land use decision-making and water management. In terms of monitoring aspects, it is planned to involve local population as volunteers to monitor certain environmental conditions, such as waste management, control of erosion and water pollutants. The basic idea is to account with people as a valuable source of local environmental information.

5.7 Conclusions

This chapter has surveyed the situation of the complexity involved in goal setting in ecosystem-based management projects. The need to focus the goal setting procedure was underscored, taking into account characteristics of the multiple goals, the viewpoint of the planner and sustainable development, as well as academic, national and international contexts. As a consequence, it was concluded that goal setting for this case study had to reflect:

1. International concerns about fragile ecosystems and biodiversity protection.
2. The scope to encompass the interests of multiple stakeholders.
3. The scope to be consistent with sustainable development issues, such as multifunctional broad regions, collaborative decision building, organisational change and adaptive management.

On the other hand, the possible role and the viewpoint of a landscape/regional planner was also analysed, who faces the development-conservation problem in the Iztaccihuatl-Popocatepetl region. As a result, the author supports the idea of a planner taking on the role of a coordinator of regional planning processes and of a builder of land-use alternatives.

This chapter also dealt with the issues about the delineation of geographically limited areas that are appropriate for use in developing an ecosystem-based management approach. The appropriateness of the boundaries of an area was examined with respect to regional conservation concerns and to save time and money. Also, the selection of the most appropriate criteria to delineate ecologically sensitive areas was studied. The outcome of these studies was the conclusion that on the one hand, the choice of the regional upper watershed seems to be the best option from the point of view of conservation and time and money savings. On the other hand, it was concluded that threats associated with fragility of habitat and biodiversity value seem to be the right selection to be treated as the main concerns for nature conservancy.

This chapter also examined the problems and procedures involved in the construction of a weighted hierarchy of criteria and attributes, the construction of a regional GIS database and the estimation of regional land-use change over a specified period. The complexity involved in these problems was faced through the design of appropriate procedures. Particular emphasis was made on the procedures involved in the construction of the weighted hierarchy and the regional GIS database. The Analytical Hierarchy Process procedures seem to be appropriate to account for the complexity of interrelated criteria and attributes. The selected GIS based approach to construct the database and to estimate regional land-use change enabled the desired results to be obtained. In addition, the invention of the "dominance gradient" not only streamlined the participation of experts, but it also seems to be a potential procedure for shared analysis and consensus building. Finally, the results from land use change patterns, at regional and sub-watershed levels prompted the general conclusion that the loss of vegetation cover is the main threat to the conservation of the area

This chapter also surveyed the delineation of Ecologically Sensitive Areas using weighting criteria and attributes, and the assessment of the social context on regional threats to biodiversity protection. The results led to the conclusion that the analysis and procedures applied have enormous potential for supporting a holistic approach. The examination of the ecologically sensitive areas maps and the situational flow chart demonstrated that the change of landscape patterns could not be explained only by biotic and abiotic causes. Therefore, it follows that landscape/regional systems cannot be deeply understood by reducing them to partial analyses, the central theme of holistic approaches. This holistic approach is also supported by the entire set of results from the landscape diagnosis. It maintains a comprehensive viewpoint of the entire landscape/region as well as the regional synergies of interrelated problems associated with the contradiction of nature conservancy vs regional development.

The chapter evaluated regional potential for environmental sustainability, a space-based proposition, and a strategy to confront regional threats to their conservation.

From the results it is possible to infer that, in terms of environmental sustainability, the volcanoes region has enough area-related characteristics to enable the improvement of conservation and protection. In addition, the characteristics linked to its capabilities as reserve areas for the future justify the promotion of sustainable development in the region. In contrast, the topics related to a regional planning culture and strategies for the future seem to be the issues which currently stand in the way to achieve regional environmental sustainability or sustainable development.

The results displayed in Figure 5.16 point to the development of a municipality-based regional planning culture as the central line for a regional conservation-development strategy. Furthermore, the proposed multi-stakeholder scheme seems to provide the best basis for the achievement of regional planning culture and pioneering new organisational procedures to meet the goals of sustainable development.

This chapter reported the main results of the application of the designed methodology in a case study. The discussion of these results and the extent of achievement of the five main objectives of the research will be the subject of chapter 6.

Chapter 6 Discussion of the results of this research

6.1 Introduction

The goal of this chapter is to present a discussion and evaluation of the results to the extent to which the goal and objectives of this thesis were achieved. In addition, the results from each phase of the methodology, applied in the case study, are also discussed and evaluated. The main aim will be to demonstrate that the results confirm the achievement of the principal objectives of the research and support the applicability of an ecosystem-based management approach in the context of a real life landscape planning case study.

The chapter presents a general discussion of the extent to which the general goal of this thesis has been achieved. It also discusses the degree of achievement of the five main objectives, as well as the main results previously reported in chapter 5. For this reason the chapter is organised in two sections.

The first section is the general discussion, from a theoretical point of view, of the degree of achievement of the major objectives of the research, postponing a more detailed discussion of the findings for chapter 7. The second section presents a discussion of results obtained in the case study. The presentation is ordered according to the different phases of the methodology. As explained in chapter 5, the discussion of results centers on the phases of focus, analysis, diagnosis and the partial results from the phase of prognosis.

Particular effort has been devoted to try to demonstrate how far the empirical results are consistent with the aims. The results of the application to the Iztaccihuatl-Popocatepetl case study are discussed in the light of theoretical and practical perspectives and this discussion is organised according to a strength-weakness analysis. The results considered to be strong as well as those considered to be weak are both highlighted. In addition, recommendations are included for further and required research.

Finally, the conclusions are presented, seeking to reflect a series of views based on a theoretical reasoning which goes from contrasting results and theory, to the main empirical findings of this research. The discussion of the main findings and contributions of the thesis is postponed for next chapter, which draws conclusions on the strengths, weaknesses and potential of an ecosystem-based management project focused on the delineation of ecologically sensitive areas.

6.2.1 Discussion of the goal of the thesis

"To investigate the applicability of a landscape planning methodology founded on an

ecosystem-based approach and focused on the delineation of ecologically sensitive areas"

In terms of an overall budget, the goal of this thesis was achieved. The development of an organised methodology to implement ecosystem-based management projects, the contribution to the research of problems involved in the management of fragile areas, and the exploration of the potential of an ecosystem-based management approach in a restricted resource (human and material) environment, were accomplished. From a land use planning perspective, an ecosystem-based management planning methodology was constructed and tested, within which an emphasis was made on its holistic characteristics and sustainability as prerequisite for planning. Furthermore, research results derived from its application support that it has indeed the potential for further landscape planning applications. In addition, from a fragile areas management viewpoint, the outcomes from the case study that relate to the process of delineation of ecologically sensitive areas confirm the capabilities of the multidimensional approach and multi-criteria analysis employed to define and bound the areas of interest for planners.

Results from the case study confirm that an ecosystem-based management approach has potential as a basis for developing a land-use planning strategy in a restricted resource environment. In this research, most of the characteristics of ecosystem approaches could be achieved in a developing country, Mexico. The integration of different logical models, methods and procedures into a general methodology, permitted the analysis of the Iztaccihuatl-Popocatepetl volcanic region in a manner consistent with those central aspects recommended for an ecosystem approach, including the following:

1. The description of its watershed-ecosystems and their interactions.
2. The inclusion of the interests of the population and their activities within the region.
3. The description of regional dynamics and cause-effect relationships.
4. The definition of the landscape/ecosystem in terms of natural and bioregional units instead of arbitrary areas.
5. The treatment of the landscape at different spatial levels/scales.
6. The establishment of goals and management orientations.
7. The inclusion of actor-systems' dynamics and of institutional factors in the regional analysis.
8. The recognition of limits to action in terms of defining and seeking sustainability (Grzybowski and Slocombe, 1988;Grumbine, 1990; 1994; Kay, and Schneider, 1994; Christensen, et al. 1996; Slocombe, 1992, 1993a, 1993b, 1998).

Particular attention should be paid to the attempt to achieve a holistic, comprehensive and transdisciplinary approach in the study of a landscape/region. This approach was the epistemological "spinal column" of this research. In addition, the main results modestly contribute to the development of the field of holistic and transdisciplinary landscape research approaches.

The application of a recent holistic approach to landscape research, developed by Tress and Tress (2001), allows the integration of the eight issues that have already been described. According to these authors, this viewpoint applied to landscapes/regions's analysis involves taking into account at least five dimensions of the landscape: as a spatial entity, as a mental entity, as a temporal dimension, as a nexus of nature and culture and as complex system. In this research, these dimensions were followed as theoretical guidelines in the construction of the methodology and further applied in the case study.

Results presented in chapter 6 demonstrated that watershed areas could be an appropriate spatial entity to describe the landscape. Although spatial dimension is the cornerstone of the concept of landscape, the delineation of boundaries is still a controversial issue. For this research, the problem of how management areas can be naturally delineated was solved through the application of hydrological criteria. The Iztaccihuatl-Popocatepetl region was delineated as a basin-watershed-sub-watershed network. The appropriateness of this hierarchy to provide a spatial dimension to the region was demonstrated. In addition, the use of the hydrological-altitude zones criterion resulted in the selection of a set of areas that made sense in terms of landscape research and planning.

Landscape was regarded as a mental entity through its conceptualisation, as a network and as a set of watershed-ecosystems. Both concepts in practice were demonstrated to be appropriate choices. First, by defining landscape as a network of hydrological units, it was possible to deal with the need, not just to delimit but also to conceptualise a nested hierarchy of spatial units. Second, the watershed-ecosystem concept also proved to be a proper choice. The use of this concept avoids the endless discussion of what is an ecosystem, where to draw its boundaries and which its environment is. This thesis agrees with the application of the ecosystem-watershed model (Bormann and Likens, 1979) as the basic concept for ecosystem analysis and planning. In addition, it is also assumed here that both, the network and watershed ecosystems concepts, when linked, offer the potential for the development of a heuristic approach to the management of ecosystem-based projects. This is consistent with Naveh's theoretical viewpoint where landscape is considered as a hierarchy level composed by ecosystems (Naveh, 2000). Thus, it is greatly attractive for the author to think of a landscape as a network of watersheds-ecosystems.

It was recognised that it was not possible to achieve the conception of landscape as a temporal dimension in the way that would have been ideal. Landscapes are the visible product of the evolution of people, which do not just influence landscape, but viceversa as well Although it was possible to compare two satellite images and these permitted the identification of the main land use change, the period under consideration was not enough because it is needed a time series to develop a model capable to estimate and predict precisely regional land-use change. The actual result should be considered just as a gross estimation of the land-use change rate. Although a pattern of estimated data was obtained that relates to the rate of land use change and the areas that had suffered important vegetation cover loss were identified, the results are still partial and insufficient to reflect with precision the spatial and temporal dynamics of the areas concerned. It also has the potential to provide with data that will be useful for the development of landscape modelling. Summing up, the seven-year period employed to estimate the loss of vegetation cover, is insufficient for a comprehensive analysis of the temporal and spatial dynamics of the region. Thus, a sequence of 5-year intervals is proposed to be appropriate if annual sequence comparisons are unfeasible. Therefore, it is recommended that this space and temporal dynamics should be investigated further in order to produce a more complete impression of regional land use change patterns. It is also suggested that planners and politicians should be aware of these dynamic trends and their effects at different spatial scales, mainly in the areas under the threat of rapid change in land-use patterns.

The application of the analysis of complex problems, derived from Strategic Situational Planning, allowed having a partial vision of the synergy between social and cultural issues that were involved in the pattern of regional land use change. Although, this vision is not the result of a consensus, it reflects at least the viewpoints of an academic and policy-making group. It also summarises the field survey's results.

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The representation of the landscape as a complex system was achieved by the integration of the issues discussed above, mainly those aspects regarded as a mental entity in the landscape. The perception of landscape as a system, as a whole and as a hierarchically ordered system was accomplished through its conceptualisation as a network of watersheds-ecosystems. Furthermore, the characterisation of a landscape as pattern, structure and process are linked to the dynamic aspects related to land use change pattern, previously discussed.

From a planning perspective and in the light of the results, the author argues that the phases of sustainable landscape planning methodology seem to be an appropriate framework for a landscape planning approach oriented to nature conservancy. The results of this thesis, derived from building and testing these phases, support the idea that this methodology facilitates the integration of holistic and systemic viewpoints, inter-transdisciplinarity, interagency and interpersonal cooperation as well as the building of strategies to define and delineate those areas of interest to planners. In addition, practical results demonstrated that the focus and syntheresis phases are key to provide flexibility to the process of landscape research and planning. Particular aspects of the phases of this methodology are discussed below.

6.2.2 Discussion of the objective one

"To investigate and validate the need for an overall scheme that facilitates holistic-multi-dimensional viewpoints in an ecosystem-based management project focused on the delineation of ecologically sensitive areas"

This objective was totally accomplished. The results originating from a review of literature, as presented in chapter 1, demonstrated that a multi-dimensional approach is needed to tackle problems associated with the environment and development planning. It has also been shown that environment and development cannot be approached separately when the concepts of sustainable development and environmental sustainability are implied.

The results of the literature review also explained the international claim for landscape planning methodologies that seek to facilitate multi-dimensional viewpoints emphasising interdisciplinarity, interagency and interpersonal cooperation. Particular importance was given to the potential of an ecosystem-based planning option, in order to prove its applicability to include multi-dimensional viewpoints. Finally, the need of a multi-dimensional approach to define and bound areas of interest to planners was discussed. This last point was oriented to the delineation of ecologically sensitive areas.

Nevertheless, having demonstrated the need for these multi-dimensional approaches and methodologies, the author recognises that the lack of a substantial empirical foundation gives rise to questions that still need to be answered. These questions are strongly linked to three main weaknesses of these approaches: the relative importance that has to be given to different viewpoints, the vagueness of goals and objectives and the effectiveness of proposals in terms of acceptance and sustainability. These unanswered questions are formulated next. For example, how can those socio-cultural issues that seem neglected, such as politics, power and equity, be included? Slocombe (1993) pointed out that the lack of inclusion of socio-cultural issues is one of the main disadvantages of comprehensive and holistic approaches. It is as well important to answer how can nebulous goals, vague objectives, often associated with multi-dimensional approaches, be dealt with? Setting goals and objectives seems to be the most complex task in ecosystem-based management projects (Slocombe, 1999). Finally, how can multi-dimensional choices about land use, wildlife protection and resource development be built, that are acceptable to entire communities and regions, and that are sustainable? According to Slocombe, (1993) this may be the hardest task that awaits land use planners.

The results of chapter 5 provide a modest contribution to answering the two first questions, but the third is still unanswered because the case study did not treat aspects relative to the implementation of land use proposals.

6.2.3 Discussion of objective two

"To investigate the potential for the integration of multi-dimensional models, methods and procedures into a landscape planning methodology founded on an ecosystem-based approach and focused on the delineation of ecologically sensitive areas"

This objective was also totally reached. Results in chapter 5 showed how to integrate different logical models, methods and procedures to achieve a planner's goal: the definition and delineation of ecologically sensitive areas was indeed successfully carried out. It was also possible to construct a landscape planning methodology that helps to provide a multi-dimensional viewpoint. The methodology followed a holistic approach in the analysis of the landscape/region. Table 6.1 summarises the interrelationship between different dimensions of the landscape/region and the respective logical models, methods and procedures that support each viewpoint.

However, the constructed methodology requires further development, because other requisites for this kind of methodology, like inter-transdisciplinarity, interagency and interpersonal cooperation were poorly tackled. In this research for example, inter-transdisciplinarity was considered more a target than a requisite. On the other hand, interagency and interpersonal cooperation were only mentioned in the prognosis phase, where the emphasis is on future strategies.

Table 6.1 Interrelationship between different dimensions of the landscape/region and the respective logical models, methods and procedures that support each viewpoint

Landscape holistic dimension	*Devices for supporting*
Landscape as a complex system	Analytical Hierarchy Process model, GIS-procedures, Satellite image processing, Strategic Situational Planning methods.
Landscape as a spatial entity	Analytical Hierarchy Process model, GIS-procedures, Satellite image processing
Landscape as a dynamic entity	GIS-procedures, Satellite image processing, Strategic Situational Planning methods.
Landscape as a mental entity	Landscape network, watershed-ecosystem models
Landscape as a nexus of nature and culture	Analytical Hierarchy Process model, GIS-procedures, Satellite image processing, Strategic Situational Planning methods.

6.2.4 Discussion of objective three

"To investigate the applicability of the watershed-ecosystem paradigm (Bormann and Likens, 1979) and the ecological network principle (van Lier, 1994, 1998) in the context of a real-life ecosystem-base management project".

This objective was partially achieved. In spite of having a selection of two ecological models, the watershed-ecosystem model and the ecological network principle, only the first was applied. The sole option of the watershed-ecosystem model (Bormann and Likens, 1979) enabled the development and support of an ecosystem-based planning project.

The ecological network principle could not be applied due the low degree of fragmentation showed by the vegetation types of the region. On the other hand, the adoption of the watershed-ecosystem model avoided the endless discussion about the concept and limits of an ecosystem. Therefore, this also simplified the development of an ecosystem-based management project.

However, although watershed-ecosystem based territorial units potentially solve the theoretical problems related to defining an ecosystem's limits, and in practice, seem to be a good alternative to cope with arbitrary, politically defined management units, they may not be appropriate when a flat or extremely steep region is analysed. This means that, if there are no mountains and visible watercourses or, in contrast, if the terrain is extremely abrupt, the terrain may not be readily analysed like a nested watershed network. Therefore, there is another open question: Are the watershed-ecosystem based territorial units the most appropriate for landscape/ecosystems analysis and planning? Empirical results derived from ecosystem-based management projects suggest that a more flexible attitude might be advisable during the delineation of management units (Slocombe, 1998). In fact, Slocombe discusses the restrictions of the watershed network approach in strong steep mountain regions and proposes the use of the arbitrary, politically defined management units (!!!) The author of this thesis advocates a flexible attitude during the definition of territorial management units, yet, while theoretical arguments seem to support a flexible and practical attitude, he still considers that an ecosystem-based management planning project should have ecologically defined territorial units. Therefore, other ecological approaches, as those proposed by the Slovakian school of landscape planning deserve to be tried in extreme cases like the ones described (see Zigrai, 1996).

6.2.5 Discussion of objective four

"To integrate the overall holistic multi-dimensional scheme, the strategies to define

and delineate ecologically sensitive areas, the application of the watershed-ecosystem paradigm and the ecological network principle into an anticipatory and flexible planning methodology"

This objective was also fully achieved. Results in chapter 4 show a general methodology capable of being applied to ecosystem-based management projects. Although it is focused on the delineation of ecologically sensitive areas, it is thought to be sufficiently general to be applied to other ecosystem-based management case studies. Furthermore, it was assumed that features associated with specific case studies should be treated with different procedures. Meanwhile, the integration of different logical models, methods and procedures into this general methodology was accomplished. Particular attention was paid to the key characteristics of a holistic approach, mainly those in connection with flexibility and with the inclusion of different viewpoints and procedures.

Undoubtedly, the major strength of the methodology is the degree to which it can be comprehensive. The adoption of the phases of sustainable landscape planning (Botequilha and Ahern, 2002) allows a complete and systematic viewpoint of a landscape planning process. It is important to underscore the inclusion of the syntheresis phase, the phase related to implementation and monitoring. Until the middle of 1990s, the concerns about implementation and monitoring were uncommon in landscape planning methodologies. Most methodologies before 1995 ended in a prognosis phase focused on setting land use priorities, as can be seen in the proposals by Ruzicka and Miklos (1982), Steinitz (1990) and Hasse (1990). In contrast, particular attention has been paid since 1995 to the inclusion of implementation and monitoring. These issues are discussed and explored more fully in the methodologies proposed by Zonneveld (1995), Ahern (1999) and Botequilha and Ahern (2002).

The comprehensive or holistic treatment also enables the methodology to cope with the multipurpose issues involved in ecosystem-based management projects. These are mainly related to the maintenance of a systematic, holistic, comprehensive and inter-transdisciplinary approach, using an anticipatory and flexible planning process, recognising limits for action in defining and seeking sustainability (Slocombe, 1993).

Nevertheless, the results prompt an open discussion about the general versus the particular aspects that must be included in a methodology. In this thesis, this debate is illustrated in chapters 3 and 5. Chapter 3 displays a general methodology emphasising planning phases and broad logical models, methods and procedures to be included. The purpose of the chapter was to maintain enough generality, keeping thus compatibility in further ecosystem-based management projects elsewhere. In contrast, chapter 5 accentuated the logical models, methods and procedures employed to work on the case study. It is there argued that a distinction is necessary in facing the particular issues that arise in each ecosystem-based management project. Finally, in the light of results, the author believes that his decision to maintain generality has been vindicated. However, it is still important to emphasise the details of logical models, methods and procedures when a case study is being tackled.

6.2.6 Discussion of objective five

"To consider and validate the applicability of this planning methodology to a real-life context"

This objective was achieved through the selection of an acceptable case study as a research strategy and the Iztaccihuatl-Popocatepetl volcanoes region as a representative mountain ecosystem. Chapter 5 presented the assumptions that support this choice. First, the advantages of a case study as a research strategy were discussed for proving a constructed methodology. Five factors support this selection: (1) The advantage that a false or a true hypothesis could be identified with the results from one case, as a practical solution to the problem that useful hypotheses might be rejected. (2) The possibility of the use of a variety of research methods and source of data. (3) The adoption of a holistic research approach rather than one based on isolated factors. (4) The capability to deal with the subtleties and intricacies of complex/wicked problems. (5) The feasibility of developing knowledge and, simultaneously, searching for a remedy to problems similar to those present in the case. Second, evidence was provided to support the contention that the Iztaccihuatl-Popocatepetl volcanoes region is a typical example of fragile mountain ecosystems of the world. Also, that its complex problems and management challenges are similar to those occurring in other mountain ecosystems around the world. For these reasons, the Iztaccihuatl-Popocatepetl area provides an opportunity to face many of the common obstacles of ecosystem-based management planning.

In addition, it was demonstrated that this region exemplifies environmental problems such as glacier loss and associated water sources depletion, accelerated soil erosion and a consequent soil loss and landslides, an alarmingly rapid loss of habitat and genetic diversity, widespread poverty among mountain inhabitants and loss of indigenous knowledge.

Despite the demonstration that the Iztaccihuatl-Popocatepetl volcanoes region is a representative case of a fragile mountain ecosystem, the debate again concerns whether the results obtained for this region can be generalized, commonly the weakest point of case studies as a research strategy. However, some issues related to ecology as a science should be set straight. In the first place, ecosystems ecology and landscape ecology are not experimental sciences. Despite some attempts carried out to support the experimental approach in ecosystems research, the results have ultimately come from case studies.

Even the most famous world experience in seeking to improve an experimental approach in ecosystems research, that carried out in Hubbard Brook, USA during the 1960s and 1970s, is a case study (Bormann and Likens, 1979). Furthermore, many of the environmental management problems considered by landscape ecology are dependent from context, and hence, unrepeatable. Therefore, the case study is the most common research strategy in landscape and ecosystems ecology.

Consequently, this author thinks that, despite the fact that many aspects of landscape and ecosystems ecology are dependent from the biophysical and socio-economical context, some similarities in case studies around the world, could give rise to general methodological applications. Meanwhile, the regional particularities must be treated as context dependent aspects.

The results of this work support the contention that it is possible to construct a general methodology suited to face complex environmental problems related to fragile ecosystems. In addition, that ecosystem-based management is an appropriate environmental planning approach to be applied on the Iztaccihuatl-Popocatepetl region and other mountain regions around the world.

6.3 Discussion of the applicability of an ecosystem-based management approach in the context of a real-life problem: The Iztaccihuatl-Popocatepetl case study

This section discusses the results that arise from the application of the constructed methodology. The focus was on the solution to the problem of delineating areas of interest for the author: the ecologically sensitive areas.

6.3.1 Discussion of results from the focus phase

The focus phase was carried out in a satisfactory manner. Goal setting was tackled from the general perspective of the implementing a framework for planning and management. Therefore, a general goal was set for the protection of the Iztaccihuatl-Popocatepetl region/ landscape and for the conservation of its biological diversity. In addition, two subordinated goals were focused on the procedural aspects. It was then proposed to promote integrated watershed management and encourage the development of a planning culture, involving multistakeholders, that would be municipally based.

The watershed approach to landscape/regional analysis and planning was applied to define appropriate geographic areas, taking into account geographical, ecological, economic, social and cultural criteria. Subsequently, a hydrological criterion was employed to delineate an area appropriate for nature conservancy with additional time and money saving concerns.

A group of applicable criteria for the delineation of ecologically sensitive areas was finally chosen.

It is important to highlight here that a key point in the focus phase was the role of the planner and his proposals. It is considered a central point in terms of its importance and influence over the planning process. It was necessary for the author, before the development of the focus phase, to clarify his role as planner and the purposes behind a case study.

Therefore, it was decided initially to assume the role of promoter of a planning process, instead of a traditional adviser; and further on to exploit the opportunities that a case study offers for basic analysis and for the solution of problems. It was considered that this decision the crucial point in planning because it conditions the focus of the planning process.

As well is considered that the focus phase plays the most important role in any planning process. Hence, particular emphasis will be made on the discussion about goal setting results, the use of watersheds as geographically defined units for analysis and management and the selection of criteria for the delineation of ecologically sensitive areas.

A general discussion of the results of goal setting is related to the pitfall of setting objectives in ecosystem-based management. Slocombe (1998) described this pitfall as the imperative need to distinguish between the goals that ecosystem-based management is trying to achieve and the obstacles it faces. He argues that sometimes it is tempting or easy, to define goals in terms of what must be changed, or of the obstacles that must be overcome. He identified this as a mistake that confuses strategic and tactical thinking.

However, in the light of the results, the author thinks that the confusion between strategic and tactical thinking is an inevitable pitfall when the planner must contemplate other stakeholders' interests. Empirical data have demonstrated the need to involve other social and government stakeholders besides those in the planning team (Yaffee, et al., 1995). Yet, government and social actors usually have narrower visions on the aspects that must be changed, or the obstacles that must be overcome. Therefore, it is very hard for a planning team, to convince others to follow ambitious, long-term or not clearly practical land-use projects, regardless of how well supported they might be in terms of their strategic-tactical benefits.

On the other hand, if the planner wants to involve government agencies in an ecosystem-based management project, as is the case of this research, it is impossible not to consider the opinions and objectives of these agencies. Besides, the possibility that the visions of government agencies become the predominant ones should be contemplated. In addition, in terms of land-use planning in Mexico, the predominant land-use decision- making is mostly dependent on what must be changed and what is politically profitable. Hence, it is unavoidable not to include short term and shortsighted goals, unless the role and influence of these agencies is prevented.

Thus, in general terms, the results of this research in setting goals lead the author to consider that identifying goals is still the greatest challenge in ecosystem-based management planning.

Despite the recommendations of Slocombe (1998) to search for goals that are characteristically integrative, complex, dynamic, applicable and adaptive, in practice, a goal hardly might fulfil all these prerequisites, unless it is expressed as a very generally.

For this reason, the present work opted for an eclectic approach, setting one general goal and two subordinated. Five issues were taken into account in guiding this eclectic attempt.

- The important role that the Mexican government has on physical planning in Mexico. It is very hard to think of a project in regional land-use planning without taking into account the role played by Mexican government agencies.
- It was realised that the main purpose of the planner should be that of involving government agencies in a project to protect the Iztaccihuatl-Popocatepetl volcanoes landscape and its associated biological diversity.
- The complementary objectives related to protecting mountain fragile ecosystems and biodiversity were taken from Agenda 21. The role of Agenda 21, as an agenda that Mexican environmental government agencies must follow was also recognised. Often this duty gives leads to a desperate search for pilot projects. The author hopes that the Iztaccihuatl-Popocatepetl landscape project will be considered such a pilot project.
- Sustainable development and environmental sustainability were taken into account as prerequisites for planning landscapes and multifunctional territorial units. Here, multi-functionality and sustainability were considered to be complementary concepts, because the goals relative to the achievement of regional sustainability depend on the use of landscape for multiple purposes.
- The need to develop an understanding of regional ecosystems and the implementation of a framework for planning and management were taken into account. These aspects are also reflected in the construction of a strategy to confront regional threats to biodiversity conservation described in the prognosis phase.

However, as a result of this eclectic solution to goal setting, the author feels trapped in a generality-particularity paradox. On one side, the degree of generality involved in statements such as improving coordination of regional efforts at all policy and decision-making levels, encouraging the development of a planning culture and promoting integrated watershed management programmes; on the other, for the limited scope of the goals set, when give only a partial view on the goal of conserving natural capital, leaving out other important competitive goals like the need to identify critical natural capital (Ekins, 2003) or defining regional systems of ecological stability (Zigrai, 1996). The author considers that the results from the syntheresis phase, the phase related to implementing and assessing the plan, have the answer to this paradox. As it can be seen, goal setting is a very complex task indeed.

The results also support the approach of watersheds as units for analysis and planning. Their selection permitted the consideration of a landscape as a real geographical unit and the advantages linked to treating them as water-related units. In addition, this approach facilitated the operational aspects of integrating a good database and the delineation of the limits of the region under study. Although, this procedure accomplished the aim of reducing the area under study and having a clearer focus on the regional conservation problem, it did limit the landscape/ regional perspective needed for the prognosis phase. In the light of the results, the author recommends the use of the watershed approach for the delineation of areas in land-use planning.

Focusing on the selection of criteria to delineate ecologically sensitive areas, it is important to highlight this point as one of the cornerstones of this research: the use of a multi-criteria approach. Although, the criteria chosen come from another research, their integration to an analytical hierarchy process is a contribution of this thesis. A hierarchy provides an easy way of ordering these criteria and the related attributes, through an interrelated arrangement of levels of complexity. This process was focused on fragility of habitat and on ecological and cultural values criteria.

Particular consideration should be given to another criterion that was originally taken into account: landscape fragmentation. Without exception, the landscape planning schools of thought and landscape theories consider landscape fragmentation as the main problem and its control as a main goal. Hence, this criterion was initially contemplated as important, but to be subordinated to fragility of habitat. However, the results derived from the application of some fragmentation indexes (number of patches, patch richness and connectivity) to the spatial data were inapplicable or of no value in delineating ecologically sensitive areas. This failure was explained at first by the source of the indexes, many of which were based on the analysis of spatial patterns that were computer-derived but not real data. Thus, this author supported the hypothesis that computer-derived landscape patterns poorly represented actual landscape patterns. However, the employment of the same indexes in subsequent landscape planning studies in Mexico has permitted the postulation of an alternative hypothesis: these indexes are applicable only under conditions of high or extreme fragmentation and they are useless in low fragmentation conditions, as it seems to be the case with protected areas. Therefore, it appears that further research is necessary to to identify appropriate measures that permit the delineation of areas under different degrees of fragmentation.

6.3.2 Discussion of results from the analysis phase

Results from this phase reveal the strengths and weaknesses of the regional analysis carried out in this thesis. On one side, the results support the strengths associated with the integration of a logical model of multi-criteria analysis, a satellite image processing method and GIS procedures. On the other, it also shows the main weaknesses of this analysis, considering the short period employed to assess regional land-use change patterns.

An overall evaluation of this phase must now be presented. The basic information for the further diagnosis of the landscape/region and the delineation of ecologically sensitive areas was successfully assembled. Weighting criteria/attributes to reflect a range of different criteria were successfully derived. The results of this phase represent important contributions of this thesis to the improvement of the way to reflecting the views of experts. Despite the short period under consideration, important information related to the loss of regional vegetation cover was generated.

Undoubtedly, the flexibility and complex analysis capabilities of the Analytic Hierarchy Process were the main support behind the results of this section. The Analytical Hierarchy Process permitted a broader representation of criteria/attributes and the interrelationships between them. This analytical process also provides a systematic basis for the weighting procedures to evaluate the priorities of each attribute/criterion used to delineate areas that were ecologically sensitive to erosion.

Particular mention should be made of the procedure designed for consulting and capturing the views of experts. One of the main procedural contributions of this thesis was the design itself. The results demonstrate the usefulness of two aspects related to the meeting format and the "dominance gradient" respectively. Both aspects facilitated the work of experts and profited from their scarce time. The meeting format saved much time, including the characteristics of the session, the clear statement of aims and objectives and the procedures to be employed. On the other hand, the "dominance gradient" allowed data for the calculation of the priorities vector to be obtained, enabling a high level of consistency in the judgements. Also, a surprising result from this case study was the utility of the "dominance gradient" for consensus building. It is suggested that this heuristic instrument should be employed in the future whenever criteria/attributes need to be weighted.

However, the application of the Analytical Hierarchy Process had a weak point. A bias was detected during the judgement of the contribution of soil cover to erosion susceptibility. This bias was occasioned by the way in which selected information was made available to the experts. The table of soil loss according to different land uses, as suggested by Bormann and Likens (1979), strongly influenced the judgements of the experts. As a consequence, soil cover was considered as the most important criterion to explain erosion susceptibility (50%). In addition, natural vegetation cover was viewed as the attribute with the lowest value (0.6% - 1.8%). The most important repercussion of this bias was that, those areas without a natural vegetation cover were extremely sensitive. Those areas with urban-bare soil cover were distinguished as those with the maximum value of susceptibility. This influence can be seen in the map of areas sensitive to erosion, where most of them are located in areas without vegetation cover. Therefore, it is suggested that further research is required in order to establish more accurately the influence of soil cover on susceptibility to erosion. This author argues that if this influence is as strong as it appeared to be in this case study, the use of other criteria such as steepness, drainage density or soil depth could become not useful at all.

The most outstanding point of the construction of the GIS regional database is in connection with the quality of the sources of information. The partial availability of recent data sources is the limiting factor of regional analysis in Mexico. Sometimes these sources are non-existent or they are reserved for the exclusive use of government agencies or selected academic groups. The lack of up to date regional data is a common situation in Mexico. This lack impedes appropriate research on regional dynamics in this country. As an example, this research was affected by the unavailability of enough satellite images for a better and up to date estimation of the dynamic of soil cover changes. This fact gave rise to the main weakness of the analysis phase about the limited period for which it was possible to estimate this dynamic. However, despite this limitation, the results at a regional level show a loss of about one sixth of the total vegetation cover from the surface above 2 500 meters over a seven years period. This large value further encourages the application of effective coordinated measures required to protect the Iztaccihuatl-Popocatepetl region/ landscape as well as the conservation of its biological diversity. Mainly, as the greater part of the surface above the 2 500 meters is a national park, more protection should be given to it in the future.

At the level of sub-watersheds, the results enabled the local factors that explain land use change patterns to be identified. Thus, the five sub-watersheds could be located in two major groups: sub-watersheds affected by urban use pressures and those under the pressure of an expanding agricultural land. Urban growth seems to affect the Texcoco-Zumpango and Balsas-Santo Tomas sub-watersheds, being in both cases the neighbourhood of these areas characterised by rapid urban growth. On the other hand, the need of agricultural soil affects the remaining sub-watersheds of Atoyac-San Martin Texmelucan, Tetlanapa and Huautla. An interesting point related to this set of sub-watersheds is the increasing need for agricultural soil caused by the proximity of the largest market for farm products in Mexico.

6.3.3 Discussion the results from the diagnosis phase

The results from this phase are a diagnosis of the current landscape/region and watershed ecosystems of the Iztaccihutal-Popocatepetl region. This diagnosis provides a general view concerning the degree to which this region is functioning well in terms of nature conservancy and regional factors that threaten it. In addition, these results also permit an overall evaluation of the spatial analysis chosen in the methodology.

Results allow an optimistic viewpoint of the constructed methodology because this phase was successfully achieved. There are results that also support the success in the integration of logical models and GIS procedures: (1) The integration of priority vectors derived from the application of the Analytic Hierarchy Process with the delineation of ecologically sensitive areas to erosion. (2) The integration of uncertainty/information measurements with the estimation of biodiversity in the delineation of ecologically sensitive areas to biodiversity. Likewise, GIS procedures were used successfully in the integration of satellite image processing methods for the delineation of ecologically sensitive areas to land use change. Results derived from the employment of methods from Strategic Situational Planning permitted an identification of spatial conflicts.

However, it is important to mention that the results of this phase were strongly affected by two previous decisions: the selection of the area under study and the high value assigned to the vegetation cover by the experts. In the first place, the selection of the area under study limited the possibilities for a richer regional analysis. In the second place, the large weight assigned given to vegetation cover possibly biased the susceptibility to erosion analysis, as was previously discussed.

Although results of the diagnosis of threats to nature conservation and the identification of spatial conflicts were achieved successfully, they did not arise from a consensus building. Despite the fact that this author attempted to summarise diverse opinions from different stakeholders involved in the nature conservancy problems of the region, in the end, the results ultimately reflect only his viewpoint.

It is important to point out that while the integration of logical models, methods and GIS procedures are common routines in multi-objective land-use decision making, there is an important logical and theoretical work behind the decisions about objectives to be achieved and criteria and attributes to be employed. This is exemplified in the case of the delineation of areas ecologically sensitive to erosion. According to van Zuidmann (1986), the criteria to be considered should be steepness, vegetation cover and soil depth. However, this last criterion is not easily available for really large areas, as is the case when dealing with landscapes/regions. Thus, alternative criteria should be employed in these circumstances. Of more general value was the estimation of drainage density made in this research, a criterion that can be estimated without expensive fieldwork and that could be applied to further erosion studies.

Moreover, the lack of empirical data to determine the influence of soil cover on erosion was tackled through a procedure designed to consult experts. The influence of soil cover is often estimated in a nominal form, but the results of the different priority vectors support a more systematic and objective estimation. Consequently, it is suggested that the Analytic Hierarchy Process for multi-criteria analysis be employed to support multi-objective and multi-functional landscape planning.

Similarly, the use of uncertainty measurements to estimate biological diversity has been a common practice in ecology during the last 50 years. Nevertheless, they are not often employed in the case of regional habitats (beta diversity). The results of this research contribute to this field through the application of a common diversity index, the so-called Simpson's index (Simpson, 1949), for the assessment of the regional diversity of vegetation types. This application allowed the identification of the more heterogeneous areas in terms of vegetation types, and as a consequence, those with greater habitat richness. Fortunately, these areas in the volcanoes region are located inside the Iztaccihuatl-Popocatepetl National Park, and in addition, they are not fragmented. Hence, there are enormous possibilities for their protection. The success of its application recommends it as an appropriate indicator for regional studies on diversity of habitats and for the delineation of areas under a biodiversity criterion. Certainly, a finer vegetation classification and more satellite images would also permit a detailed description of the regional shifting mosaic (Bormann and Likens, 1979).

In contrast to the previous results, those related to the delineation of areas ecologically sensitive to erosion were disappointing. All areas under erosion risk coincide with those areas dedicated to agriculture or those with bare soil that are located on a broad strip surrounding the area under study. Therefore, there were not any areas ecologically sensitive to erosion in the area under study, except those located at the top of the volcanoes. In addition, it was supposed that the delineation of the areas sensitive to erosion and to vegetation cover change could help. However, the attempt failed because the results were a set of scattered areas far from the region of the study.

The arguments that explain these results have been discussed previously. The results reflect the effects of the selection of the area under study and the high weight assigned to the vegetation cover by the experts. Thus, in the light of these results, this author suggests that this methodology should be applied only to those regions or areas which are subject to significant human impacts. Otherwise, in order to evaluate the fragility of habitat, it is recommended that only the biodiversity of habitats measure be employed in those regions with a relatively well-preserved vegetation cover.

Results derived from the delineation of areas ecologically sensitive to land use change were also affected by the choice of the area under study. From a landscape perspective, it shows few effects of land-use change. However, at the sub-watershed scale, there are two hot spots. Those hot spots are located in Tetlanapa and Atoyac-San Martin Texmelucan sub-watersheds, both of which display a big loss of vegetation cover as a consequence of the development of those areas that are dedicated to farm activities, mainly agriculture and orchards. From a methodological perspective, the author considers this application is appropriate for the delineation of areas derived from land use change. The satellite image processing provides a strong database for updated analysis and the GIS procedures provided the support needed for database management and the visualisation of results. Therefore the methodology is also recommended for application in delineating areas that have suffered land use change and finding significant trends in regional land-use change.

According to the results of the analysis of the conservation of nature in the volcanoes region and its treatment as a complex-wicked problem, land use change patterns are considered the main threat to nature conservancy. In addition, the problem associated with undefined conservation and development policies and programs at the state and municipal levels was identified as the main cause that is producing change in land-use patterns in the volcanoes region.

The results that have arisen from the analysis of a top-level policy-making and decision-making perspective reflect the regional socio-economical context. They also support the potential of the methods employed to analyse complex-wicked problems, such as those used to achieve regional sustainability. The author of this thesis argues that the selection of these methods was a correct decision. They permitted significant issues to be revealed, not only for diagnosis purposes but also to feeding the prognosis phase. Particular attention should be paid to the complete causality network and the tree of main problems. The causality network provides a global view of the complex problem and the synergy among related problems. The main problems' tree summarises the complex problem and provides a clearer focus for the prognosis phase.

However, despite the methodological potential employed to obtain the results, there is a weakness in this process. The analysis of this complex problem of nature conservancy only reflects the viewpoint of this author; it is not a result of a consensus building process. Even so, this analysis can be considered to be a good approximation to the regional reality and an excellent start point for initiating a discussion involving a wide range of different multistakeholders. For that reason, this methodology is also recommended for application in regional policy-making and decision-making analysis in the highest level.

6.3.4 Discussion of results from the prognosis phase

The results from this phase reflect the integration of the outcomes from the focus, analysis and diagnosis phases. It presents and integrates the results of an evaluation of the potential for sustainable development of the Iztaccihuatl-Popocatepetl volcanoes region.

The integration of the focus, analysis and diagnosis phases is reflected in the construction of a strategy to confront the regional threats to biodiversity conservation in a context of environmental sustainability and sustainable development. The focus phase contributes with the identification of the goals for progressing towards regional sustainability. The main contribution is those aspects related to the improvement of coordination of regional efforts at all policy and decision-making levels, the promotion of integrated watershed management programmes and particularly, the encouragement for developing a planning culture that accommodates multistakeholders and is based on municipalities. Relevant contributions from the analysis phase are the data employed to estimate regional land-use change during the period 1993-2000. The diagnosis phase is the foremost contributor to the prognosis phase. It provides with substantial information needed to propose a network of ecologically sensitive areas, as well as the essential information related to the problems of land-use change patterns in the Iztaccihuatl-Popocatepetl region. In addition, this phase displays results that are derived from a typical prognosis. A forecast of the evaluation of the region's potential for sustainable development was developed.

Also, based on the outcomes, a strategic proposal to achieve regional sustainability was constructed, focused on supporting the development of a municipality-based planning culture.

As an overall evaluation of this phase, the results fortunately support the planning process. Particularly noteworthy is the prognosis exercise, designed to evaluate the regional potential for sustainable development. These results and those related to the evaluation of threats to nature conservancy are the cornerstone of the subsequent strategy to confront them. For this reason, the contribution of the BLFUW team (BLFUW circa, 2000) should be acknowledged in the development of indicators of potential for sustainable development and checklists. Their catalogue of indicators and checklists integrate a practical instrument to assess, in a simple form, the regional capabilities to achieve sustainable development. However, the integration of attributes and sub-criteria derived from the potential sustainable development criterion into a hierarchy, weighting procedures and AHP methods is the topic for a future research. Meanwhile, this author recommends further applications of this set of indicators in regional assessment studies, independently, if the search is involved or not with ecologically sensitive areas.

A particular aspect of the outcomes from the prognosis application is worthy of mention. Despite the outcomes arising from the simple expert's checklists of indicators, they gave enough data to characterise the regional potential for sustainable development. Thus, these data permit the author to assert that, at least for the set of area-related indicators, the volcanoes region is a region in which sustainable development can be achieved. Hence, there exist possibilities for improving its conservation and protection as well as promoting the sustainable development of the region.

However, particular attention should be given to the topics related to the lack of a regional planning culture and strategies for the future. They seem to be the restrictive factors to be dealt with if the plan is to move towards regional sustainability. For this reason, the strategic proposals are focused on the development of a municipality-based planning culture.

Nevertheless, in spite of this optimistic viewpoint about potential indicators of sustainable development, they should be taken with some reservations. It seems that these indicators are still very general but also context dependent. Their degree of generality could lead to the conclusion that almost any well-conserved and protected area has good potential for sustainable development. Also, that a well-structured regional planning regime would, by itself, increase the regional potential for sustainable development. On the other hand, in terms of context dependency, it is possible that a combination of well structured regional planning and highly fragmented landscapes can occur in a European developed country. In contrast, in a developing country, this situation is the opposite: a low fragmented landscape and a poor or non-existent planning culture. Therefore, the employment of sustainable development potential indicators should be complementary to other regional analyses. For this case study, these indicators were an excellent complement to the social context analysis carried out using Strategic Situational Planning methods.

Likewise, the proposition of a regional network of ecologically sensitive areas has also an optimistic result. This network is not necessary as a result of the well-connected spatial pattern of vegetation cover. However, the outcome should be analysed in the context of theoretical and decision-making aspects that led to it. First, the network principle (van Lier, 1998) that was cited in support of this proposition seems to be applicable only under conditions of fragmented or very fragmented landscapes. It may also apply only in cases where the object under study is just one species and the purpose of the study relates to its pattern of spatial distribution and meta-population relationships. This was not the case of the Iztaccihuatl-Popocatepetl region, where the approach was based on the spatial pattern of the vegetation cover which showed minimal fragmentation.

Another theoretical aspect that influenced this result was the spatial scale aspect. Spatial scale influences the phenomenon of fragmentation. Many times small-scale approaches disguise regional fragmentation. This is the case in this research, where the results of fragmentation in the upper-watersheds hide the regional problem of fragmentation as is discussed below.

Moreover, the selection of the area under study influenced strongly this result. The interest of the author for nature conservancy and saving time and money led to the selection of only the upper-watersheds of the volcanoes region. Although these sub-regions have suffered from human impact, their mountain characteristics such as altitude (up to 2 500 meters above sea level), steepness (up to 15 degrees), relatively cold climate and thin soil, all tend to limit farming activities. Besides, the main surface of this sub-region is an area under legal protection. This fact precludes open access to its resources. For these reasons, the area has a low degree of fragmentation. In contrast, if all of the five regional watersheds are taken into account, this is a major area under the effect of human impact; the result is a fragmented natural vegetation cover pattern. This shows a pattern characterised by the vegetation that remains at the top of the regional mountains. As a consequence, there is a need for a regional land use plan that includes them as part of a regional network.

In terms of the construction of a strategy to face the regional threats to nature conservancy, the results show that the development and arrangement of a series of proposals was achieved. The author thinks that this is one of the most outstanding results from the thesis. The development of strategies was supported by integration and synthesis efforts. On one hand, it was possible to integrate results from the analysis of regional land use change as a complex/wicked problem with the evaluation of regional potentials for sustainable development. On the other, it was feasible to establish guidelines from a practical perspective. This arrangement contributed to the achievement of the main goals for this case study, which were to improve coordination of regional efforts at all policy and decision-making levels and to promote encourage and understand the importance of the measures required to protect the Iztaccihuatl-Popocatepetl volcanoes region/landscape and conserve its biological diversity.

It is assumed also that the developed strategic axis and prior actions schemes could play the role of "trigger mechanisms" to achieve regional environmental sustainability and to support regional pathways towards sustainable management.

It is postulated that the strategic scheme that has been developed, correctly confronts the situation of the lack of required skills and capabilities for the achievement of a regional planning culture at the municipality level. This lack of skills and capabilities was previously stated as the main obstacle to achieve or realise the regional sustainable development potential. Also, it was noted that the selected multi-stakeholders scheme is the best means of achieving the general purpose of improving regional planning culture. It is assumed here that it is acceptable to propose the establishment of inter-institutional task forces, the selection of possible stakeholders and the coordination of these tasks forces.

From a theoretical perspective, the developed strategies confirm the robustness of the Strategic Situational Planning methods to tackle complex problems and lead to their possible solutions. This is supported by the strategies developed to face the problem of land-use patterns change in the volcanoes region. Undoubtedly, the method based on the identification of critical nodes is its main heuristic characteristic. The application of this method in the case study has led to the creation of solutions to the main difficulties associated with the complex problems of land use change. Additionally, the set of possible solutions permits the construction of a plan that is characterised by a holistic viewpoint of the complex problem that accommodates the synergy needed to attempt an integrated solution. Consequently, the author recommends the adoption of this approach in the analysis and development of solutions to complex planning problems.

Nevertheless, it is also recognised that the strategies developed also have a strong weakness: they are the result of the point of view of one expert. They are not the result of a consensus built among multistakeholders about the regional problems related to the achievement of sustainability. Despite the fact that the author sought to summarise other experts' viewpoints, the results still just reflect a personal point of view. Thus, it is likely that the author's interests in environmental sustainability and nature conservancy biased the perception of the problem. Undoubtedly, there is a lack of other disciplinary viewpoints that would be needed to picture a more refined vision of the volcanoes region sustainability problems. However, the author contends that his vision is a valid viewpoint. Therefore, there is a willingness to examine other viewpoints and convince their advocating stakeholders.

6.4 Conclusions

In the light of the obtained results, this chapter has discussed the achievement of the general goal of this thesis. To this end, the following issues have been examined

1. The accomplishment of the design of an ecosystem-based management planning methodology and with an emphasis on holistic characteristics and considerations of sustainability as a prerequisite for planning.
2. The fulfilment of the application of multi-criteria analysis to the delineation of ecologically sensitive areas as those that need to be taken into account in nature conservancy.
3. The potential of an ecosystem-based management approach to the development of a land-use planning strategy.
4. The integration of different logical models, methods and procedures into a general methodology,
5. The five dimensions of a holistic landscape research. The application of multi-criteria analysis to this process demonstrated that a holistic approach could be applied to define and bound those areas of interest to planners.

As a consequence, it can be concluded that the two main processes were accomplished: the construction of an ecosystem-based management landscape planning methodology and the delineation of ecologically sensitive areas for nature conservancy planning.

As well, it is assumed that this methodology is applicable to other landscape planning situations. Also, the outcome from the literature review demonstrated the need for:

1. A multi-dimensional approach to solve problems associated with the environment and development planning;
2. An integration of environment and development, when the concepts of sustainable development and environmental sustainability have been involved;
3. A landscape planning methodology hat seek to facilitate multi-dimensional viewpoints emphasising interdisciplinarity, interagency and interpersonal cooperation;
4. A multi-dimensional approach to define and bound those areas of interest to planners, i.e. ecologically sensitive areas.

The lack of a sufficient empirical foundation to avoid the three main weaknesses of holistic approaches was examined: the relative importance that must be given to different viewpoints, the vagueness of goals and objectives and the effectiveness of proposals in terms of acceptance and sustainability. As a consequence, it is concluded that modern landscape research should be oriented to holistic and inter-transdisciplinary approaches, but particular attention should be given to answer the questions related to the weakness of holistic studies.

In addition, a discussion has been presented of how the results of chapter 5 support the integration of different logical models, methods and procedures to define and delineate ecologically sensitive areas. This has contributed to the construction of a landscape planning methodology that helps to achieve a multidimensional viewpoint and the interrelationship between different holistic dimensions and the respective logical models, methods and procedures that support each of them. Other requisites such as inter-transdisciplinarity, interagency and interpersonal cooperation were not treated as satisfactorily.

Consequently, it is suggested that has been demonstrated that it is possible to achieve a successful integration of different models, methods and procedures into a landscape planning methodology. It is believed as well that the holistic landscape scheme proposed by Tress and Tress (2001) is a good framework for a multi-dimensional viewpoint of a region/landscape. Finally, the need of further developments in the constructed methodology was considered, in order to emphasise issues related to inter-transdisciplinarity, interagency and interpersonal cooperation.

In this chapter, the potential of the sustainable landscape planning methodology (Botequilha and Ahern, 2002) was analysed and the watershed-ecosystem model (Bormann and Likens, 1979) has been explored to allow the development of a theoretical and practical support for an ecosystem-based planning project. Emphasis was made on to the flexibility of this methodology for organisation and integration, as well as on its adaptive managing possibilities. On the other hand, the watershed-ecosystem model was noted as a model that facilitates the development of an ecosystem-based management project. Consequently, it is concluded that the sustainable landscape planning methodology and the watershed-ecosystem model have convincing potential for ecosystem-based management projects.

The practical issues associated with the constructed methodology were questioned. As a consequence of the lack of implementation of a plan, it is questioned if it is applicable or not. Similarly, the watershed-ecosystem model is questioned in the case of extreme cases: flat or highly abrupt terrains. As a consequence, it is thought that further studies should be carried out focused on the evaluation of an implemented plan and on the application of other ecological models such as those originated in the Slovakian school of landscape planning (Zigrai, 1996).

This chapter has discussed the results of the construction of a general landscape planning methodology, suitable to ecosystem-based management projects. Its three main properties were analysed: its generality enable it to be applied to other ecosystem-based management case studies; its harmonizing capabilities for models, methods and procedures; those holistic characteristics related to flexibility and to the capability to include different viewpoints and procedures. As a conclusion, the comprehensive nature of this methodology was regarded as a major strength to cope with the multiple purposes involved in ecosystem-based management projects. Meanwhile, a debate is opened, as to the general and particular aspects to be included during the construction of a methodology.

This chapter also surveyed the discussion about the acceptability of selecting a case study as a research strategy and the Iztaccihuatl-Popocatepetl region as a representative mountain ecosystem. Particular emphasis was made on the debate of whether the results in this region could be generalized and to the case study as the most common research strategy in landscape and ecosystems ecology. As a consequence, it is proposed that general methodological applications might be generalised and that an ecosystem-based management approach is an appropriate approach to be applied to the Iztaccihuatl-Popocatepetl region and to other mountain regions around the world.

In the second section of this chapter, the results of the applicability of the theory and general principles of ecosystem-based management in the context of a real-life problem were discussed. Results derived from the Iztaccihuatl-Popocatepetl case study were reviewed in the light of theoretical and practical perspectives.

The pitfall of goal setting in an ecosystem-based management project was examined in depth. This process is seen still as the greatest challenge in ecosystem-based management planning and that it was concluded an eclectic approach might be the best alternative. The role and proposals of the planner were also discussed and, as a consequence of this discussion, the author considers that the planner should play the role of promoter of the planning process, instead of that of a traditional adviser.

Also, the adequacy of the watershed approach and hydrological criteria for landscape/ regional analysis and planning was discussed. A watershed approach for the delineation of areas in land-use planning was recommended. In addition, the applicability of a series of criteria for the delineation of ecologically sensitive areas was also reviewed and, as a result, the multi-criteria approach was considered one of the cornerstones of this research, because it gave place to a holistic view of the ecologically sensitive areas.

Results about the integration of a logical model of multi-criteria analysis, a satellite image processing method and the GIS procedures for the delineation of ecologically sensitive areas were also examined. The results support this integration as one of the strengths of this work. In contrast, a weakness linked to the analysis of the short period employed to assess regional land-use change patterns was acknowledged. Particular emphasis is made on the availability of recent data sources as the limiting factor for regional land use dynamics studies in Mexico. However, despite this limitation, important regional data related to natural vegetation cover loss in the volcanoes area were generated.

The flexibility and complex analysis capabilities of the Analytic Hierarchy Process were discussed. Particular attention was paid to the potential of a hierarchy to give rise to a view of criteria/attributes and to the interrelationships among them. In this research, the Analytical Hierarchy Process is considered as the main logical support behind the results of multi-criteria analysis. In addition, the contributions of this work to improve the consultation of experts were noted. Namely, the procedures designed to include the experts′ judgments. Further use of these contributions (meeting format and "dominance gradient") as heuristic instruments for improving consensus building among experts is suggested.

A bias during the judgement of the contribution of soil cover to susceptibility to erosion and its influence during the delineation of ecologically sensitive areas was analysed. It is suggested there is the need for further research in order to establish accurately the influence of soil cover.

This chapter also discussed the results of a regional diagnosis to provide a vision about nature conservancy and the regional factors that threaten it. Results of land use change patterns from a landscape and sub-watershed scale were noted, as well as a limitation related to the analysis of the regional complex problem of nature conservancy. However, despite the limitations of this diagnosis, it might be considered a good approximation to regional reality, and an excellent start point to initiate discussions involving different stakeholders. In addition, two hot spots related to loss of vegetation cover were located in the Tetlanapa and Atoyac-San Martin Texmelucan sub-watersheds.

This chapter has also revised the results achieved during the prognosis phase. Procedures employed to construct a strategy to confront regional threats to biodiversity conservation in a context of environmental sustainability and sustainable development were discussed, and also the limitations of the network principle (van Lier, 1998) and spatial scale influences under condition of fragmented or not fragmented landscapes. It is concluded that the network model is not applicable to areas where the natural vegetation cover patterns show minimal fragmentation. It was concluded as well that a small-scale could disguise regional fragmentation.

Finally, the lack of skills and capabilities required to achieve a regional planning culture at the municipal level was also noted. As a consequence, it was concluded that a goal related to improving the coordination of regional efforts at all policy and decision-making levels, integrated watershed management programmes, and specifically, the development of a planning culture, based on multiple stakeholders at the municipal level, should be forested. The role of strategies linked to this goal, as a "trigger mechanism", to achieve regional environmental sustainability has also been proposed

Chapter 7 Conclusions

7.1 Introduction

This chapter puts forth the final conclusions of this thesis. The chapter begins by summarising the rationale behind the logical framework and case study that has been carried out. Secondly, the lessons that the author has learnt from this research are discussed and partial conclusions provide that are derived from the logical framework. Thirdly, future research possibilities in the wider spectrum of ecosystem-based management and sustainable land-use planning are discussed and a research agenda presented. Finally, the main contributions of the thesis are presented and discussed.

7.2 Research summary

This thesis started with two basic research questions: What in theoretical and practical terms, does landscape planning for sustainability mean? and what does it mean to conceptualise the landscape as the appropriate scale and context for sustainable planning and sound resource management? These questions were tackled through two simultaneous research tasks: (1) a bibliographic investigation, searching for the conceptualisation of sustainability and landscapes in terms of landscape planning and how these concepts have been considered and integrated by the main schools of thought in landscape planning. The main findings were presented in chapters 1 and 3. As a result of this investigation, two central points of this thesis were decided: the need to consider sustainability and landscape from a multi-dimensional-holistic viewpoint; and to focus the landscape planning process on an approach that considers sustainability as a prerequisite and has a well-supported ecological basis. Thus the ecosystem-based management approach was selected, a variant of the ecosystem management landscape planning school of thought. Theoretically, ecosystem-based management seems to be a scientific and integrative approach that seeks to include of different perspectives in landscape planning. It considers sustainability as a prerequisite, seeks to be holistic and to use anticipatory and flexible research and planning processes. Nevertheless, many of these characteristics are derived from theoretical reflections on ecosystem approaches, yet on few applications. It was considered an interesting research challenge to search for the development of an ecosystem-based approach, and in a developing country, where these kinds of approaches have never been attempted.

The choice of ecosystem-based management leads to another research question: How can a landscape planning process be constructed, in order to accomplish sustainability as a prerequisite, while satisfying all the characteristics linked to ecosystem-based management approaches, such as holistic viewpoints, the involvement of multistakeholders and agencies, the employment of an anticipatory and flexible research and planning process and so on?

This research question was answered considering theoretical and practical aspects. It was first investigated what theoretical basis could support landscape research that was holistic, comprehensive, transdisciplinary and systems approach-oriented and what the theoretical support to naturally define management units could be (the main results were presented in chapters 1 and 3). Second, the practical aspects were analysed, relative to a landscape planning approach that would allow focusing on clear goals and active management, an anticipatory, flexible research and planning process, along with the inclusion of stakeholders and their activities (whose main results were presented in chapter 2).

The results of the investigation of the theoretical aspects led to the adoption of a recent approach in landscape research: the holistic, multi-functional and transdisciplinary approach (Naveh, 2000, 2001; Palang, et al., 2000; Tress and Tress, 2001). In addition, results on the practical aspects contributed to take into account the sustainable landscape planning methodology (Botequilha and Ahern, 2001). The analysis of these theoretical and practical aspects in landscape research and planning gave rise to yet another research question: How can the holistic, transdisciplinary approach to landscape research and the phases of sustainable landscape planning methodology be integrated?

This question led to a reconsideration of how the problems related to the land-use decision making process had been treated in order to achieve sustainability. As a result of the literature review process, two points were found to be of paramount importance: the role of the planner and his main challenges. According to van Lier (1998), a land-use planner plays the role of a finder of creative solutions (strategies) to address the problems related to sustainability of conservation and development. On the other hand, Slocombe (1993) argues that the main challenges of a planner, in terms of land use planning, are the development of methodologies that seek to facilitate holistic and systemic viewpoints, inter-transdisciplinarity, interagency and interpersonal cooperation; and also the construction of strategies to define and delineate areas of interest.

These two challenges provide the focus needed for the integration of the theoretical and practical aspects as already described. Hence, it was decided to construct a holistic, comprehensive and inter-transdisciplinary methodology and to orient the landscape planning process to the delineation of a particular type of area related to nature conservancy: i.e. ecologically sensitive areas (main results were presented in chapter 3). Thus, the scope of this thesis was decided: the construction and testing of a landscape planning methodology founded on an ecosystem-based approach and focused on the delineation of ecologically sensitive areas.

In other respects, to what extent can this methodology be applicable, was the last major research question. The application of this methodology in a case study gave the needed empirical support for the assumptions included in its design. The application also gave rise to a set of particular research questions that were included and addressed in chapter 5. Results from the application to the Iztaccihuatl-Popocatepetl region, in Mexico, demonstrated the usefulness and potential of the methodology (whose main results and their meaning are presented in chapters 5 and 6). The case study proved to be a real research challenge, characterised by wicked problems related to nature conservancy in a hard, social, economic and cultural context, common obstacles fund in ecosystem-based management projects in a developing country.

The volcanoes region exemplified a typical case of a mountain region that is experiencing environmental and cultural degradation. Results of this research underscored the main problems related to conservation, management and recovering of mountain ecosystems as fragile ecosystems in developing countries. This research emphasised the problems landscape fragmentation in natural areas, caused by both natural and anthropogenic causes. These problems were shown to be the main cause of habitat loss and consequently detrimental effects on regional biodiversity and essential ecological processes. In addition, these results also contribute in a significant manner to the analysis and planning of this important fragile mountain landscape of Mexico. Finally, this research also evaluated the regional potential for sustainable development. A common paradox of developing countries was analysed: despite the threats to nature conservancy, protected areas in these countries usually show enormous area-related potentialities to sustainable development. However, the lack of a planning culture and regional strategies for the future is the common factor that impedes a regional sustainable development. Consequently, an indicative plan, based on the development of a municipal planning culture was proposed.

7. 3 Main lessons of this thesis

The thesis started with an overall research question: What does landscape planning to achieve sustainability mean, in theoretical and practical terms? After this research, it was learned that sustainable landscape planning could be conceptualised as a form of land-use planning that has five main characteristics: (1) it makes emphasis on landscape resources and environmental attributes as the primary determinants in land-use decision-making (van Langevelde, 1994); (2) focuses on landscapes/regions as areas that are enough large (from 100 to 2 500 Km^2 accordingly to Klinj and Udo de Haes, 1994); (3) it includes a multifunctional concept of a landscape that meets environmental goals and human needs (Naveh, 2001; Fry, 2001; Tress and Tress, 2001); (4) sustainability is considered to be a prerequisite for planning (it is the all-inclusive, underlying and fundamental goal); and (5) it is an integrative way of planning that includes the three main steps in land-use planning, as proposed by van Lier (1998): physical planning, land (re) development and land management (Botequilha and Ahern, 2002).

The next questions to answer were whether landscapes/regions can be recognised as the scale that might be the most important for attaining sustainability and the most appropriate context for sustainable planning and essential to sound resource management and what does all this mean. (Forman, 1995; Gustafson, 1998; Botequilha and Ahern, 2002). Addressing this question, this research gave rise to several lessons.

The first lesson learned from this research was to maintain an open-ended attitude to the concept of sustainability and sustainable development. It meant to consider that, in essence, sustainable development should to be considered a continuous process of change, seeking harmony among exploitation of resources, direction of investments, orientation of technological development and industrial change (van Lesterijn, 1994; Bossel, 2000). The second, that in practical terms, the concept of sustainability gives rise to other important concepts in landscape planning, such as multi-functional landscapes, sustained natural resource yield, carrying capacity of the landscape and a holistic viewpoint on landscape research and planning (Steiner, et al., 1988, 1991; van Langevelde, 1994; Zigrai, 1996; Miklos, 1996; Naveh and Lieberman, 1994; Naveh, 2001; Fry, 2001; Tress and Tress, 2001). The third lesson was the meaning of space and time scales in landscape research and planning. This moves consider in landscape research and planning those ecological concepts related to temporal dynamics and spatial principles. A fourth lesson was that the conceptualisation of a landscape as an appropriate context for sustainable planning leads to a multidimensional viewpoint of it. Therefore, holistic landscape schemes like the one proposed by Tress and Tress (2001) enable multi-dimensional landscape research and planning.

The main research question of this thesis: How could an integrative scheme that facilitates a holistic-multi-dimensional viewpoint on landscapes be constructed as the scale and the appropriate context for sustainable planning? gave origin to the most important lesson: that an ecosystem-based management approach seems to be an appropriate general framework to face landscape research and planning. It eases the integration of sustainability as a pre-requisite for land-use planning; it fosters a holistic approach to landscape research, and allows the use of an anticipatory, flexible, research and planning. What in theoretical and practical terms, the integration of these issues? was the following major question addressed by this research. In answering this question it was learned that:

1. Sustainability comprises many dimensions. Using a coarse classification, at least three dimensions could be distinguished: environmental, economic and social (van Lesterijn, 1994; Opschor, 1996; Bossel, 2000).
2. A holistic approach means assuming a dialectic position with respect to the interactions between a whole and its parts, and to give rise to a synthesis of knowledge from different disciplinary viewpoints. Therefore, it is important to attempt to undertake interdisciplinary landscape research, which seeks to go beyond the level of parallel studies to develop theory across disciplinary boundaries, gaining a transdisciplinary understanding of landscape processes (Fry, 2001). However, holistic approaches should go beyond the studies that involve unrelated academic disciplines. Despite the efforts to cross subject boundaries to create new knowledge and achieve a common research goal, it is not enough. According to Nicolescu (2202) it is needed an open vision that traverse and lie beyond different disciplines. This view is intended that recognise the different levels of reality governed by different types of logic. The logic of the exact sciences, social sciences, art, literature, poetry and spiritual experience. This is recognised as a transdisciplinary vision. This research is beyond to the achievement of this kind of vision. It only tackles the employment of multi-criteria analysis to support a multi-dimensional analysis of a landscape. Thus, a key dimension for a holistic approach, the landscape as a nexus of nature and culture was poorly tackled.
3. Landscapes and ecosystems must be seen as hierarchical and complex systems that should be analysed from a holistic viewpoint (Borman and Likens, 1979; Ruzika and Miklos, 1982; Haber, 1990; Naveh and Lieberman, 1994; Ruzicka, 1995; Farina, 1998; Muller and Jorgensen, 2000). The application of the hierarchy paradigm permits complexity of landscapes to be partially simplified by decomposing them into a framework, in which each level of scale may have its own properties and mechanisms. A watershed-ecosystem networks seem to summarise the concept of landscape as a nested hierarchy .
4. Adaptive resource management and reconciliation of objectives and actions of the various stakeholders within the domain of an ecosystem seems to be the most appropriate strategy to confront uncertainty and unpredictability inherent to ecosystems and social systems.
5. Sustainable landscape planning methodology and the watershed-ecosystem model have convincing potential to cope with the multiple purposes involved in ecosystem-based management projects.

To what extent can this methodology be applicable was the last major research question. Results from the application of the designed methodology have taught important lessons. In the first place, general methodological aspects can be generalised. The five phases of the sustainable landscape planning methodology permit to integrate successfully several models, methods and procedures. Thus, this methodological framework enables an integrative approach in regional/landscape planning. It is important to highlight the strong relationship between focus and syntheresis phases, which enable the development of a key characteristic of an ecosystem based management project, a flexible and adaptive management. In addition, the employment of a problem solving approach enables the flexibility to include several method and procedures according particular regional characteristics and context. It means, the selection of methods and procedures are context dependent in terms of time, sources of data, quality of data, stakeholders involvement and so on. Additionally, an ecosystem-based management approach is appropriate to confront the complex problems inherent to fragile mountain ecosystems around the world. It looks for a more integrated and more effective management of resources and ecosystems at regional and landscape scales. This approach also tackle three basic issues to improve the regional/landscape planning, the definition of management units, the development of understanding of the different dimensions of the ecosystem/landscape and the creation of planning and management frameworks.

Other lessons were learnt during the application of the designed methodology. From the application of the focus phase applications it was learned that it is unavoidable not to include short term and short sight goals in landscape planning. In practical terms, it means the construction of visions more narrowly related to aspects that must be changed or obstacles there must be overcome. These visions are often derived from other stakeholders different to the planning team. Another lesson was that the identification of goals, is still, the greatest challenge in ecosystem-based management planning and an eclectic approach could be the best approach. In addition, the planner must play the role of a promoter of the planning process, instead of that of a traditional advisor.

Considering the phases of analysis and diagnosis, a number of lessons were learnt. It was found that it was necessary to count with enough satellite images to define regional trends in land-use change. The usefulness of the Analytical Hierarchy Process in the application of multi-criteria analysis was another important finding. Finally, the limitations of the attributes employed in the delineation of ecologically sensitive areas to estimate erosion in regions without strong human impacts and in contrast, the applicability of the biodiversity of habitats as a criterion for those regions or areas with relatively well conserved vegetation cover can be counted as yet another lesson learned.

Finally, from the prognosis phase arose one main lesson. Due the generality and context dependent nature of indicators of regional potential for sustainable development, their employment should be complementary to other regional analysis. The empirical results shown that it is enough that a region counts with a large well-conserved area to be considered as a region with potential for sustainable development. Therefore, the social context analysis carried out using Strategic Situational Planning methods is proposed in order to improve the regional analysis.

7.4 What is next?

A future research agenda depends on the application of different theoretical issues included in this research. These applications were discussed across a wide range of circumstances and they are related to the necessities that require developing an ecosystem-based management project. These include, mainly those issues linked to holistic/comprehensive/inter-transdisciplinary viewpoints, the delineation of areas using natural criteria, the understanding of landscape processes from different scales and levels, the analysis of those complex/wicked problems related to the accomplishment of complex goals (as those associated with the prerequisite of sustainability), the use of anticipatory and flexible planning processes and the incorporation of institutional and stakeholder factors.

1. This research acknowledges the international claims for the need of holistic approaches to landscape research (Naveh and Lieberman, 1994, Naveh 2000; Pelag, et al., 2000; Tress and Tress, 2000). This research applied the holistic transdisciplinary approach to landscape research as developed by Tress and Tress (2001), in order to tackle the required holistic and systems viewpoint of landscapes in ecosystem-based approaches. Results derived from the case study justified the conclusion that the five dimensions proposed by Tress and Tress (2001) are applicable to landscape research. Also, as a consequence of this research, further theoretical reflections can be proposed in order to include a new dimension with planning and management purposes.

2. It was considered that the application of multi-criteria analysis is a needed logical support for a multidimensional approach in landscape research and planning. This issue arises both in landscape research and multi-criteria analysis (Zionts, 1998; Naveh, 2000; Pelag, et al., 2000; Tress and Tress, 2001). This research employed the Analytical Hierarchy Process (Saaty, 1990, 1995) as the logical model for multi-criteria decision-making. Results have proved that this logical model facilitates the ecosystem-based approach and the delineation of ecologically sensitive areas. This author acknowledges the enormous importance that Analytical Hierarchy Process procedures have had in this research. Hierarchies are the core frameworks of this thesis because of their systemic and systematic characteristics, and also for its potential to analyse unstructured problems and measure intangible aspects. However, there are other logical models that have been applied to different multi-criteria decision methods in environmental

planning (Lahdelma, et al., 2000). It is necessary to develop comparative studies, in order to analyse the sensitivity, precision, benefits and the costs of their application in an ecosystem-based management project.

3. This research took into account the application of ecosystems ecology theory to landscape analysis and planning. Mainly those aspects used to support the natural delineation of areas. For this thesis, an old model was selected: the watershed-ecosystem model (Bormann and Likens, 1979). Its selection addresses on one hand, those demands of ecological principles to be applied to landscape/ ecosystem planning and to integrated watershed management (Healy, 1998); on the other, there is the fact that despite the age of the Bormann-Likens model, its worthiness has not yet been recognised; this model is, to date, the one with the greatest body of empirical support, a generally agreed requisite for modern ecosystem theories (Jorgensen and Muller, 2000). Results from the case study proved the applicability of the model of watershed-ecosystem to landscape/ regional analysis, mainly in those aspects having to do with the conceptualisation of the volcanoes' region as a nested network of watersheds and subsystems, and to delineate future management units. Nevertheless, this model is not applicable in either plain or extremely abrupt terrains where it is not easily to define the limits of a watershed. As a consequence, it is thought that further studies should be carried out focusing on the evaluation of other ecological models like those originated in the Slovakian school of landscape planning for instance (Zigrai, 1996). This author considers, as appropriate, the employment of other natural units like geotopes, biotopes and anthropotopes.

4. The claims for the application of spatial principles and multi-functional viewpoints to landscape analysis and planning, mainly those that permit to regard processes from different scales and levels (Baker, 1989; Berger, 1987, Ahern, 1995; Fabos et al., 1995; Dramstadt, et al 1996; Ahern, 1999; Botequilha and Ahern 2002). In this research, particular importance was granted to the ecological network principle (van Lier and Cook, 1994; van Lier, 1998) because its role is that of facing landscape fragmentation and isolation problems. In addition, it was considered a multifunctional approach for landscape analysis and planning (Naveh, 2000; Pelag, et al., 2000; Fry, 2001; Li, 2000; Luz, 2000;Tress and Tress, 2001) while it was not possible to apply the network principle to the case study, because of the low fragmentation in the volcanoes region, this author suggests a further application could be useful, considering the totality of the watersheds in the region. Contrastingly, results from the case study suggest the possibility of multifunctional regional planning to achieve sustainability. Hence,

it is proposed that in the near future, it will be necessary to develop individual land-use plans for each watershed in the area.

5. It was possible to satisfy the need for strategies to analyse complex/wicked problems related to the establishment of complex goals (as those associated with sustainability as a prerequisite), to use an anticipatory and flexible planning process and to incorporate institutional and actor-related factors (Saaty, 1995; Matus, 1989; Castillo, 1995). The Strategic Situational Planning (Matus, 1989) was chosen as the source of methods to analyse this kind of problems. Although the effectiveness of these methods has already been proved, they had not been employed in a problem of regional conservancy, and the results corroborate their robustness in dealing with complex problems. However, further application is required in order to prove this robustness.

6. The use of an anticipatory and flexible planning process and the incorporation of institutional and stakeholder factors is an issue only partially developed in this thesis. Although, in the general methodology it is presented as the syntheresis phase (the phase for implementing, monitoring and evaluating the planning process) it is only described but not tested. Undoubtedly, a priority point in a future research agenda should be the challenge of putting into practice the ideas of the phase of prognosis. Consequently, there are pending planning tasks to confront institutional and stakeholder factors in the region.

7. Other minor applications are associated to procedural aspects. Some of them deserve mention. First, is the application of uncertainty measurements to habitat diversity. Although, these measurements have been applied since the 1950's, their application to vegetation type diversity as a measurement of habitat diversity and its subsequent spatial representation in a data layer is a new contribution, and predictably testing their applicability certainly requires further study. Second, is the multi-objective GIS procedures employed. Similarly to the previous point, they have already been applied to multiple problems in relation to the optimisation of land use allocation. However, the application employing the inter-phase multi-criteria analysis results-land-use allocation for nature conservancy requires further application to fine tune it. Further research is also necessary to accurately establish the influence of soil cover on the susceptibility to erosion criterion, and to determine appropriate fragmentation measurements that permit delineating areas with different degrees of fragmentation. Third, it is suggested further use of the meeting format and the "dominance gradient" is advocated, as heuristic instruments for further expert consensus-building, whenever criteria/attributes need to be weighted.

7.5 Contributions of this thesis

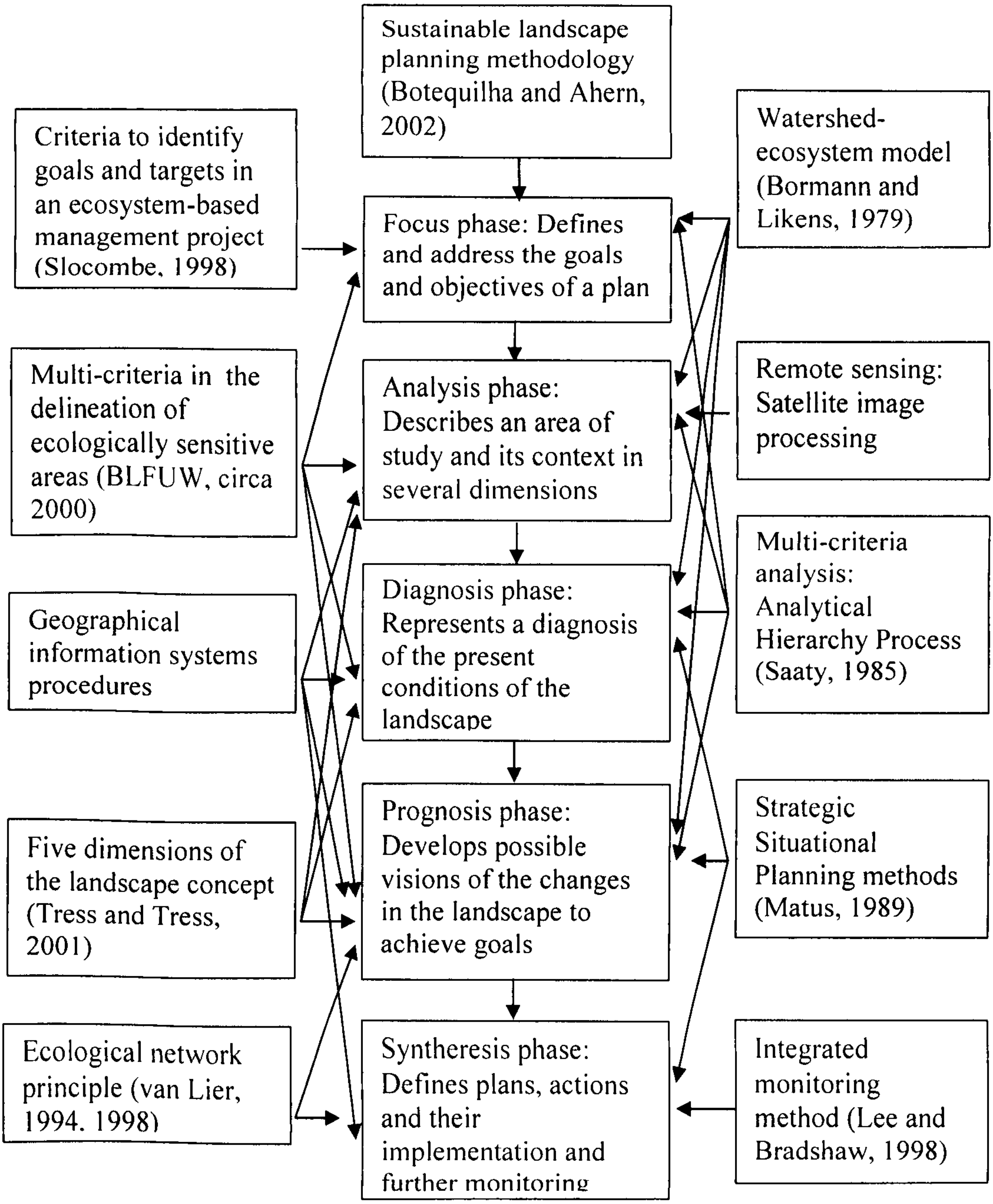
The main goal of this thesis was to investigate the applicability of a landscape planning methodology founded on an ecosystem-based approach focusing on the delineation of ecologically sensitive areas. To achieve this, the main aim of this thesis, the seven past chapters have been involved with the theory and practice that has to do with the basic challenges of an ecosystem-based management project: the construction of both, a holistic scheme to understand ecosystems and landscapes and of an anticipatory and flexible landscape planning process. In addition, it has been argued that the general goal of this thesis has been comprehensively achieved. The value of this research might be summarised as follows.

The major contributions are related to theoretical and practical issues in an ecosystem-based management approach. In terms of a theoretical approach, this research presumes that in order to construct the holistic scheme of a landscape, the integration of different theoretical models, principles and methodological instruments from different knowledge fields is needed. Also, that in order to support a congruent planning process, an effort must be made to integrate this scheme into a flexible and anticipatory landscape planning methodology must be attempted. On the other hand, in practical terms, this thesis assumes that results derived from the practical case study provide important inputs (database, diagnosis and proposals) to improving the planning process of the Iztaccihuatl-Popocatepetl region. Also, this methodological approach can be useful to solve the problems linked to fragile mountain ecosystems.

Figure 7.1 summarises the major contributions of this thesis: the integration of multiple theoretical bases and methodological instruments into a landscape planning methodology. It is important to stress that this integration was made with a goal seeking approach: to analyse landscapes towards a later sustainable landscape planning with particular interest on ecologically sensitive areas.

In addition, there are other issues that were incorporated in order to support the delineation of ecologically sensitive areas. Issues such as: (1) a dominance gradient, a decision-making instrument designed to facilitate the judgement of experts in a preference vector calculation, (2) a monitoring approach targetting ecologically sensitive areas included in the syntheresis phase, (3) the uncertainty measurements used to assess the diversity of habitats, introduced in the case study to evaluate ecological value, and (4) a set of criteria to evaluate ecologically sensitive areas.

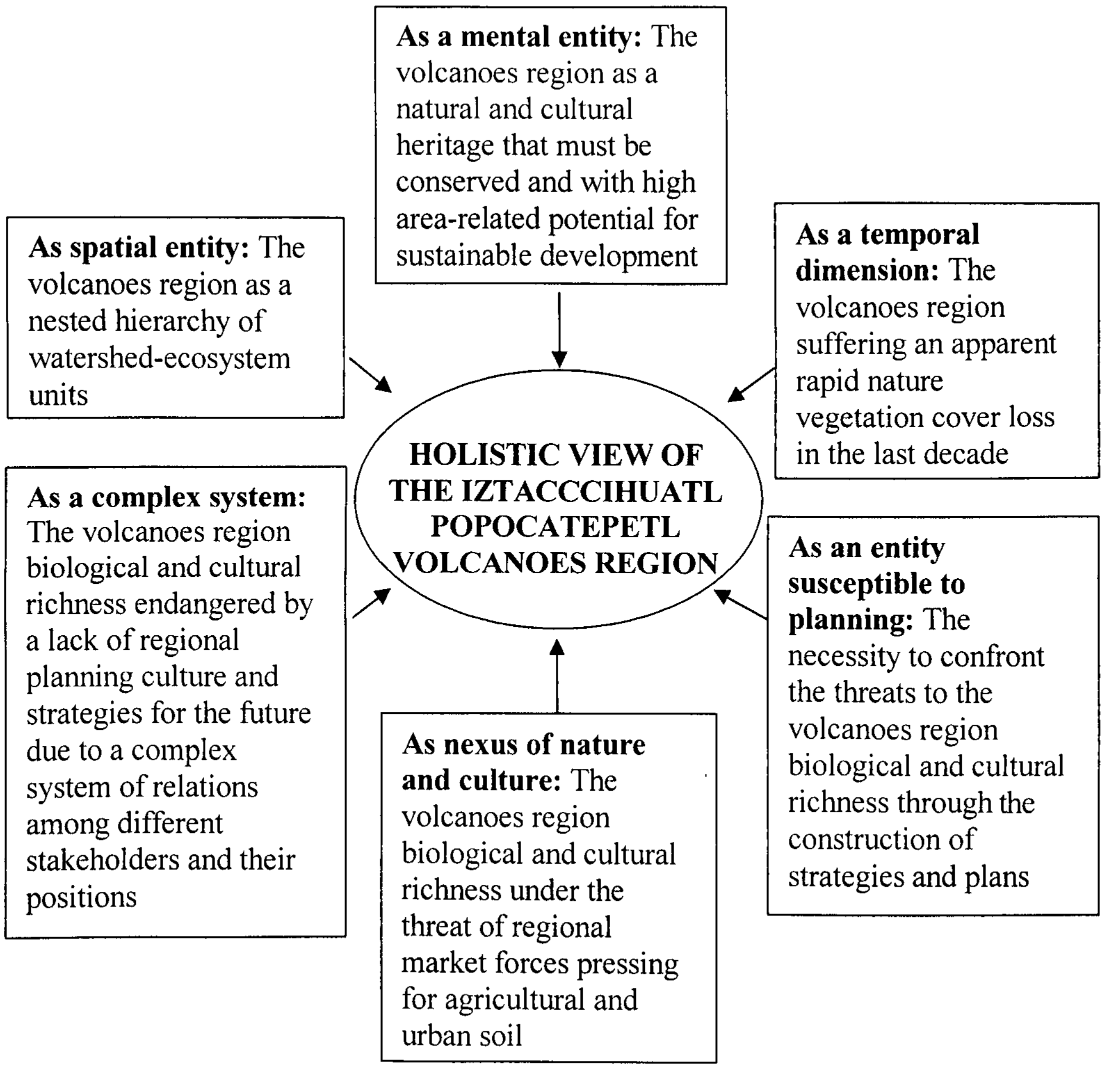
Figure 7.1 Integration of a multidimensional-holistic scheme into an anticipatory and flexible landscape planning methodology



Source: The author

While, admittedly, this thesis only comprise the author's perspective of the region, it does provide a review of a series of issues needed for a further region planning towards sustainability in the Iztaccihuatl-Popocatepetl volcanoes region. In order of importance, the results provide a multidimensional view of the region (figure 7.2), a structured proposal for developing a regional planning culture that is municipality based, a GIS regional database of physical and biological features and human impacts, a set of data layers on threats to nature conservancy areas, a brief vision of regional land-use change patterns, and an assessment of the complex regional problems involved in the achievement of environmental sustainability.

Figure 7.2 Holistic view of the Iztaccihuatl-Popocatepetl volcanoes landscape



Source: The author after Tress and Tress (2001)

It should also be mentioned that there have been a number of limitations in the development of this investigation, as was previously pointed out in chapter 6. However, attention has been paid to overcome those that were within the author's reach. The main limitations from the inherent characteristics of a holistic-multi-dimensional approach, which is designed to gain interdisciplinarity and further transdisciplinarity: it should be more the result of team efforts than the work of an individual. In addition, during the development of this research there were two aspects far from the reach of the author: a Ph. D. thesis must be the result of personal efforts (not those of a research team), and that fact is not yet possible to have a multidisciplinary team in Mexico to undertake the planning of the volcanoes region. The first limitation is unsolvable, and in order to overcome it, the author developed a simple strategy, which consisted in discussing some disciplinary and procedural topics of the thesis with other colleagues that are part of the research team. While they were not directly involved in the landscape dimension of the volcanoes region, their comments, judgments and advice were invaluable. Nevertheless, despite the attempt to summarise these other viewpoints, in the end, the holistic view displayed in figure 7.2 only reflects personal assumptions about the volcanoes region.

Another important limitation is related to practical aspects. This thesis designed a phase for implement, monitor and evaluate the proposals. Although this research did not consider the development of this phase, it is a pending issue for the future; in the light of the improvement of a municipality based planning culture.

A second set of limitations was linked to the quality and periodicity of the basic data sources. This limitation is a common issue in Mexico and in other developing countries. This thesis was affected mainly by the lack of an adequate series of satellite images to estimate the regional spatial and temporal dynamic of the landscape. As it was discussed in chapter 7, this lack explains the weakness of the estimation of the volcanoes regional land-use change dynamics.

The role of modern landscape planning is to create more sustainable regional systems and search for enduring multifunctional landscapes for the future. Ecosystem-based management is taking shape as a potential ecologically well-founded landscape planning approach capable of playing this role. On the other hand, the construction of the holistic scheme inherent to this approach, which is the key theoretical issue of this thesis, is still a challenge. Even when the results of this research support the idea that landscape/ regional systems cannot be completely understood by reducing them to partial analyses, which is the central theme of a holistic approach, it should be emphasised that they are only partial results. It is the author's contention that there lies still *a long and winding road* to be travelled in order to construct theoretical and practical holistic schemes that capture more fully an understanding of how the world works in practice.

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