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Conceptual Framework For Scientific Research Program in Department of Planning and Designing the Environment

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Abstract

It is the aim of this article to show what contribution landscape modeling can make to the analysis of environmental effects and environmental planning. The term landscape modeling is used instead of regional modeling to clarify that both, ecological effects related to area and economic effects related to human action, are concerned. Landscape planning is from its origin interdisciplinary which is reflected in the fact that soil scientists, landscape ecologists, landscape planners, etc. should work together on this realm. In the modeling procedure, the principle of primary integration of disciplines is followed. The concept suggests a real interaction between all the disciplinary modules. It exceeds the commonly used concept of secondary integration, where only the results of independently calculated models are interpreted together, at the end. In the Environmental Sciences Research Institute of Shahid Beheshti University, the Department of Planning and Designing the Environment has directed its research program towards scientific themes with a multidisciplinary and interdisciplinary approach, and has aimed to practice the conceptual framework of causes and effects of landscape change as a scientific base for land-use decisions in planning. This article outlines an introductory explanation for practice demands and landscape trends. It presents a framework based on a particular type of landscape change research that uses the principles and theories of landscape ecology as an underlying paradigm for explaining changes in landscapes. It introduces principal recommendations for interdisciplinary landscape change research program, and characterizes the key themes and issues about the conceptual framework of ecological networks in landscape ecological modeling.

Key words: landscape ecology; landscape change, interdisciplinarity, ecological networks.

چارچوبی مفهومی برای برنامه علمی پژوهش در واحد پژوهش برنامه‌ریزی و طراحی محیط

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چکیده

هدف این مقاله معرفی جایگاه مدلسازی سیمای‌سرزمین در تجزیه و تحلیل اثرات محیطی و برنامه‌ریزی محیطی است. مدلسازی سیمای‌سرزمین به جای مدلسازی منطقه‌ای استفاده می‌شود تا اشاره شود هم اثرات بوم‌شناختی مربوط به منطقه و هم اثرات اقتصادی و اجتماعی مربوط به عملکرد انسان هر دو مورد توجه‌اند. برنامه‌ریزی سیمای‌سرزمین متأثر از نهاد خود میان‌تخصصی بوده و تأکید دارد خاک‌شناسان، بوم‌شناسان سیمای‌سرزمین، برنامه‌ریزان سیمای‌سرزمین، و دیگر متخصصین کارشناس از ابتدای مسیر باهم همکاری نمایند. در روند برنامه‌ریزی، اصل ارتباط اولیه بین تخصص‌ها مورد تأکید فراوان است. این اصل به ارتباط اولیه و واقعی بین واحدهای تخصصی اشاره دارد که از مفهوم عمومی ارتباط ثانویه بین تخصص‌ها پیشی می گیرد. در ارتباط ثانویه تخصصی، نتایج مستقلاً محاسبه شده مدل‌ها فقط در انتهای مسیر مطالعه در تعامل با هم قرار می گیرند. "واحد پژوهش برنامه‌ریزی و طراحی محیط" پژوهشکده علوم محیطی برنامه پژوهشی خود را به سمت استفاده از نظریه‌های نوین با رویکردهای چندتخصصی و میان‌تخصصی سوق داده و قصد دارد چارچوب مفهومی "عوامل و اثرات تغییر بوم‌شناختی سیمای‌سرزمین" را تحت عنوان بنیانی علمی در تصمیم‌گیری‌های مربوط به کاربری‌زمین بکار بگیرد. این مقاله، ابتدا توضیحی مقدماتی درباره خواست‌های تخصصی و روندهای سیمای‌سرزمین ارائه نموده، چارچوبی مفهومی بر اساس نوعی خاص از مطالعات تغییر سیمای‌سرزمین که در آن اصول و نظریه‌های بوم‌شناسی سیمای سرزمین به عنوان اصلی علمی در بیان تغییرات سیمای‌سرزمین به‌کار می‌رود را معرفی می‌نماید. در انتها، در راستای برنامه مطالعات میان‌تخصصی تغییر سیمای‌سرزمین توصیه‌هایی ارائه نموده، موضوعات کلیدی در باب چارچوب مفهومی "شبکه‌های بوم‌شناختی"، قابل استفاده در مدلسازی بوم‌شناختی سیمای‌سرزمین، را معرفی می‌نماید.

کلیدواژه‌ها: بوم‌شناسی سیمای‌سرزمین، تغییر سیمای‌سرزمین، میان‌تخصص گرایی، شبکه‌های بوم‌شناختی.

Introduction

The effects of human alteration of the environment could rapidly change the landscapes of today. Landscape change is defined as the alteration of structure and function over time through their interaction and mutual influences. This concept is embedded in several theories such as holism, complexity and general system theory that emphasize the interrelationship of landscape change and human activities. Landscape change researchers, who are usually employed by universities, governmental agencies, and non-governmental organizations, are leading the way to study landscape change and are responding by working together to develop interdisciplinary approaches to study this phenomenon. A wide range of disciplines are involved in landscape change research, including landscape ecologists, landscape architects, regional planners, geographers, economists, wildlife biologists, foresters, and many others.

1- Landscape Change Research Program in the Department of Planning and Designing the Environment

1-1-Practice Demands

Landscapes change because they are the expression of the dynamic interaction between natural and cultural forces in the environment. Cultural landscapes are the result of consecutive reorganization of the land in order to adapt its use and spatial structure better to the changing societal demands (Antrop, 2005). History has recorded many successive and even devastating landscape changes, which have left barely any relics today. Today, the changes are seen as a menace, as a negative evolution because they cause a loss of diversity, coherence and identity, which were characteristic for the traditional cultural landscapes that are rapidly vanishing. The combined effect of the driving forces such as accessibility, urbanization, globalization and the impact of calamities have been different in different periods and affected the nature and pace of the changes as well as the perception people have had about the landscape. It is argued that this changing perception also influences what kind and aspects of landscapes are studied, protected and managed.

1-2- Landscape Trends

The main trend of actual landscape changes is the one of polarization between more intensive and more extensive use of land. There is a continuing concentration of people and activities in rather small, highly intensive and densely crowded areas, while vast areas of land become disaffected or even abandoned. The following trends of the transformation are recognized in many landscapes (Vos and Klijn, 2000):

- intensification and scalar increase in agricultural production, the transformation of wetlands and natural areas into agricultural lands;
- urban sprawl, the growth of infrastructures and functional urbanization;
- development of specific tourist and recreational forms of land use;
- extensification of land use and land abandonment, affecting remote rural areas with less favorable and declining social and economical conditions.

The driving forces behind all these are urbanization, accessibility and globalization. All three interact simultaneously and differently according to the geographical situation of a place or area.

1-3- Research Aims

- Focusing on the causes and effects of land-use and land cover dynamics as well as the ecological and social impacts of alternative design, planning, policy, and management schemes on landscape and region;
- Concerning about a particular type of interdisciplinary landscape change research that uses the principles and theories of landscape ecology as an underlying paradigm for explaining changes in landscape;

- While landscape ecological change is the focus of collaborative research efforts, the way in which the collaboration itself is carried out is the subject of debate;
- Presenting a framework for academic consideration that characterizes the key themes, questions, and issues in the debate about the interdisciplinarity–disciplinarity nature of research.

1-4- Program Outputs

- Initiating a campaign to raise awareness of local authorities and stakeholders and to stimulate co-coordinated actions;
- The process of integration between the scientific disciplines and between the researchers (interdisciplinary) and program team and stakeholders (transdisciplinary) involved in the projects;
- Evaluating and discussing the potentials and difficulties encountered in the successive phases;
- Realization of the integrated landscape biography for regions, including scientific results as well as integration of the complex legal and administrative instruments, which are necessary for the implementation of the studies;
- Developing a methodology for assessing landscape values.

2- Bridging Human and Natural Sciences in Landscape Change Research Program

Landscape is a subject of interest in the natural sciences, social sciences, humanities, and the arts. However, each of these fields is organized in disciplines, which have their own interests and preferences in investigating landscape issues. Demands and challenges from society, government, and the economy are seldom seen as an opportunity for collaboration among disciplines. In fact, the complexity of the real world and its problems are in contrast to the disciplinary organization of science. Communities, legislators, industry, business, local stakeholders, and the public at large simultaneously make different demands on landscapes while also contributing to landscapes. Landscape research can help solve and coordinate the conflicting interests when approached as a common effort by several disciplines. This implies from researchers a "come and go" between disciplinary and inter- or transdisciplinary approaches (De´camps, 2000), as well as constant communication among disciplines (Antrop, 2001). The concept of bridging human and natural sciences intends to foster and coordinate communication about landscape-related issues, within academia and between science and society.

2-1- Landscape and Landscape Ecology

A landscape comprises the visible features of an area of land, including:

- physical elements such as landforms [categorised by characteristics such as elevation, slope, orientation, stratification, rock exposure and soil type];
- living elements of flora and fauna;
- abstract elements such as lighting and weather conditions; and
- human elements, such as human activity or the built environment.

The phrase built environment refers to the manmade surroundings that provide the setting for human activity, ranging from the large-scale civic surroundings to the personal places. In architecture and environmental psychology, the phrase is a useful acknowledgement that a small fraction of buildings constructed annually, even in the industrialized world, are designed by architects, and that users of the built environment encounter issues that cross the traditional professional boundaries between urban planners, traffic engineers, zoning authorities, architects, interior designers, industrial designers, etc. Specific uses of landscape include:

- Landscape art: the depiction of scenery in landscape painting, landscape photography or other media.
- Landscape architecture: the art of planning, designing, and managing public and private landscapes and gardens. Related terms include:

- Landscape design: the design of open space of urban or rural areas;
- Landscape engineering: the technical aspect of landscape architecture;
- Landscape planning: the planning of large scale and/or long term landscape development projects;
- Landscape management: the care of human-made or natural landscapes;
- Landscape gardening: the practice of designing large scale estate gardens and seen as a precursor to landscape architecture.
- Cultural landscapes: "combined works of nature and of man." Illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal.
- Landscape ecology: a sub-discipline of ecology that investigates the ecological causes and consequences of spatial pattern, process and change in landscapes.

Landscape ecology is a sub-discipline of ecology and geography that address how spatial variation in the landscape affects ecological processes such as the distribution and flow of energy, materials and individuals in the environment. Landscape ecology addresses the causes and consequences of spatial heterogeneity (Forman, 1995). Heterogeneity is the measure of how different parts of a landscape are from one another. Landscape ecology looks at how spatial structure affects organism abundance at the landscape level, as well as the behavior and functioning of the landscape as a whole. This includes the study of the pattern, or the internal order of a landscape, or process, or the continuous operation of functions of organisms (Turner, 1989). Landscape ecology also includes geomorphology as applied to the design and architecture of landscapes (Allaby, 1998).

Landscape ecology is comprised of four main principles, which include: 1. the development and dynamics of spatial heterogeneity, 2. interactions and exchanges across heterogeneous landscapes, 3. influences of spatial heterogeneity on biotic and abiotic processes, and 4. the management of spatial heterogeneity. The main difference from traditional ecological studies, which frequently assume that systems are spatially homogenous, is the consideration of spatial patterns (Turner and Gardner, 1991).

2-2- Landscape Ecology Theory

Landscape ecology, as a theory, stresses the role of human impacts on landscape structures and functions and proposes ways for restoring degraded landscapes (Naveh and Lieberman, 1994). Landscape ecology explicitly includes humans as entities that cause functional changes on the landscape (Sanderson and Harris, 2000). Landscape ecology theory includes the landscape stability principle, which emphasizes the importance of landscape structural heterogeneity in developing resistance to disturbances, recovery from disturbances, and promoting total system stability (Forman and Godron, 1986). This principle is a major contribution to general ecological theories which highlight the importance of relationships among the various components of the landscape. Integrity of landscape components helps maintain resistance to external threats, including development and land transformation by human activity (Turner *et al.*, 2001). Analysis of land use changes has included a strongly geographical approach within landscape ecology. This has lead to acceptance of the idea of multifunctional properties of landscapes (Ryszkowski, 2002).

Another related theory is hierarchy theory which refers to how systems of discrete functional elements operate when linked at two or more scales. For example, a forested landscape might be hierarchically composed of drainage basins, which in turn are composed of local ecosystems or stands, which are in turn composed of individual trees and tree gaps (Forman, 1995). Recent theoretical developments in landscape ecology have emphasized the relationship between pattern and process, as well as the effect that changes in spatial scale has on the potential to extrapolate information across scales (Turner and Gardner, 1991).

2-3- Perspectives of Landscape Ecology

Landscape ecology is introduced as a young transdisciplinary science for the solution of environmental problems. Bastian and Steinhardt (2002) stress the need for a transdisciplinary systems approach in the science, and look at transdisciplinary landscape ecology as able to bridge the gaps among disciplines on the one hand, and society on the other. In this perspective, it is the end of linear and beginning of non-linear network and systems thinking in landscape ecology.

In this perspective, the concepts of landscape functions (economic, ecological and social) and natural potentials, provide helpful paths to analyze and assess landscapes, concerning human needs, demands and goals. Potentials and functions characterize the capability and usability of a landscape. Researchers deal with landscape functions and natural potentials, and suggest possible assessment procedures, assessment of heterogeneous spatial units, and changes in landscape functions, which lead to the stage of landscape evaluation. They consider landscape evaluation, described as the crucial step in processing analytical data for decision making and action, i.e. to convert scientific parameters into socio-political categories (Table 1).

Assessment methods, scaling, and demands on evaluation methods and scenarios for land use options, receive attention, as does the issue of landscape assessment and multicriteria optimization, looking toward producing an integrated view needed for a planning region. It is noted that a common approach of superimposing different assessment maps to generate "conflict maps" does not fully meet the requirements of an accurate planning tool. It only highlights the incompatibility of the different land use options when the conflict zones are obvious, and cannot produce the integrated view needed for a planning region. A delineation of a Method of Multicriteria Assessment and Optimization, designed for a low structured agrarian landscape is needed, followed by optimization aims for conservation goals, and maximization and compromises. A conclusion is that functional assessments and optimization used in turn are a powerful instrument in the preparation of political decisions (Bastian and Steinhardt, 2002).

2-4- Transdisciplinarity in Landscape Ecology

The stress which has placed on transdisciplinarity in the science of landscape ecology is characteristically European. In the United States it is now increasingly being recognized, as witness the 19th annual symposium of the U.S. Chapter of the International Association of Landscape Ecology, being held in March–April 2004, whose subject is "Transdisciplinary Challenges in Landscape Ecology". The symposium notice identifies that "solving current and future environmental issues requires transdisciplinary approaches that integrate the physical, ecological and social sciences in space and time.

It is found that Lattuca's (2001) continuum of interdisciplinarity to be one of the most compelling concepts for explaining the debate about the nature of collaboration in landscape ecology change research. As He States, two approaches have been used to define interdisciplinarity in academic research in the United States: (1) the level of integration in team-based scientific research programs and institutions; and (2) the level of formal and informal interactions between researchers from a variety of disciplines (also known as interdisciplinary studies) (Lattuca, 2001).

The first approach emphasizes the organizational management of scientific research teams in universities, especially in the natural sciences and engineering (Roy, 1979). Roy (1979) describes this approach as interdisciplinary problem-based research. This approach is important because it recognized the fact "that the real problems of society do not come in disciplineshaped blocks". The alternative approach, known as interdisciplinary studies, includes a wide

Table 1- Landscape Ecological Evaluation (Source: The Author)

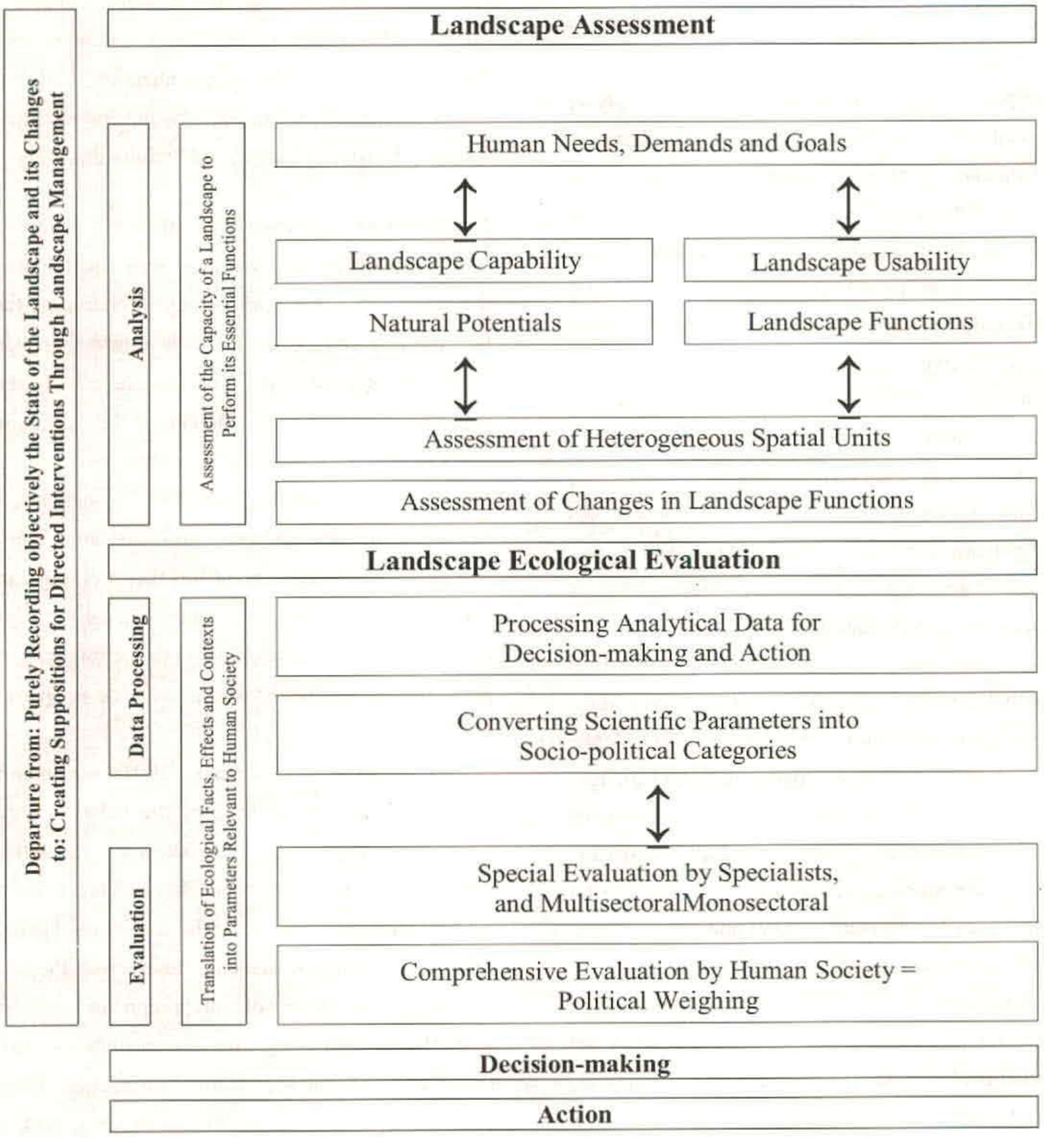

Table 2- Continuum of Interdisciplinary Research (adapted from Lattuca, 2001)

	Type of research	Definition
1	Informed disciplinarity	outreach to other discipline(s) Disciplinary questions requiring
2	Synthetic interdisciplinarity	Questions that link disciplines
3	Transdisciplinarity	Questions that cross disciplines
4	Conceptual interdisciplinarity	disciplinary basis Questions without a compelling

range of interdisciplinary interactions among a community of scholars on a campus or network of campuses (Klein, 1994). This approach includes not only interdisciplinary problem-based research, but also activities in classrooms, collaborative research without a team focus, and research in all disciplines.

Lattuca's concept of interdisciplinary research is an example of the alternative approach to interdisciplinarity. Her classification of interdisciplinarity included a wide range of epistemologies and is based on this definition (Lattuca, 2001): "Interdisciplinarity—An adjective describing the interaction among two or more different disciplines". This interaction may range from simple communication of ideas to the mutual integration of organizing concepts, methodology, procedures, epistemology, terminology, data, and organization of research and education in a fairly large field (Table 2). An interdisciplinary group consists of persons trained in different fields of knowledge (disciplines) with different concepts, methods, and data and terms organized into a common effort on a common problem with continuous intercommunication among the participants from the different disciplines.

3- Principles for Landscape Change Research Program

An important factor linking natural and human oriented sciences in landscape research is the mutual relationship between people and the landscape: social groups not only influence landscapes, but are also influenced by landscapes. Indeed, various natural and cultural processes interact in landscape dynamics. However, human and natural sciences as well as the arts still need to be integrated in landscape research. Landscape change research needs to acknowledge the following:

- All landscapes consist of both a natural and a cultural dimension. The perceived division between nature and culture is counter-productive and must be overcome since all landscapes are multidimensional and multifunctional.
- The communication process among scientists and others has to be given much higher priority.
- Results from future landscape research must be published and promoted in a way that makes them available and useful for all kinds of experts, decision-makers, and the general public.
- A transdisciplinary approach that goes beyond the efforts of multidisciplinary and interdisciplinary research should be sought. It is imperative to reach consensus on an overarching goal or purpose for this common research.
- Communication, education, transdisciplinarity, and multifunctionality are keywords in the first five recommendations and main tasks for future landscape research. There are following suggestions to implement these keywords in the agenda and action of future landscape change research:
  - Landscapes should be regarded as holistic and dynamic systems, which consist of the interacting geosphere, biosphere, and noosphere. The co-dependency between people and the landscape is the most important linking factor between natural- and human-oriented sciences.
  - The expression ''multifunctional landscapes'' refers to the different material, mental, and social processes in nature and society that take place in the landscape and interact accordingly. Multifunctionality exists in all landscapes through the co-existence of ecological, economic, cultural, historical, and aesthetic functions.
  - Communication between the disciplines and education for transdisciplinary cooperation are important. Disciplinary backgrounds are a precondition for transdisciplinary research. Transdisciplinarity needs researchers who are well educated and firm in their own disciplines, but open minded enough to transcend their disciplinary borders.
  - All disciplines can contribute to developing a common research strategy and no one discipline predominates over the others or possesses the ''right'' definition and interpretation of

landscape. Integrators would arise according to specific research needs and the participants involved.

- Methods and tools must be appropriate to the multifunctionality of landscapes. Not only land use, land cover, distribution of landscape elements, and functional demands on a given landscape, but also the individual's or a community's perspective on it have to be considered.

4- Landscape Modeling for Environmental Planning

4-1-Landscape Planning

If "Landscape ecology" examines how heterogeneous combinations of ecosystems are structured, how they function, and how they change, "Landscape planning" examines the various ways humans structure their land use changes, and "Landscape design" involves the physical strategies and forms by which land use change is actually directed. Landscape planners tend to work on projects which:

- are of broad geographical scope
- concern many land uses or many clients
- are implemented over a long period of time

It is argued that landscape planners must look beyond the 'closely drawn technical limits' and 'narrowly drawn territorial boundaries' which constrain design projects (Arnold Weddle). Urban park systems and greenways are key examples of urban landscape planning. In rural areas, the damage caused by unplanned mineral extraction was one of the early reasons for a public demand for landscape planning.

It is the aim of this part to show what contribution landscape modeling can make to the analysis of environmental effects and environmental planning. Highlighted as especially successful is the possibility of the model to combine and evaluate ecological and economic aspects. The landscape model represents an interdisciplinary model, which focuses on specific topics within distinct landscape parts. The procedure creates a clearly defined working frame. The comprehensibility is achieved by not aggregating the data after elaborating strongly disciplinary results. A set of rules, implemented in the model, makes the transition from the overlay of data to a quantitative correlation possible. The condition for this, however, is close team work between the developers of the model and the decision makers in policy and administration.

4-2- Ecological Planning and Ecological Networks

Sustainable development is a widely accepted strategic framework in decision-making about the future use of land. Steiner (2000) introduces "ecological planning", defined by "the use of biophysical and socio-cultural information to suggest opportunities and constraints for decision-making about the use of landscapes". Sustainable landscape development requires that landscape planning aims for "a condition of stability in physical and social systems achieved by accommodating the needs of the present without compromising the ability of future generations to meet their needs" (World Commission on Environment and Development, 1987). This implies that in decision-making about a future landscape a balance is achieved between ecological, cultural and economic functions (Linehan and Gross, 1998). It follows:

- the landscape structure supports the ecological, social and economic processes required;
- the landscape can deliver its goods and services to present and future generations;
- the landscape can change over time without losing its key resources; and
- stakeholders are involved in decision-making about landscape functions and patterns.

Within this respect, the spatial pattern of the landscape should support the ecological processes required for resilient populations in respect of a species diversity target and the spatial scale that is ecologically relevant to that target. An ecologically sustainable landscape provides the conditions for the long-term maintenance of a regionally defined conservation aim as a starting point of planning; and a key factor for that purpose, the spatial cohesion of the network of ecosystems is needed to fill the knowledge gap between ecology and planning (Opdam *et al.*, 2002a).

It is so "not the steady state that is seek, when trying to manage for landscape sustainability, but rather a sustainable trajectory for ecosystems and landscapes" (Haines-Young, 2000). The local extinction of species can be acceptable as long as the population at the regional level persists. A strategy could be to spread the risk of such uncoordinated local changes over a wider regional scale, by linking local sites in a larger coherent ensemble of sites (Opdam *et al.*, 1995).

Stakeholders are also involved in defining the species diversity goal and in finding an appropriate landscape design for it. Local actors have valuable knowledge about the biophysical and social constraints and opportunities to change a landscape within the boundaries of ecological sustainability (Buchecker *et al.*, 2003). Planning a sustainable landscape starts with a decision for a feasible "ambition level" of conservation. The term 'ambition level' is based on the assumption that the more species are included in the target, the more area of semi-natural ecosystems is required, particularly when the views of local stakeholders (for example, conservation groups, farmers) weigh heavily in decision-making (Linehan and Gross, 1998; Von Haaren, 2002). This can be achieved by generating several ecologically sustainable options differing in spatial configuration. A key feature of this landscape planning approach is that "it recognizes that in any situation there is no single sustainable state, but a whole set of landscapes that are more or less sustainable" (Haines- Young, 2000).

Ecological networks are defined as a set of ecosystems of one type, linked into a spatially coherent system through flows of organisms, and interacting with the landscape matrix in which it is embedded. Hence, the ecological network is a multi-species concept, linking ecosystems, whereas the term habitat network as defined by Hobbs (2002) and Opdam (2002) refers to the habitat of a single species. This term does not refer to the function of the network. Related terms like reserve or conservation network focus on the function of species diversity protection. An ecological network may be single purpose (Jongman, 1995) as well as multipurpose, but its name emphasizes that the network coherence is based on ecological processes.

Greenways (Ahern, 2002) are linear landscape structures for multipurpose use, including nature conservation and aesthetics, and recreational and cultural purposes, but exclusively contain linear elements. A key feature of ecological networks is that they can have different configurations and still serve the same goal. This is due to the variation in four physical features of ecological networks: total network area, quality, network density, and permeability of the matrix (Opdam *et al.*, 2003). Together, these features constitute the spatial cohesion of the landscape. Also another key feature is that ecological networks can be delineated at any spatial scale. Species differ with respect to the spatial dimensions of their networks (Vos *et al.*, 2001). For small species, sustainable ecosystem networks have a local to regional spatial scale. Larger species need ecological networks on larger spatial scales, which may encompass different countries.

In many landscapes with intensive human exploitation, the degree of fragmentation of natural ecosystems develop to such a degree, that local areas can not support viable populations of most of the species (Saunders *et al.*, 1991; Myers, 2003). A solution is proposed to this fragmentation problem based on considering the set of local populations to form a network. Metapopulation ecology states that the long-term persistence of such network populations depends on the spatial cohesion of habitat networks in the landscape (Opdam *et al.*, 2003). The degree of cohesion of the habitat network determines whether or not local extinction and recolonization rates are in equilibrium, and whether the network allows the population to be resilient enough to stochastic demographic processes and environmental perturbations (Hanski, 1999).

As Holling (2000) highlights the paradox of sustainable development that change is essential, and yet stability is necessary, a solution is proposes by himself distinguishing slow and fast moving adaptive cycles of growth, accumulation, restructuring and renewal. He defines sustainability as the capacity to create, test and maintain adaptive capability, while development is the process of creating, testing and maintaining opportunity. Ecological network is a spatial structure that accommodates these inseparable dimensions of sustainable landscape development.

Within ecological networks, humans can create a structure, which can be changed over time without losing the conservation potential for target populations. The explanation is found in the nature of spatial cohesion, a unified measure for the conservation potential of an ecological network (Opdam *et al*., 2003). For a population to be resilient, the cohesion in a planning area should exceed a certain minimum threshold. Four structural components of the ecological network (quality, total area and density of network and landscape permeability) contribute to the cohesion. Hence, a decrease in one component may be compensated by improving another component. Also, a lost local element may be replaced by developing an element elsewhere in the network. Hence, the ecological network is spatially flexible. By this flexible nature, ecological networks have the potential to integrate development and conservation, and make conservation of species diversity adaptive. In this way, conservation may find its place in the sustainable development of landscapes. This is a fundamental difference with isolated protected areas (Bouwma *et al*., 2003).

4-3- Decision-making in Landscape Ecological Modeling

Sustainable landscape development requires a continuing decision process about landscape change, in which ecological, social and economic requirements are balanced, while not losing irreplaceable entities. It entails the controlled adaptation of the landscape to future needs of society, and requires that all actors in the process accept the aim of long-term persistence of biodiversity. However, balancing also implies that, for the planning region, the functions end up with optimal, rather than with maximal conditions. Balancing implies negotiations and compromise is part of the process (Kingsland, 2002).

It means, the planning process should lead stakeholders through decisions about priority ecosystem types and target species, and about the required physical conditions needed (including enough space and connectivity in the right location). Governmental laws and national conservation targets may impose constraints and opportunities in setting regional targets, whereas amounts of available space and funding, as well as support by the local stakeholders may set limits to the conditions. Ecological networks:

- help to focus on an ecologically relevant part of the landscape, a part that can be pictured as a concrete structure that appeals to the actors' imagination of what biodiversity needs;
- facilitate negotiation about feasible goals and required area, configuration and location of ecosystems;
- can be designed in alternative options with more or less equal ecological sustainability.

Therefore, negotiations between stakeholders in the planning group are facilitated by focussing on ecological networks, and enhanced by the "hard" scientific data on minimal distances and minimal area required for a commonly agreed level of ambition. Multi-actor landscape planning requires alternative ecological design options to choose between. One does not achieve sustainable conditions by simply offering a rational ecologically based landscape pattern that should be developed.

The solution to this problem is to develop a series of alternative options that all guarantee sustainable ecological conditions, from which a group of stakeholders can choose the socially most acceptable and economically most profitable ones. It also allows decision makers to choose the option that best fits the existing landscape patterns or that can be best combined with other land use functions. Given a certain required level of network cohesion, ecological networks are flexible in design. The four structural components (quality, total area and density of network and landscape permeability) can be imagined as the knobs of a virtual cohesion generator. We can achieve the required cohesion in the network by turning any of these knobs.

Conclusion

There is an increasing contradiction between the short-term views of current political agendas at the country and global levels, and the longer time frames needed for effectively tackling environmental issues and problems. Not all the stated problems can be resolved within the environmental science and policy realms. They belong to the society at large. However, environmental science is now in the position to make a significant contribution to a sustainable future for all.

Landscape change researchers need to address environmental problems from a truly systemic and interdisciplinary perspectives. Environmental science is particularly suited to advance a new scientific paradigm, where researchers will give prominence to the study of non-deterministic, non-equilibrium, complex and adaptive systems. Scientists are still trapped in a reductionist-disciplinary approach, which works well for clearly defined and replicable problems, but has proven largely inadequate to guide research and provide practical guidance on issues that are essentially non-replicable, highly uncertain and interdisciplinary such as climate change.

Also, interdisciplinary research and teaching programs (both professional, undergraduate and graduate) need to be significantly strengthened, putting particular attention to the integrated analysis of the complex relationship between environmental, social, and economic problems and issues.

There is also need to extend scientific practice beyond peer review journals. It is urgent to improve the communication with other social groups, particularly those in charge of natural resource management and to establish more effective dialogue with them. The value of indigenous knowledge has already been recognized in areas such as agriculture and forest management. It is the time to build research agendas that are sensitive to the local context and priorities, and are therefore more effective in responding to environmental problems. There is also need to end ways to solve problems using a pluralistic multi-scale approach rather than imposing global solutions.

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