

Anthropogenic landscape changes in Central Europe and the role of bioindication

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Abstract

Anthropogenic landscape changes in Central Europe occurred in several stages. Characteristic features include an acceleration in the sequence of changes, a continual increase in the scope and complexity of ecologic problems, growing destabilization of the natural household and a rising proportion of irreversible changes.

Various bioindication techniques are excellently suited for detecting and evaluating landscape changes, as reflected in a large number of case studies. Of these, a number are classified by the authors according to the following criteria: landscape features/components, structure of the test area, and time framework for the studies.

Thorough changes must be brought about in man's relation with nature to remedy the aggravated environmental situation, with these priorities: making human thinking and action compatible with the environment, transforming material production along ecological lines, and applying ecological principles to landscape management, for example in the form of landscape planning.

Introduction

Landscape management is now a guide for practical action worldwide, a development which has been prompted by man-made intervention into the environment and/or landscape especially during the past 30 to 40 years. These changes, so diverse as almost to defy systematic description, have reached a global scale and keep multiplying at ever shorter intervals, thus creating grave and growing risks for mankind.

In Central Europe, human activity has more or less deprived about 15% of the region's surface of its natural functions, sealing or completely transforming these areas by road and building construction, strip mining, etc. Most of the remaining land is quite intensively used mainly for bioproduction

and a variety of other purposes (water catchment, recreation, waste recovery, nature conservation). In this situation, each new element of utilization is bound to affect the landscape economy and often has undesired side effects apart from the proposed benefit.

Landscape change is a qualitative transformation caused by social activity and mostly extended over long periods (hundreds and thousand of years) in the past. These times have now shortened considerably, and the changes in question are both intentional (as in land reclamation practiced by the Dutch, landscapes resulting from the strip mining of brown coal, and more intensive land use), and unintentional (e.g. meadow loam deposits along watercourses, forest damage, eutrophication, the decline of species).

The most sensitive indicator of any type of change in landscapes including deserts and ice-covered areas, is probably the biotic component. Both the flora and fauna not only respond instantly to current variations but also show moments of inertia in the form of relicts which provide important clues to past processes and their consequences. Bio-indication, then, has an outstanding role to play in the documentation of past and present landscape changes, and in related forecasts.

Principal stages of anthropogenic landscape change in Central Europe

In a detailed survey for Central Europe, Bernhardt and Jager (1985) distinguished four major stages of landscape change, all related to the development of the productive forces:

1. *Agricultural acquisition and use* (ca. 5,000–6,000 years) began when Neolithic man settled down to grow crops and livestock, and lasted through the Bronze Age until the large-scale clearing of woods ('colonization') by Slavic and German settlers between the 7th and 13th centuries. This created vast stretches of open countryside and changed the water balance and regional climate. There was extreme water and wind erosion particularly in the early stages until the topsoil stabilized. For the first time, natural landscapes underwent considerable changes as reflected in the widespread accumulation of meadow loam along watercourses or, primarily in karst regions, excessive erosion of the soil cover.

Light-loving animal and plant species migrated to Central Europe and began to flourish, including species associated with the growing patterns of crops and specialized varieties, among them many annuals. Over a long period of evolution, the land thus cultivated by man reached a new equilibrium.

2. *Integrated development* (ca. 1,000 years) made wide use of all the other potentials and resources the natural landscape had to offer beyond purely agricultural pursuits, both in extensive and intensive forms. Ore-mining areas arose with a network

of facilities that have largely survived to this day, such as settlement and transport/communication structures. Particularly important was the use of water for energy production and goods haulage and also for catching fish (as a meal to be eaten on fast days). Hydraulic engineering created many different structures (water mills with impounding weirs, canals, ponds and channels for timber rafting, washing plants, pounding mills, fish ponds), and a high level of water retention provided an enormous number of wetland and water biotopes. Natural forests were partly devastated by multipurpose and purely extensive use (timber, derivatives, wood pasture, litter, hunting, etc.), leading to forest management around the turn from the 18th to the 19th century.

This integrated and varied utilization of landscapes vastly increased the availability of habitats, particularly because natural sites retained their varied character (in the absence of large-scale soil improvement). Over several centuries, the animate world had time to adjust to new equilibria. This gave Central Europe its greatest ever biological diversity around the mid-19th century, the only exception being the extinction of the large carnivores – the bear, lynx and wolf (see Butzek *et al.*, 1988).

3. *The industrial revolution* (just over 100 years) led to marked agglomeration in the settlement structure and created areas for the large-scale exploitation of resources. At the same time, the number of new and intensive uses for farmland and woodland was limited. About 10% of the earth's surface became completely transformed, or was sealed by residential construction, industrial development, transport routes and mining. New factors included the extensive utilization of fossil fuels and the rapid expansion of chemical manufacture. Landscapes now had to deal with *substances* that were *extraneous to nature*, but pollution for the time being was largely confined to the agglomerations. The functions of running waters changed from being sources of energy to becoming carriers of goods and effluents. Water retention decreased, partly through land improvement and the disappearance of ponds, impounding weirs and bogs, but also as a result of growing water consumption.

Agricultural bioproduction also contributed to change because of the need to feed, at much reduced man power levels, the industrial proletariat that had migrated to the cities. Agricultural lands, at the same time, became more homogeneous because of fertilization, land improvement and attempts to increase the depth of the arable layer.

All this had the effect of reducing the biotic diversity of landscapes. Major habitats were lost, and conservation had its beginnings with the proclamation of the first nature reserves.

4. *The scientific and technological revolution* (for the last 35–40 years) has drawn intensively on nearly all the resources and potentials inherent in natural landscapes, through the use of large machinery systems, chemicals and automation. The aim is to maximize benefits and yields, excepting only small plots which are difficult to reach with machines. Now all landscapes are exposed to anthropogenic materials and energy throughputs at levels many times those of the past, with substances extraneous to nature becoming omnipresent and pollution spreading to large areas (in gaseous, liquid and solid form). There is also a rapid increase in the multiple use of landscapes leading to interferences and neighborhood effects. Biotic diversity is further reduced by land improvement and the resulting homogenization of agricultural and related sites, and by landscape engineering measures which are assuming ever larger dimensions. In addition, higher levels of mobility (mass travel) are making great demands on the remaining stretches of landscape that have retained their natural character.

With man-made innovation cycles recurring at ever shorter intervals, natural processes and equilibria are being disturbed and have no time to stabilize. Homogenized and overstrained landscapes, the constant injection into nature of substances which are foreign to it, and imbalances have in the last three to four decades created hazards and a danger of extinction for many plant and animal species, and entire biocenoses. Around the globe, the northern temperate latitudes now suffer from environmental degradation which is concentrated particularly in Central Europe, eastern North America and East Asia.

Conclusions to be drawn from the past

From what has been said above, the following trends can be derived which are important not only for understanding the current situation but also to open up a future perspective:

1. In the last few thousand years, landscape changes in Central Europe have been brought about almost exclusively by material and technological advances, and social developments.

2. Each principal stage in the process has been initiated, and accompanied, by a radical innovation of the productive forces, and each of the four stages can be subdivided into shorter phases which deserve closer study and are set off from each other by qualitative leaps. The related changes affect essential characteristics of the landscape which, by diminishing or enhancing its potential, become relevant to society.

3. The periods of time occupied by each of the main stages in Central Europe have become successively shorter (5,000–6,000 years; ca. 1,000 years; ca. 100 years; under 40 years), an almost logarithmic sequence.

4. The acceleration in the pace of man-made intervention makes it difficult for natural processes to stabilize and the landscape economy to reach equilibrium. As a result, the interaction of landscape factors, and the landscape economy as a whole, has been subject to destabilization at an increasing rate, particularly during the last two stages. This in turn has meant greater risks and, at the same time, more spending designed to maintain artificial equilibria and to repair damage, while the pattern of relations linking the individual factors has become increasingly complex.

5. Man-made intervention and innovation, in the course of history, has diversified and spread to almost all elements of the landscape. Such multiple use is leading to overlaps and interference on a growing scale.

6. During the second stage, environmental degradation was only local and limited. It spread to larger regions, the agglomerations and mining areas, in the third stage, and has now reached global dimensions.

7. Changes in quality which then take the form

of conspicuous landscape transformations, are normally preceded by 'creeping' and invisible quantitative losses (e.g., in the vitality of forests before emission damage occurs).

8. Anthropogenic landscape changes involve all geofactors, but to a differing extent. The most dramatic response can be expected from the biotic components, while the relief is least affected, with the exception of mining areas.

9. There is no clear proportional relation between cause (the intensity of social impact) and effect (landscape change) in the course of history, as can be seen in the case of biotic diversity. The number of species and ecosystems in Central Europe grew continuously over long periods in which land use was almost exclusively manual/mechanical and increasingly versatile. It reached a maximum around the middle of the 19th century and then declined again in the last 150 years, first gradually and at an alarming rate more recently. For the last few years in particular, this development is illustrated by a large number of comparative studies. It has been found that already a multitude of plant associations are endangered (Knapp *et al.*, 1985). Even nature reserves no longer seem capable of fully protecting all species in the long run, for example in cases where critical levels of man-made substances are contained in the air and in rain or snow. In some regions these are as high as 20–35 kg of nitrogen per hectare and year (or 20–25% of the nitrogen routinely used on fields for fertilization).

10. The intensity of social use, and the effect on landscapes, is continuously rising, with technogenic elements and largely homogenized farming areas now dominating in many regions. These 'useful' ecosystems, at the same time as they grow more efficient also become detached from their natural roots and thus require ever increasing outlays to keep them under control, and inputs such as irrigation/drainage, fertilizer, and biocides. From an economic and ecological angle alike they are approaching a critical cost/benefit ratio. At the same time, there is a negative effect on other resources, and on the number of species in neighboring ecosystems.

11. There has been a rapid increase in the proportion of landscapes which have suffered irreversible

change. Natural succession in these regions is incapable of restoring them to their original state, which now applies not only to the so-called technogenic landscapes but also to meadows and lowlands subject to hydromelioration, fens, vast stretches of arable and grassland and, more recently, a number of forest areas. Between them, these make up the bulk of our landscapes.

12. Different landscapes with different assets react differently to the same type of human activity, as reflected in various degrees of buffering and stress capacity. In this connection, mention must be made of those surviving landscapes in Central Europe which have retained a wealth of natural assets. Such particularly valuable stretches of land can be found in areas which have, in whole or part, eluded man's utilitarian claims. They include steep slopes, bad soils, waterlogged land unsuitable for improvement, areas with rough climates, and, in many cases, fragmented plots on which machinery can not be used. There is still a great variety of habitats, and places where endangered plants and animals may survive, in landscapes which contain one or more of these elements, as islands, spots, bands or wider spaces utilized only in an extensive manner or not at all. In Central Europe, they are places for environmental monitoring and the last sites where processes related to landscape ecology can be studied in relatively undisturbed conditions. In addition, they mostly have esthetic value and are used for recreation.

13. Even though a number of promising attempts have been made to conserve nature (including the beginnings of landscape planning), human intervention continues to be spontaneous to this day. Its positive, neutral or negative effects on the landscape balance will normally be seen only after longer periods and may then require corrective action. There is a growing risk of disturbances and breakdowns, however, as these interventions are allowed to become more frequent and complex.

Bioindication and landscape change

Among the many approaches to collecting and evaluating data on landscape changes, bioindica-

tion occupies a prominent place. With its various methods, all related to the biotic world, it reflects a much wider range of environmental conditions than the abiotic geocomponents. This has earned it the name of 'superindicator'.

For a number of years, geographers and particularly landscape ecologists have described vegetation as the main ecologic feature of a landscape (Neef 1961). They have used it for analysis, mapping and structuring and, more recently, also for monitoring and detecting, landscape changes. Vegetation is the most conspicuous of the biotic components; it covers most of the earth's continental area but also grows in the aquatic regions and even in the oceans. Along with the fauna and the water balance, it is among the most unstable variables in geosystems and therefore one of the easiest to alter. The extreme vulnerability of the plant and animal world has been demonstrated in spectacular ways, with an alarming decline of species (gene erosion), forest damage and the disappearance of forests (immission damage and the destruction of tropical rainforests), dwindling vegetation in the Sahel zone, oil pollution, and the killing of fish and seals. Further, defunct vegetation cover, affects other geofactors, including the persistent ones – the climate, soil and relief. It is the very complexity of biotic phenomena and processes that has so far relegated them to second place compared with the well-established methods available to the landscape ecologist for studying the abiotic components (Ružička 1985). The fauna in particular has been neglected when it comes to landscape research and bioindication, possibly because as an indicator it is even more complicated than the plant cover. This is regrettable insofar as animals have a great deal to contribute to the landscape through soil formation, in aquatic geosystems, by feeding on the vegetation, with the construction of burrows, and other activities.

Methodical problems and a lack of knowledge seem to be the reasons behind this neglect, as exemplified by the mobility of animals, their ecologic valence which is manifold and often unknown, the almost infinite number of species, a concealed existence which allows observation of many species for short periods only, and the high cost of study (Bas-

tian 1988; Terek 1985).

Despite these limitations, plants and animals make good indicators in landscape research, for example in assessing the quality of the air, water and soil, and in detecting pollution and landscape changes. Bioindication, then, makes it possible to estimate the total impact of a variety of non-specific harmful effects and illustrate it for larger areas.

Similar to the various stages in the organization of biological systems, several stages of bioindication can be distinguished (Schubert 1985) which are, however, not sharply demarcated from each other:

- biochemical and physiologic reactions to environmental pollutants, *e.g.* changes in enzyme activity, reduced chlorophyll content in leaves, metabolic disorders;
- morphologic and biorhythmic deviations and similar phenomena in biological behavior such as leaf necrosis, premature shedding of needles by coniferous trees, height and diameter growth of trees, industrial melanism in insects;
- biogeographic changes in the flora and fauna, *e.g.* decline of emission-sensitive bark lichens, changes in the distribution and population density of bird species;
- changes in ecosystems, *e.g.* woody plants growing on xerotherm grassland in the absence of pasture;
- complex landscape changes as expressed in the extent to which the vegetation is natural (*e.g.* hemeroby).

In assessing most landscape functions, and within the general context of landscape diagnosis, qualitative and quantitative components are important criteria. Repeated analysis and evaluation can document the changes that have taken place, and help identify necessary limitations or possible wider uses by man.

Case studies

It is almost impossible to follow the wealth of literature that has been published on the subject, but the authors have studied a large number of papers deal-

ing with landscape change and bioindication for this report. Bastian (1986a,b, 1987a,b) has, in addition, analyzed findings from a number of test areas in the southeast of the GDR, and some results gathered in the 'Westlausitz' (Western Lusatia) conservation area will be used for illustration in the following. The area in question has mountain crests, valley basins, plateaus with loess and glacial sediments and is mostly used for farming, with some forestry on the mountain crests.

Under the heading 'landscape change' one can classify all papers concerned with the effects of human activity on areas of different dimensions. The vast amount of source material studied can be further subdivided into groups using the following basic criteria:

1. the number and character of the features investigated;
2. the geographic situation of the test area and its structure; and
3. the period(s) chosen for study.

Features

The scope of investigation may range from a limited number of landscape components which have an indicator value sufficient to reflect the condition of the ecosystems concerned, to comprehensive surveys of landscape development covering a variety of interactions and phenomena.

In view of the close connections which exist between new uses, landscape changes and social consequences, it is advisable not to leave the social background out of consideration when discussing these questions (cf. Bernhardt and Jager 1985; Buchwald 1980).

The most promising approach to dealing with a multitude of variable landscape features is limitation to a few meaningful indicators. One of these is land use (Fig. 1), which is so significant because it is involved, directly or indirectly, in all the demands society makes on nature. Studies of land use changes can therefore

- directly identify trends of geographic organization for a country, region or locality, and
- indirectly (in most cases) register and assess

related trends towards ecological change, and the success of landscape management measures (Schonfelder 1984).

Land use data can provide information on the status of the animate world within a landscape.

The multitude of phenomena can be narrowed down to certain land-use activities and their mechanisms of action, such as farming or fruit-growing.

Repeated mapping of biotopes and local features in an agricultural landscape can document how growing social demands have the effect of leveling out diversities (Biotopgruppen 1986; Brandt 1985; Ewald 1978; Weiger and Frobel 1983). Larger fields and a standardised landscape partly remove the borders between various land uses or ecosystems and therefore reduce the potential habitats of a varied flora and fauna living in these so-called ecotones (Mander *et al.* 1987).

Relying on the indicator value of the biotic landscape components alone, comparative studies have been made of the vegetation (incidence and distribution of plant associations), and the flora and fauna (existence of certain species). Particular attention has been devoted to farmland where, in the course of only a few years, the plant cover has been thoroughly transformed by much more intensive use. A case in point is grassland (*e.g.* Bastian 1987a; Bottcher 1988; Hundt 1981; Jeschke 1985; Succow 1986) (Fig. 2,3) but also segetal vegetation (Hilbig 1987).

Fertilizer intake from surrounding fields, and emissions lead to growing levels of eutrophication in remaining forests and groves thus favoring nitrophilous plant species (Bastian 1986a,b; Kosmale 1987).

Vegetation changes also occur in areas used extensively for recreation, for example on the Baltic coast (Jeschke 1985), and in urban regions (Klotz 1987). Substituting one agricultural use for another has equally uncalculable effects on animal populations (*e.g.* Tietze and Grosser 1985).

Structure

Essential data which can be generalized appear in surveys covering larger regions (*e.g.* Central



Fig. 1. Land use changes (between arable fields/grasslands/forest) in a test area of the protected landscape "Westlausitz" 1900/1957/1986 (with the aid of topographical maps and field records).

1. without any change

2. one change till 1957, 2.1 increase of the naturalness of vegetation cover, 2.2 decrease

3. one change after 1957, 3.1 increase, 3.2 decrease

4. change till 1957 and revocation to the former land use type till 1986, 4.1 increase in the mean time, 4.2 decrease

5. a twofold land use change, 5.1 increase in comparison to 1900, 5.2 decrease

Apart from smaller land use changes, most essential changes took place in recent times by introducing large area agriculture. Small plots (e.g. meadows in rivulet valleys) were abolished in favour of very big field or connected grasslands. Simultaneously, there began a considerable intensification of land use on almost the whole area. The consequences are a strong decline of diversity and a biotic impoverishment.

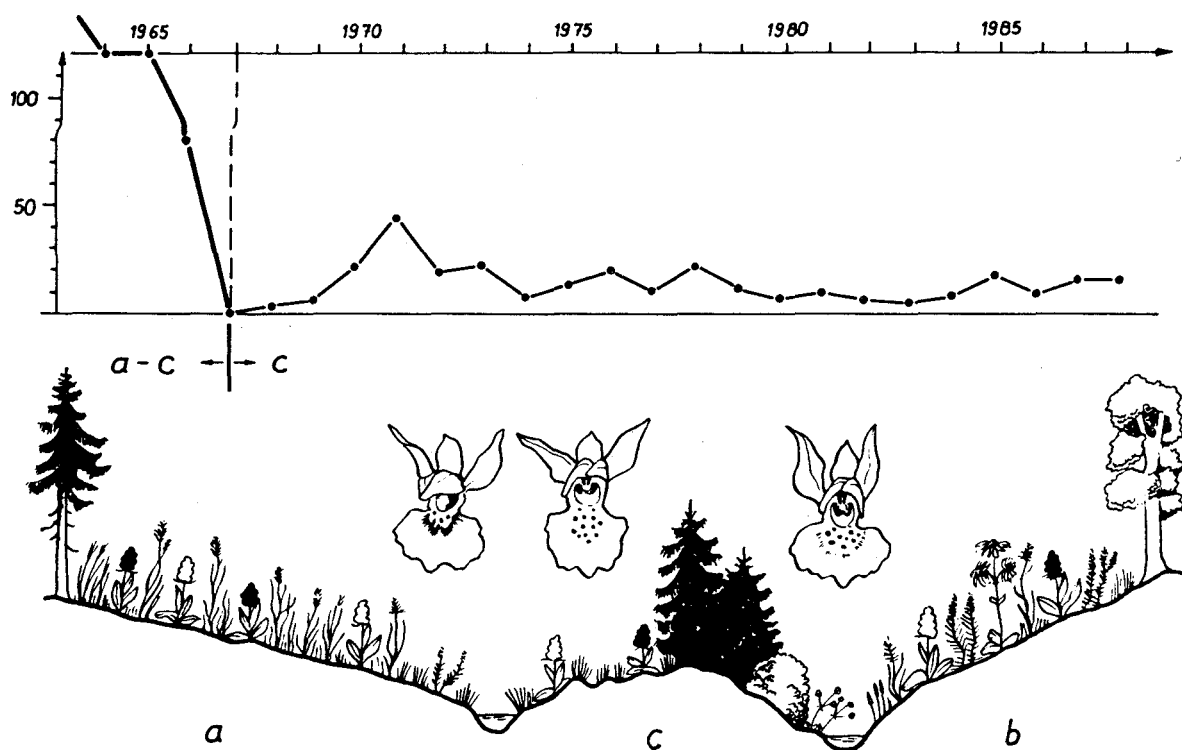


Fig. 3. Decline in the population of *Dactylorhiza sambucina*, an orchid species, on an upland meadow of the Thuringian Forest over a period of 25 years (abscissa), and no. of plants which reached flowering stage (ordinate);

Types of vegetation:

a: *Poa chaixii*/*Trisetum flavescens* meadow without water surplus, devastated by overgrazing 1965–67

b: *Trisetum flavescens* meadow without water surplus, with patches of *Arnica montana*/*Calluna vulgaris* heath, extinct after disuse 1967

c: extremely dry form of *Nardetum strictae*, now refuge for *Dactylorhiza sambucina*

(From: Kiimpel et al., 1989).

size such as administrative units (counties, districts, conservation areas), microchors and geometric units (grids).

Using natural area/landscape units as a basis for reference makes it possible to demonstrate relations between types of natural areas and changes in land use, vegetation and fauna (Bastian 1987c; Kolečka 1987; Brandt 1985; Solon 1988; Steffens 1984). Grids avoid the problems encountered in demarcating geographic reference units; their borders are clearly reproducible, and these patterns are particularly suitable for evaluating topographic maps, and for computer-assisted data processing.

Timeframework

These are widest for studies reviewing anthropogenic landscape changes in Central Europe over ap-

proximately the last 7,000 years (e.g. Bernhardt and Jager 1985; Hempel 1983; Buchwald 1980). At the beginning of that period, man became detached from the natural ecosystems and created the first artificial ones by forest clearing and crop farming. The related changes in the flora and vegetation are summarized in a number of papers (e.g. Knapp et al. 1985; Hempel 1983; Sukopp 1972), and these are also several outstanding local studies which have required extensive historical investigations (e.g. Hanspach 1989; Kosmale 1980; Schmidt 1977). Long-term landscape changes are fairly well reflected in work covering the process which ended with the extermination of Europe's major predators, the bear, the lynx and the wolf (Butzek et al. 1988).

A second group of studies looks back only as far as the 19th century, when a much more rapid and radical phase of landscape changes was ushered in

by the industrial revolution.

A large number of case studies deal with the past few decades (medium term), and a number are now complete with documentation for comparative purposes (including vegetation maps) and ecological data (sometimes by the same author). Still other work is concerned with rapid short-term changes such as pasture plots turning fallow when disused (e.g. Schreiber 1980; Neuhausl and Nauhäuslova-Novotna 1985) intensive fruit growing being introduced on cropland and related changes in the spontaneous vegetation (Bastian 1987b), the detection of forest damage (Papke *et al.* 1987), and the succession of plants and animals settling down on the virgin soils left behind after brown coal strip mining (e.g. Mader 1985).

The number of time segments is also of interest, and it is accepted practice today to repeat studies dealing with land use, vegetation, and other elements at certain intervals (20 years, for example). Even greater insight is provided by three (see Fig. 1) or more time segments which may also allow forecasts as to the expected condition of a landscape in future (cf. Ružička *et al.* 1982).

Types of presentation

These vary widely for landscape changes, and only a few examples can be given here. Quite often a verbal description is given in the literature, but some authors also quantify the changes observed in a test area and summarize them in table form.

A rather informative technique consists in the compilation and comparison of maps (describing land use, vegetation, flora, sometimes using grids). This form is best suited for two, but no more than three, time segments (where landscape changes are shown in one map). Beyond that it tends to become cluttered.

Another approach is to calculate indices which characterize the status of a landscape, such as coefficients of landscape stability (Ružička *et al.* 1982; Kolečka 1985), and of ecological equilibrium (Kolečka 1982). The varying intensity of human action with regard to landscapes can be shown with the aid of the hemeroby quotient (Bastian 1988). It

is obtained by finding the average degree of hemeroby per grid quadrant for two different points in time and dividing t_2 by t_1 .

Changes in (land use) diversity can be illustrated by the difference in the Shannon-Wiener index determined at various times, or in terms of evenness, *i.e.* the relation between actual diversity and its possible maximum. A similar procedure is used for changes in the density of the ecotone network (Mander *et al.* 1987), and for boundaries between types of land use.

Forecasting landscape development

The present situation regarding demands on landscapes, human interference and the resulting processes has become extremely complicated, as illustrated by the following three aspects:

- A rising tide of new encroachments resulting from attempts on the part of industries/establishments to increase output and obtain better results. This leads to the undesirable effects already mentioned above – disturbances in ecosystems, a need to maintain an artificial (and therefore costly) equilibrium, a loss of free beneficial aspects for society.
- An unending and still growing injection of man-made materials into landscapes as part of their utilization, but also in the form of air, water and soil pollutants which have become omnipresent. The decomposition of such large quantities of foreign substances often presents problems and may lead to interference (including metabolites) on a scale that limits monitoring to a few classes of materials at best.
- A widespread lack of environmental consciousness and behavior caused by deficits in ecological education and information, and lifestyles and consumption patterns that are becoming increasingly detached from nature. Ignorance and carelessness at work and at home, and growing needs, are likely to cause even greater damage.

These three factors are rapidly changing the landscape economy both in a qualitative and quantitative sense, leading to the impairment of all types of use. Impressive proof of biotic impoverishment in

many countries is available in the form of Red Books and Red Lists. In the GDR, for example, more than 38% of all ferns and flowering plants were either endangered or extinct (Rauschert et al. 1978), along with a variety of plant associations, particularly those related to waters and bogs, several types of forest, and man-made plant communities from the era of pre-industrial land use (such as extensively managed meadows and pastures, dwarf scrub heaths, rough meadows, segetal cenoses supporting many species – see Knapp et al. 1985). Most animal populations have seriously declined, among them fish (of which 71% are endangered in the FRG), amphibians (58%), reptiles (75%), birds (52%) and mammals (53%), but also insects (Blab et al. 1989).

At the same time, it should be noted that the pace and intensity of anthropogenic landscape change is casting doubt on the very feasibility of some bioindication techniques. Many high-yielding fields and grasslands which have been subject to ecological homogenization now contain only a minimum of wild plant species, and these natural relics are neither sufficient to provide relevant information on the local water and nutrient balance, nor can they reveal trends which might lead to changes, or specific stresses. In most cases, these combinations of species merely reflect a cropping situation (Schlüter 1981).

Thorough changes must be brought about in man's relation with nature if this aggravating situation is to be substantially improved, as reflected in these priorities (see Bastian 1989):

1. Making human thinking and action compatible with the environment.
2. Transforming material production along ecological lines.
3. Applying ecological principles to landscape management, for example in the form of landscape planning.

The latter concept must become an integral part of regional planning and cover all aspects of economic activity with the aim of making optimal use of landscape potentials while preserving them at the same time. Such coordination should also seek to conserve landscapes and minimize interfering uses. A sound base for landscape planning would include

studies into the structure and dynamics of related ecosystems, assessing the status of these ecosystems, their capacity for social utilization, and their stability, as well as development forecasts and a scientific effort to establish management principles.

By following the above-mentioned priorities one could hope to dampen the most recent trend toward ever faster landscape changes and the continual introduction of new elements. Negative side effects in particular could be minimized. Failure to achieve these aims confronts us with the acute danger of landscapes breaking down under the load of spontaneous development.

Even now, the multitude of problems besetting the forecaster makes events in the next 10 years appear highly incalculable. A characteristic example of such risks and synergistic effects is the new type of 'complex' forest damage (particularly at medium elevations) in Central Europe which was first noticed in the 1980s and has now reached considerable dimensions (affecting a maximum of between 50% and 80% of the woods).

Public opinion and governments are becoming increasingly aware of the problem and its economic repercussions, and a number of approaches have been formulated (e.g. the Brundtland report). Consistent action is now required, including a drastic reduction of military arsenals. The enormous amounts of money thus saved could go into making production, land use and lifestyles compatible with the environment, and serve to educate people along these lines. Not until then can we expect the beginning of a fifth major stage in the history of landscape change. This would make it possible, at present and future levels of technological development, to at least retain the current status of landscapes as an investment in the well-being of human society today and tomorrow.

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