# 1 Relating Ecosystem Studies to the Management of Resources in Central Europe: A Problem of Complexity, Scales and Communication

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## 1.1 Ecosystem Studies at Plot, Landscape, and Global Scales

### 1.1.1 Global Ecology versus Resource Management

The initial development of a global perspective and perception in ecology occurred in parallel with the expeditions and explorations of naturalists that were carried out during the 19th century. As a result of these efforts, vegetation patterning was observed together with climate conditions, and comparisons were made across continents. The fields of plant and animal geography flourished not only from the standpoints of classification and identification of families, genera, and species, but also in terms of deriving an understanding of the relationship between ecosystem structure and climate, and with respect to obtaining maps that indicated the distribution of major biomes on a global scale.

During the 20th century, new studies were conducted and concepts were developed (e.g., Walter 1964, 1968; Schmithüsen 1968) that allowed a general understanding of spatial and temporal changes in ecosystem structure and function in response to climate and disturbances, especially in temperate regions (e.g., Odum 1969; Reiners 1983). The biome level comparison of ecosystem energy flows carried out during the International Biological Programme (cf. Ellenberg 1971 regarding European and German contributions) permitted the first global conceptualizations of biosphere/atmosphere gas exchange and estimates of the net primary production as limited by temperature and ecosystem water use (cf. Lieth 1976). The current International Geosphere-Biosphere Programme (IGBP) can be viewed as resulting from the increased understanding and appreciation gained during the last decades about the intimate coupling between the biosphere and the climate system, from the recognition that

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knowledge of biosphere to atmosphere transfers must be improved due to their impact on the well-being of mankind, and due to the realization that man's activities impact natural resources indirectly and over long distances. Simultaneously, the development of GCMs (global circulation models) and DGVMs (dynamic global vegetation models) may be seen as a logical culmination of efforts that began during the 19th century to understand the global environment and the distribution of ecosystems.

In past decades, we have made substantial progress in quantifying differences in ecosystem function within biospheric frameworks that have long been recognized, namely at biome scale and in terms of global applications (Cramer and Field 1999). However, global models are inadequate in spatial resolution to describe what is actually on the earth's surface. The descriptions of global level models consider Europe to be covered by a limited number of vegetation types that are homogeneous in structure, process characteristics, and energy processing potentials over vast areas and are subject to a homogeneous climate, simplifications that are of little use in the planning of resource exploitation. BAHC (1993) formally described the need to develop up-scaling as well as down-scaling techniques in order to relate global processes to the activities that take place regionally (see also Levin 1992 and Wessman 1992). Thus, while global perspectives may be useful when considering the transfer of techniques of resource management between similar climate zones, they tell us little that is locally applicable in management or use of the areas included within the pixels of global models. While some progress has been made in the up-scaling of processes related to surface energy exchange (Michaud and Shuttleworth 1997), attempts to up-scale ecosystem function, e.g., to estimate integrated carbon, water and nutrient balances at landscape, regional or continental scales, have only just begun (cf. Groffman and Likens 1994; Turner et al. 1995; Waring and Running 1998; Lambin et al. 1999; Tenhunen and Kabat 1999).

### 1.1.2 Landscape Ecology and Resource Management

The modification of natural forest vegetation was long underway in Central Europe (Chap. 30) before managers began to examine spatial variation in properties favorable to production. Planning efforts focus on economically productive surfaces and ignore extreme habitats. Ecologists and biologists, on the other hand, are attracted to diverse communities, e.g., differing forest types, wetlands, grasslands, or alpine heath. Thus, this group investigates the extremes and shows less interest in highly managed areas, unless the questions concern maintenance of structural and functional diversity.

Nevertheless, the need to understand the effects of variation in local climate, topography, and soils has become apparent over time to both groups of scientists. Furthermore, it has become obvious that anthropogenic activities directly and indirectly modify the influences of climate, topography, and soils on process regulation and material flows in ecosystems. These conclusions are primarily supported by studies that have been organized within particular scientific disciplines, e.g., emphasizing the problems of agriculture, ecology, nature conservation, or hydrology. Until recently, problems related to funding, to finding a common language and to identifying common goals have inhibited the crossing of these disciplinary boundaries and have inhibited synthesis of our knowledge with respect to integrated carbon, water and nutrient balances at landscape, regional and continental scales. We must expect this to change, given the importance of such integration.

In Central Europe, the functioning surface of the earth was historically a mosaic of forest types; then forested areas with clearings for primitive agriculture and grazing developed; and now an extremely complex mosaic is found with patches of forest, meadows, wetlands, crop fields, open water, and urbanized surfaces. We have moved away from a system that evolved to respond to natural disturbances by fire, storm damage, and insect outbreaks, to a system dominated by continuous anthropogenic disturbances carried out in highly predictable ways. The consequences of particular management methods for production are reasonably well characterized, but management alternatives have not been evaluated with respect to their full impacts at landscape scale. Although much information has been collected that allows us to characterize the time course of landscape change in Central Europe, synthetic tools at landscape scale that would allow us to evaluate their meaning for overall material balances and for questions related to long-term sustainable use of resources are lacking. While it is clear that the functions of landscapes and regions modified by anthropogenic activities do not remain the same, we cannot yet quantitatively indicate how they change or whether alternative management of landscapes and regions would lead to more favorable changes (cf. Turner 1989; Aber 1999).

A recent Dahlem Conference entitled “Integrating Hydrology, Ecosystem Dynamics, and Biogeochemistry in Complex Landscapes” concluded that progress on landscape-level understanding of coupled water, C, and N budgets is limited more by a lack of commitment to a rigorous development and application of synthetic techniques (ecosystem modelling, remote sensing, and GIS) than by basic site-level measurements in various disciplines (Tenhunen and Kabat 1999; see also Burke et al. 1994; Pickett et al. 1994). Based on this premise, we must ask ourselves how experimental designs for future field studies can optimally support spatial modelling and the coupling and closing of water, C, and N budgets at the landscape level. Attempts to close these budgets are extremely important, since a spatially explicit understanding of budgets means that trade-offs in impacts on natural resources can be quantified and local impacts (e.g., on protected areas) may be understood in terms of contributions from the surroundings. This critical need for new management methods and understanding in terms of landscape water, C, and N budgets will stimulate the development of rigorous quantitative methods for analyzing ecosystem processes in a four-dimensional framework, e.g., as they are influenced by environmental gradients (Gosz 1992) and spatial heterogeneity within areas of 100 to 100,000 $km^2$ and by disturbance and land use change over decades (Aber et al. 1999).

In complex anthropogenically modified landscapes, the focus of ecosystem studies has changed from investigating variation in management techniques and how they can increase yield, to the negative effects of overuse and/or limitations on production that occur as a result of over-exploitation. Questions that have become relevant and that are examined in the following chapters include the following:

1. What are the important boundaries in landscapes that are fragmented as a result of intensive use and what occurs at these boundaries?
2. How do intensive management and the development of a complex mosaic of landscape elements influence the flows and storage of water, carbon, and nutrients?
3. What effects do fragmentation and intensive use have on structural and functional diversity within biological communities?
4. How can one relate studies carried out at specific locations to overall function of the landscape mosaic, and at what scales is this possible?

While remaining important, an exclusive orientation of ecosystem studies to plot-level regulation of processes (ha size) is passé (Odum 1969; Levin 1992; Haber 1993). The detailed information that we gain on ecosystem function must be elevated to a new level of relevancy. Information from plot studies must be used together with new methods and techniques to develop understanding at the landscape level as well as to provide simplified process descriptions for pixels of the size used in global models. Leaping over this problem and simply extrapolating plot-level information to large scales will discredit the conclusions derived from ecosystem studies and will by-pass the utilization of potentials that we have created for environmental management purposes.

## 1.2 Networks of Landscape-Oriented Investigations in Germany

This book examines and summarizes current knowledge on process regulation within ecosystem types that are viewed as the building blocks of typical landscapes found in Central Europe. We consider how the information may be utilized to develop landscape-level models. Such models will help us to interpret the manner in which environmental change at large scales (global, continental, and regional scales) can affect everyday life and human activities. The following chapters summarize the results from several large ecosystem projects that have recently been carried out within Germany. These studies have as a heritage the scientific orientation that developed during the 1960s in the International Biological Programme (strong orientation to process regulation in plots of typical vegetation; cf. Chap. 2, and Ellenberg 1971). Independently, at each location, new emphases have developed with respect to heterogeneity in function, time and space scales, and the interpretation of plot studies in a landscape context.

The focus of much of the ecosystem research in Germany must be viewed in terms of overall policy that developed in response to the "UN Conference on Environment and Development" in Rio de Janeiro in 1992. Subsequent to the Rio conference, long-term goals for German national programmes were outlined that would balance economic competence, social responsibility, and protection of natural resources (BMBF 1998a). Research has also been influenced strongly by observed negative effects on important ecosystems caused by nitrogen and sulfur emissions, by excess nitrogen fertilization in agriculture, and in the former German Democratic Republic by extensive pollution with heavy metals. This orientation of ecosystem research toward sustainability issues is promoted in the ongoing development of a regional level (areas of ca. 100,000 $km^2$ size) programme (GLOWA – Global Change and Water Cycles) by the German BMBF (1998b – Federal Ministry for Education, Science, Research, and Technology) for integrated study of the coupling between natural science, social science, and economic systems in different climate regions of the world, especially as they affect water quality and use. Sustainable use of resources and our well-being requires that new methods allow us to couple decision-making with environmental, economic, and social assessments and acceptance of the chosen direction.

These goals place new demands on all of the disciplines involved. Ecosystem information gathering and information synthesis must be reoriented toward spatial applications, and the evaluation of spatial hetero-