landscape component	parameters basic program		parameters additional program
	records)	–	plant and animal species
land use	– land use classes	–	tillage methods
	– surface sealing	–	use of fertilizers
	– crops	–	husbandry

4.3 Landscape prognosis: future landscapes

4.3.1 Introduction

The prognosis of future landscapes has not been a very important issue in landscape ecology up to now. The physical and chemical site conditions were regarded to be more or less stable at the landscape scale, even when small scale changes might1 occur. Then, the development of landscapes would be directly controlled by human management activities.

This could be reflected in scenarios, but the major problem with scenarios is, that they are a mere collection of assumptions. They can hardly be proven. However, such assumptions have to be made, because the future direction of development in a landscape is determined by decisions in human societies. Such decisions are rather based on the socio-economic standard and financial mechanisms, than on environmental conditions. These add another **uncertainty** to the conceivable directions of future developments. These decisions are controlled and modified by zeitgeist, prosperity, and by the development of global markets. With increasing importance, environmental problems will contribute to the questions the society will ascend to the strategies that are developed.

Future changes are very much depending on the goals of a society, its needs and fears, and on the benefit that a certain management of land or a certain development might promise. **Social expectations** are changing rapidly compared to natural processes in the development of landscapes. Looking at possible future developments, such deviating expectations and needs within and between societies have to be kept in mind (see Chapter 7.2). It causes the necessity to develop competing scenarios for one specific landscape, which might become relevant if a certain setting will be implemented (Figure 4.3-1).

The focus of **landscape prognosis in the past** was laid on the planning of differentiated land use, infrastructure and tourism. According to this, particularly socio-economic developments were considered and related to site quality, climate, soils and relief. The feedback of the imbalanced landscape system to human activities is explicitly integrated into landscape ecology only since the 1990s. This is also true for the regional and global changes of the environment, that are not directly related to the management of landscapes themselves. The paradigms of landscape ecology had to shift and adapt processes with a new quality in space and time. Another aspect, which might explain the small importance of landscape prognosis in the past is the complexity of landscapes. Complex systems are difficult to predict.

Landscape ecology concentrated very much on the description and analysis of patterns and processes in recent landscapes. Related to this, historical developments and former causes for the recent environment have been investigated (see Chapter 4.1). Until the late 20th century it was assumed more or less implicitly that future developments would be as slow as they had been in the past. This is true perhaps for most geomorphodynamic processes, for soil development and for the establishment of most of the species and communities in landscapes. It will no longer hold true for species invasions and species extinctions, which become more and more important. As an effect, processes and mechanisms that formerly had been rather stable, rare or slow could be promoted now.

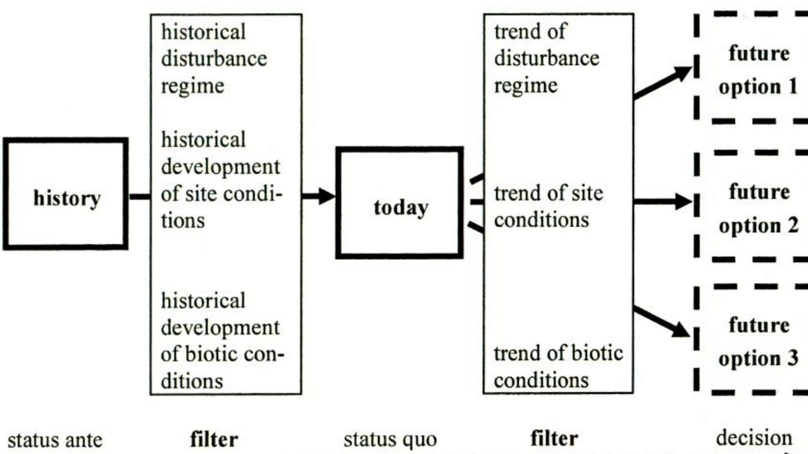

Figure 4.3-1: Scenarios of future developments of landscapes will have to consider the interactions of abiotic and biotic ecosystem compartments with new qualities that can not be compared to historical conditions. Such scenarios have to take care of the individualistic properties of landscapes. Generalizations are dangerous within landscapes, but perhaps impossible across landscapes. Scenarios also have to integrate the uncertainty of future human values. This may lead to differing directions of the development under a given environment

It seems quite clear, that the questions and methods in landscape ecology show a vast diversity of approaches (see Chapter 1.4). Only a few of them are directed to the future. But today, the **prognosis** of future developments and resulting shifts in landscape patterns **becomes more and more impor-**

tant. Today, global, regional and local changes show an increasing speed. There are reasons to believe, that rapid environmental changes will take place; rapid compared to former developments. Such changes can affect ecosystems directly, as the change of land use patterns, and indirectly as well, as the change of biodiversity within persisting patterns. The loss of biodiversity, which is mainly due to the limited ability of species to adapt to new environmental conditions as fast as they are changing, will affect ecosystem functions as erosion control, nutrient cycling or biomass production and via such mechanisms also the stability and vulnerability of ecosystems and landscapes.

Simulating complex systems is obviously restricted by the information that is available about the mechanisms and the direction in which certain parameters will react. Under recent conditions, there can be no experience with environmental conditions and impacts that are expected to occur in the near future. This is mainly true for land use changes, where the data quality is uncertain (Brialssoulis 2001). This is a major argument, why different scenarios should be applied to simulate various site performances.

Powerful **tools** to calculate and to analyze future changes exist since computers and software offer the possibility to simulate developments of landscapes within a framework that did not yet exist before. The integration of modern approaches as remote sensing, GIS, and ecological modelling algorithms (see Chapters 6.2 to 6.4), can open new perspectives for the quality and precision of prognoses. Such techniques can contribute to a better understanding of today's spatio-temporal patterns and in consequence to precise simulations of changing environments.

4.3.2 Panta Rhei

The major problem in landscape prognosis is the projection of oncoming developments on the basis of the knowledge and the environmental conditions of today. It is to ask, which present-day landscape traits will react to landscape changes or even promote them. Models to predict future conditions of disturbance regimes or in the ecological background are based on data sets gained recently. It is not clear, whether this data quality is appropriate to calculate future situations. As we do not know, what will happen, the choice of parameters to integrate into a model is a difficult task.

There are also uncertainties about former conditions within landscapes. This is why landscape models have to be applied also in order to simulate historical landscapes. If it would be possible to verify the results of landscape models on the basis of **historical data** on landforms and vegetation, soils and water regime, it would be promising to apply such models to modern questions and problems. One field of research is the modeling of glaciers or sea level fluctuations, because these mechanisms have left historical traces (Figure 4.3-2).

Figure 4.3-2: Glaciers are a favorable object indicator to model past and future environmental changes: The Marmolada glacier (Dolomites, Italy) (Photo: O. Bastian 1998)

The changes of landscapes during their development have been effective on a variety of **spatial and temporal scales**. Today, most changes caused by human activities are very much faster than the changes, which have occurred in the past (see Chapter 4.1). The industrial and technical development, the freedom to travel, global market exchanges etc. contribute to this new temporal quality. The information society offers the access to new ideas and techniques within short time periods world wide.

Processes are no longer restricted to local or regional scales. The social and demographic trends, and, related to this, the economic and technical progress, are a motor of the development. The increasing human population density creates difficulties and political conflicts in developing countries. These problems will increase and promote land use changes. Industrial countries, on the other side will continue to produce and experience new pollutions and pollutants. The changes in the atmosphere will become a central question, and intensive efforts will be necessary to protect the environment.

Other qualities of environmental change are not as obviously negative or dangerous. The powerful vectors that connect continents today (ships, airplanes, etc.), are responsible for the exchange of organisms and diaspores. Some species are successful and can establish in a new environment. Some of these plants and animals develop aggressively in new habitats. When they become a threat to natural ecosystems, they are classified as "invaders" or **invasive species** (e.g. Cronk and Fuller 1995, Figure 4.3-3).

However, not the direct threat of species, but habitat loss is and will be the major reason for the **extinction of species**. If extinction happens as a singular event, only isolated populations will be concerned, but if certain biotope types such as traditionally used meadows and pastures within whole landscapes are abandoned or changed regularly this will affect the whole species pool of landscapes or regions

Figure 4.3-3: Heracleum mantegazzianum is an invasive plant species in Central Europe originating from Caucasus tall herb communities (Photo: O. Bastian 2000)

4.3.3 From local to global scale

Today, not only the velocity of change is high, perhaps even more striking is the spatial extension of environmental changes (see Chapter 4.1). Human impact is no longer restricted to the scale of an individual human being or to a tribe or village but to much larger areas. Landscapes are affected by impacts whose sources lay in some cases far outside of its own range. And conversely, it is common, that mechanisms taking place in a certain landscape, e.g. CO_2-production by the combustion of fossil energy or the setting free of NH_3^+ via agricultural manures, will affect **global processes**.

The release of compounds into the atmosphere, the modification of the ozone layer, the pollution of groundwater and the anthropogenic global warming reached new spatial and temporal qualities in environmental change, that were hard to imagine only some decades ago (e.g. Claussen and Cramer 1998).

Landscape ecology itself - and not only its objects - was very much influenced by the technical evolution of the 20th century. Especially the broadening of the human horizon by aerial photographs was a key factor in the development of this discipline. Today satellite imagery allows world wide monitoring (see Chapter 4.2) of certain qualitative aspects of the earth's surface.

The scale of environmental change is largely related to the **vectors** that are responsible for the transport of matter, energy and information in ecosystems. On the one hand, qualitative and quantitative aspects of these three factors have changed or likely will change. On the other hand, vectors are changing as well. Connections between continents have been created via infrastructure and vehicles. In addition to that, the flow of information via communication devices as the internet creates a new speed and a new distribution of knowledge, which can be beneficial to mankind, but not necessarily has to be. The latter can become true, when possible consequences or the ranges of applicability of problematic techniques or methods are not yet clear.

4.3.4 Scenarios

How to predict landscape changes under new and only vaguely predictable conditions? One possibility would be a semantic description of scenarios or their graphical visualization. Here new possibilities in the processing and manipulation of photographs offer the tool to visualize oncoming landscape patterns. Expected landscapes can be modeled in GIS which helps, for instance, to simulate different combinations of site conditions and land use or the effects of fragmentation (see Chapters 2.3 and 7.3, Blaschke 1999).

As human decisions have a great influence on the development of landscapes, scenarios that integrate socio-economic rules and prerequisites will be an important tool in this context. Scenarios have to integrate ecological models (see Chapter 6.4). However, they have to consider that in the future, not only climate, soil conditions, water regime and biogeochemical cycles might have changed, but also human interests in natural services will have new qualities. We can ask from our current position which developments are desired, but the answers we will give today will be different from the answers that anyone would give some decades from now. This is a matter of fact, as **normative social values** always have changed during history.

This is perhaps the most problematic aspect within the prognosis of future landscapes. Perhaps we will succeed to model the development of soil nutrient availability, of precipitation regime and of other environmental aspects of landscapes in a certain time from now with a satisfying accuracy. And perhaps, which is more difficult, we will come close to predict, how species, communities and ecosystems interact. But, we have reasons to argue that it will be quite **impossible to model the oncoming social needs** and values that will presumably have a stronger effect on landscape ecological functions and performance than the environmental background.

As prognoses have to consider the direction of development of human societies, it will be necessary to take care of the various social and economic interests of people to identify the decisive mechanisms and the requirements for the future. However, scenarios can also be used to find out, which kind of landscape would be preferred. One method to apply scenarios is to produce virtual images of future landscapes and integrate them into an iterative process between landscape planning, stakeholders and decision makers (Tress and Tress 2001b, see Chapter 7.12).

4.3.5 Monitoring, experiments and models

The prognosis of future landscapes will be based on different techniques and data qualities. Methods will have to integrate monitoring, as well as experimental and modeling approaches. Data qualities will have to integrate biotic and abiotic components and first of all be able to indicate complex within-landscape interactions.

Although we are equipped with a variety of techniques to investigate landscapes, many of these will not be appropriate to forecast future developments. New methods to document for instance the effects of global warming or of changes in ultraviolet radiation have to be developed. This applies also for biodiversity loss, soil erosion, groundwater levels and many other ecological qualities and processes. Only few modern approaches really offer quantitative data at the landscape level.

To monitor such changes and to **identify the effects of changes** in overall site conditions is an important task (see Chapter 4.2). It will not be satisfying to document these changes alone. We realize that we cannot wait until landscape changes occur and perhaps restrict the quality of life or cut down resource availability and land use capacity. Advices and guidelines are needed to avoid or to reduce detrimental effects of global and regional changes to ecosystems and resources.

According to **global warming** some new research projects (e.g. Pauli et al. 1999) aim at a monitoring of ecological reactions. Long-term research has to be installed to address such mechanisms (see Chapter 4.2). The observation of the successive change of vegetation is one important approach in this field. The problem is to assure, that the target parameters are mainly driven by climate change and do not interfere with other site conditions.

Generally, we will have to apply approaches that integrate different techniques and methods. To cope with the new questions and tasks, it seems to be promising to develop a methodological design that combines monitoring, experiments and models (Figure 4.3-4). The **integration of various methods** into a methodological framework that refers to a general theory and concept and has clarified the questions and problems to deal with, can contribute to solve these problems within a reasonable time.

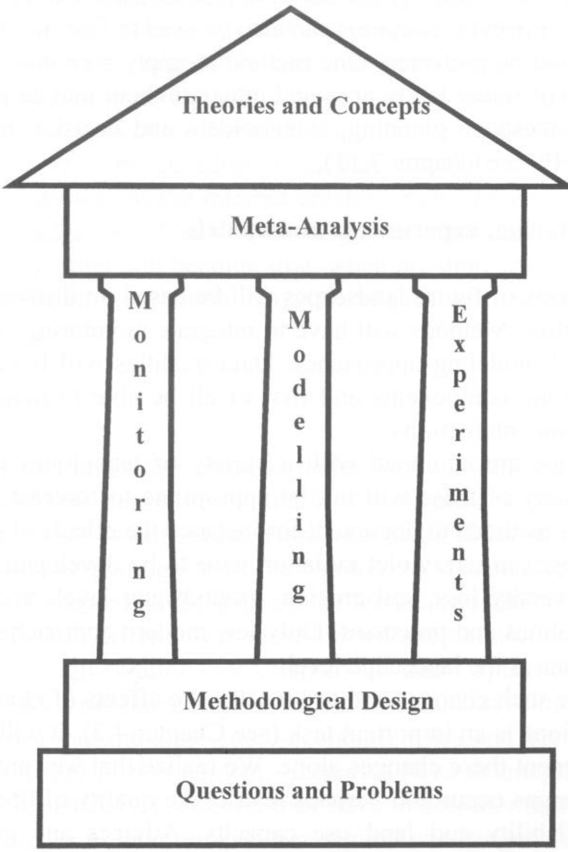

Figure 4.3-2: The methodological temple of landscape prognosis. The environmental questions and problems can only be solved under the roof of a sound theory. Concepts and theoretical background work has to be done before applying analytical techniques. On this basis a methodological design can be established, that responds to the original questions and is valid only under a certain theory. According to the prognosis of future developments, the building will be more stable, if one takes different methodological approaches into account, that relate to each other. However, first of all, these methods should be subject to a final meta-analysis, that integrates the specific results.

Within this combination of methods, the simulation of future landscape conditions on the basis of **mathematical models** is perhaps most convincing (e.g. He et al. 1999, see Chapter 6.4). Such models however are based on processes and objects which occur today under recent environmental conditions and land use. They have to be modified and integrated into a new environmental frame. This is also true in restoration ecology, where complex models will help to design management techniques (see Chapter 7.11). In nature conservation, ecological models can contribute to design habitats and reserves for endangered species.

In addition to monitoring and modeling, the application of **experimental approaches** is necessary as well. Under controlled conditions, but close to the real conditions in ecosystems, model ecosystems could be installed, to mimic site conditions that are expected to occur. At the landscape level, it will be difficult to simulate certain expected environmental conditions. However, for fragmentation or homogenization, or for the loss of biodiversity by introducing monocultures, experiments can be thought of at this level (e.g. Pither and Taylor 1998). Perhaps more important, experiments at the level of communities and ecosystems will offer the possibility to investigate the consequences of environmental change and of the loss of biodiversity (Hector et al. 1999). Model communities that are close to natural conditions can deliver insights in the functioning of ecosystems.

Finally, we have to ask: Do we have good ideas, which developments are likely to occur? Which circumstances have to be considered? What will really dominate the future environmental discussions? Will it be the global change of temperature, the increasing precipitation, the rise of the sea level, the Gulf Stream, the increasing thunderstorms and hurricanes, the land use change in tropical and subtropical regions, the technical development, the societal needs, and the population growth? One thing is sure: **there will be surprises!**