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Some remarks on recent developments in landscape ecology as a transdisciplinary ecological and geographical science[1]

Editorial Comment

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As described elsewhere in detail (Naveh 1982; Naveh and Lieberman 1984 and 1989; Schreiber 1990), landscape ecology has evolved after World War II Central and Eastern Europe and has only recently expanded into an international science. Its present status and dynamic development as a diversified global science is well reflected in the December 1989 issue of the IALE bulletin. Here we can find reports on 31 existing regional contacts, the organization of new chapters in China, in the GDR, in the Nordic countries and here in Italy, together with several active working groups and reports and announcements of several international and regional conferences and symposia dealing with different aspects of landscape ecology. These range from an international conference on the cultural aspects of landscape, held in the Netherlands in June 1989 by the working group 'Culture and Landscapes', and the role of landscape ecology in public policy-making and land-use management, held in the USA, in March 1990 by the American section of IALE, to a conference on possibilities and main fields of the practical application of landscape ecology, to take place in Hungary in October 1990.

In spite of these developments, there are still quite a number of ecologists and geographers who claim that there is nothing original and unique in landscape ecology, which would justify its recognition as a proper scientific discipline in its own right. To this I'd like to respond with arguments by Bohm and Peat (1987) in an important book on 'Science, Order and Creativity'. They state that 'in order to sustain the creative activity of mind, and of the ongoing scientific development, it is necessary to remain sensitive to the ways in which similarities and differences are developing, and not to oversimplify the situation by ignoring or minimizing their potential importance.'

They show how this process is hampered because of the tendency of scientists 'to cling rigidly to familiar ideas in order to maintain a habitual sense of control and security and not to break the old patterns of thought'. These patterns have been established according to Kuhn (1970) as the paradigms of 'normal science', namely in a whole way of working, thinking, communicating and perceiving with the mind an unconscious or tacit form of consent. In biology and ecology this is especially true for those paradigms which are grounded in a narrow reductionistic and positivistic perception of science, ignoring the broader, cultural contexts with which landscape ecology must deal.

Amongst those criticizing landscape ecology and its holistic and transdisciplinary nature are also those which Bohm and Peat (1987) have called 'hard-nosed' and which are content only with 'hard facts and logic' and have no time for 'soft' contents and intrinsic values and intangibles grounded in

[1]Condensed version of a lecture at the Seminar on Landscape Ecology: Theoretical and Practical Perspectives in Italy, organized by the Italian Society of Ecology and the Italian Section of IALE – Parma 25th May 1990.

philosophy and in the 'non-mathematical, and even non-scientific' realms of the humanities, such as arts and history.

In concluding this brief introductionary survey, it seems to me that landscape ecology is presently developing into a unique and dynamic integrative field of environmental science. If this is the case, then landscape ecologists cannot restrict themselves merely to the study of the ecology and/or geography or history of landscapes, projected, according to the definition of Forman & Godron (1986) 'as items of interest at the spatial scale of ten to hundreds of kilometers'. Landscape ecology should also become more than a ramification and spatial expansion of population, community, and ecosystem ecology. It should not be regarded only as 'the synthetic intersection of many related disciplines which focus on spatial and temporal patterns of the landscape'' – as stated by Risser (1987) – but as an innovative, transdisciplinary science of landscape appraisal and history, planning, management, conservation and restoration. As such, it should be both a problem-inquiring and problem-solving oriented science. For this purpose its recognition by decision – makers in land uses at all levels and by the public at large is of no lesser importance than its recognition by the scientific community.

Thanks to its long tradition of landscape-related studies and to a strong group of professional land planners and managers and problem-solving oriented biologists and geographers, the Canadian Society for Landscape Ecology and Management (CSLEM), as one of the younger branches of IALE, is following these trends in the best possible way (Moss 1988). I am, therefore, very pleased that the coming international conference of IALE, in summer 1991, is organized by the new president of IALE – Gray Merriam – one of the most prominent Canadian landscape ecologists, and by CSLEM in Ottawa, and I hope that thereby these tendencies can be strenghtened further.

The following is an attempt to outline shortly what are, in my opinion, some of the major, unique premises of landscape ecology, as such a holistic and transdisciplinary ecological and geographical science. For this purpose I will start by using the diagram presented by I. Zonneveld (1990), in his recent account of the present scope of landscape ecology. This shows the three dimensions of landscape ecology study as a combination of the topological dimension with vertical heterogeneity by land attributes, the chorological dimensions with horizontal heterogeneity by landscape elements and the geospheric dimension of global landscape relationships (Fig. 1).

The vertical-topological dimensions of land attributes and their functional relationships are studied also in the traditional earth science and ecological disciplines. But in landscape ecology attention is given not only to the natural, physical and biological dimensions, but also to the historical, cultural, socio-economic and human ecological aspects, connected with human land uses. Therefore, in landscape ecology, man cannot be treated merely as an external disturbance factor of natural ecosystems. He has to be recognized as an interacting and co-evolutionary ecosystem component who has added in the course of his cultural and technological evolution from Homo erectus to Homo sapiens and Homo industrialis newly emerging structural and functional qualities to these natural ecosystems.

As explained elsewhere in more detail (Naveh and Lieberman 1984, Naveh 1989(a), these non-summative qualities are not derived from the biosphere, but from the 'noosphere' – the sphere of human mind and consciousness. They caused the transformation of the biosphere into a mosaic of natural and cultural, open landscapes which are now rapidly replaced by built-up urban-industrial technosphere landscapes. All these landscapes should be regarded therefore as complex 'ordered wholes' or Gestalt systems, containing more than the measurable and tangible parameters of the Newtonian space-time dimensions and their Cartesian, mechanistic and deterministic causality. For the study of these 'hybrid systems' in the terms of Neef (1982)', landscape ecology has to transcend the realms of the natural sciences into the realms of the social and humanistic science. Their full comprehension requires the addition of a higher and more complex systems level, above the bioecosystem level of natural landscapes in the ecological hierarchy, namely a geo-bio-anthropo-level. For

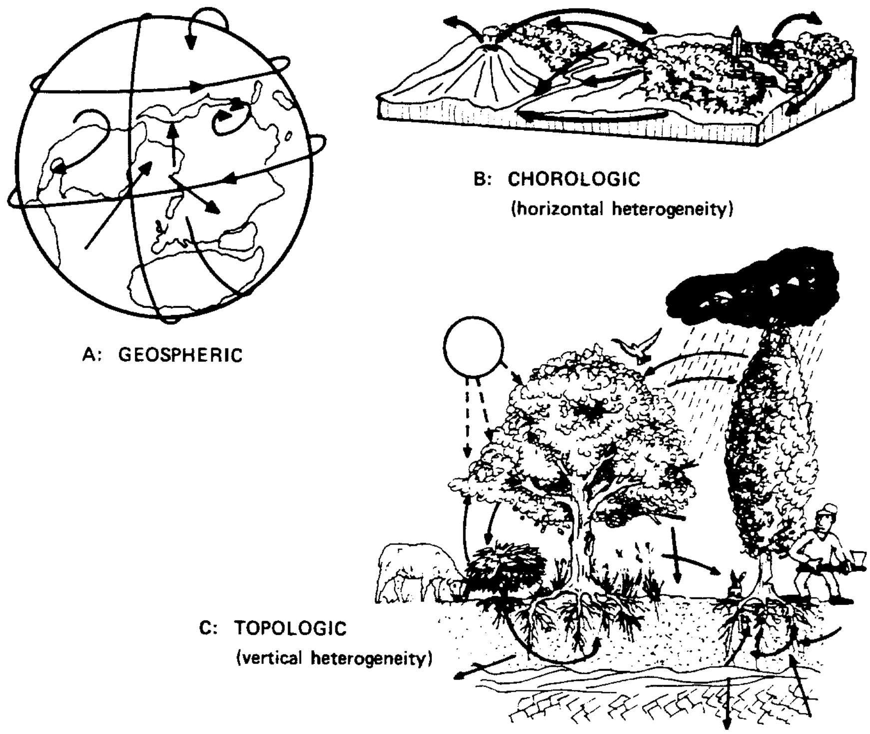

Fig. 1. Landscape heterogeneity. Vertical landscape heterogeneity is expressed by land attributes; horizontal heterogeneity by land units. The latter can be distinguished by chorological classificatio at various scales. (Zonneveld 1990).

this level I have suggested the term the 'Total Human Ecosystem', integrating man and his total environment (Naveh 1980).

In Fig. 2., this new ecological hierarchy is presented as a horizontal cross-section across an outbranching tree, amplified as a chinese box diagram. On the right hand are the major ecological disciplines studying these branches, linked by integrating sciences. As the integrative science of the Total Human Ecosystem, landscape ecology acquires a unique position, bridging between these bio-ecology disciplines and human ecology.

The horizontal-chorological dimensions of land units are studied also by the geographers. But in landscape ecology, the study of spatial heterogeneity of landscape elements in landscape mosaics, corridors, and patch structures have to be related to the above-mentioned topological and functional attributes. For this purpose many worthwhile efforts are spent presently in the development of quantitative methods. These include simulation and prediction models for the study of the interrelations between spatial landscape patterns and their heterogeneity, patch dynamics and the movement of animals, plant propagules and the flow of energy and matter through landscapes. Most of this work is carried out in North America. Thus, for instance, a very active group of landscape ecologists at the Environmental Science Division at the Oak Ridge National Laboratory, in cooperation with many others in the USA, is combining the application of innovative mathematical methods, derived from information theory, fractal geometry, catastrophe theory, percolation theory and probability theory, with remote sensing, digital mapping and Geographical Information Systems. In addition to several other papers on these subjects, a special issue of 'Landscape Ecology' (Dale *et al.* 1989), has been devoted to a workshop on the effects of different spatial and temporal scales on these patterns and processes, and to the development of 'neutral models' for predicting such changes. The hierarchical framework for the analysis of scale and the thermodynamic non-equilibrium properties of landscapes

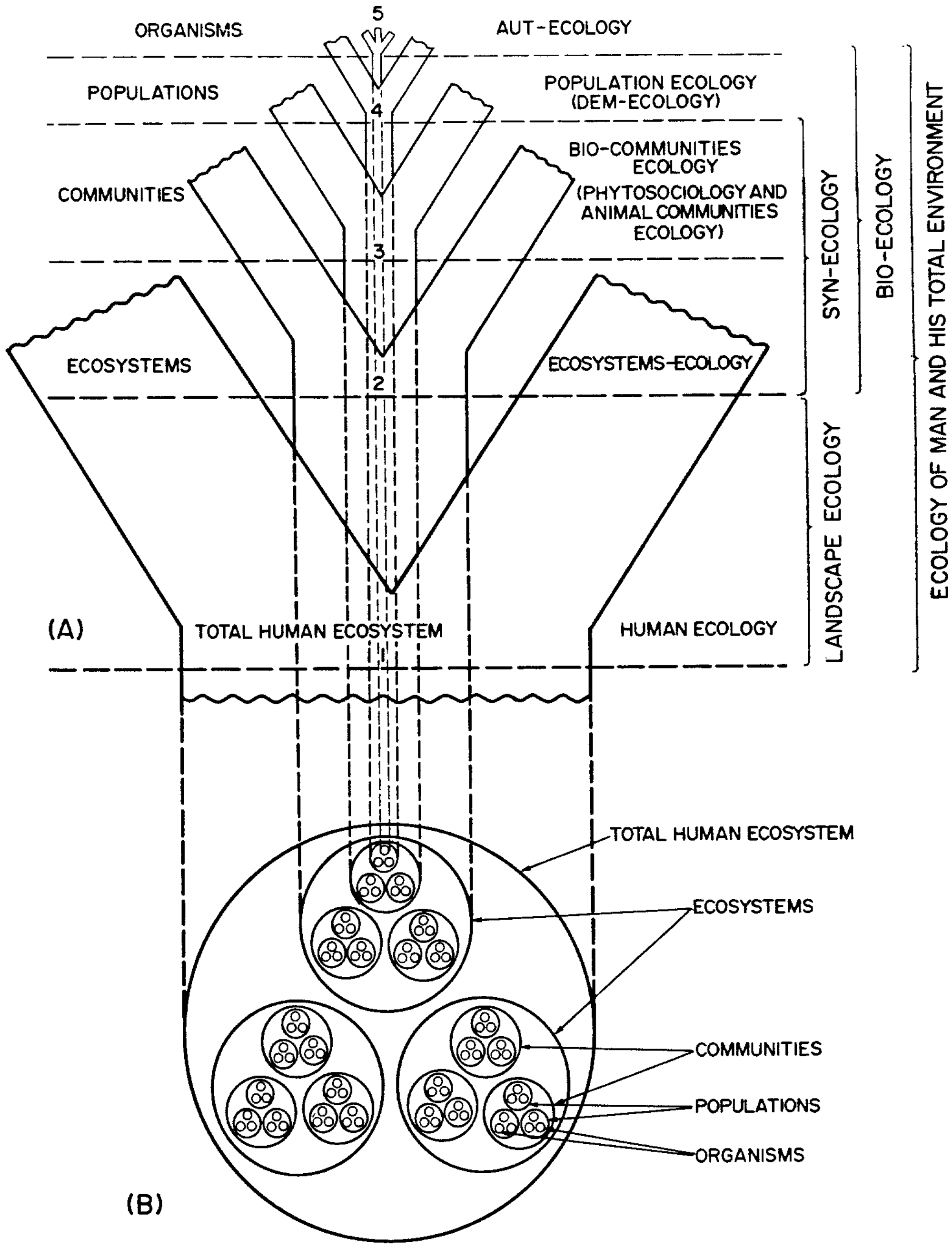

Fig. 2. The ecological hierarchy and its scientific disciplines. The hierarchy of five levels as a combination of (A) the tree; (B) the Chinese box, derived from a cross section through level 5 of the hierarchy tree. (Naveh and Lieberman 1984).

were discussed by O'Neill, *et al.* (1989). This group is preparing also a special book on these methods, to be published by Springer Verlag (Turner and Gardner 1990).

However, up-to-now, all these studies have been concerned almost exclusively with the large-scale heterogeneity of the extensive natural and semi-natural landscapes, typical of North America. They are studied as biological systems and not in their totality as ordered ecological geographical and cultural wholes, within the above-described broader human ecology perspective of the Total Human Ecosystem. Therefore, their patterns and processes are viewed only within the physical and biological hierarchical context along spatial and temporal scales and not also along cultural, conceptual and perceptional scales. Nevertheless, these are important and are of great theoretical and epistemological value to the science of landscape ecology.

Probably of greatest scientific and practical value in this respect is the concept of connectivity, as presented by Merriam (1984) and Bridgewater (1987), and in the second international symposium of IELA in Muenster (Schreiber 1988). It has led to new insights into the effect of natural and man-made corridors and barriers on metapopulation demography and genetics of animal species. In some of the recent studies the spatio-temporal landscape dimensions have been related to functional population ecology dimensions, down to the sub-cellular and DNA level (Merriam *et al.* 1989). In view of the accelerating fragmentation of natural and semi-natural landscapes and the threat to biodiversity, this may have far-reaching, practical implications for landscape management and conservation.

Furthermore, promising developments have been made in the study of order and organization in natural and agricultural landscapes by the use of the mathematical principles of information theory. (Kwakernaak 1984; Phipps 1984; Berdoulay and Phipps 1985). Such methods, in combination with advanced ordination and multivariate analyses have been used successfully in the study of vanishing landscapes in Tuscany (Vos and Stordelder 1988). The same group expanded these studies by an excellent combination of the horizontal, spatial and the vertical-topological relations with the evaluation of scenic landscape attributes and their expected impacts of the planned Farva River Barrage for the irrigation of the Grosseto Plain in Tuscany (Pedroli *et al.* 1988). This comprehensive landscape ecological study has resulted in the prevention of the implementation of the original plan and its disastrous environmental results.

The third, geosphere dimension expands the spatio-temporal and functional scales from the smallest, and relatively homogeneous landscape cell – the ecotope – which can be mapped on scales of 10 000 to 25 000 to larger landscape units and regional systems, up to the global landscape of the ecosphere. Recent threatening trends of atmospheric pollution and climatic changes, have shown clearly the importance of such a holistic global landscape approach. In this, spatial and temporal scales of vegetation, atmosphere, and climate are linked with the help of advanced remote sensing tools (Hall *et al.* 1988) and with advanced, computerized geographical information systems (Burrough 1990).

The important role of landscape ecologists in dealing with the larger scales of Earth landscapes and waterscapes and developing better ways of understanding these complex interactions between man and the biosphere and in applying this understanding effectively to problem solving, has been stressed by Frank Golley (1987) in his editorial introduction to the first issue of the Journal of Landscape Ecology.

The general principles of the application of remote sensing for holistic landscape appraisal, planning, management and conservation have been provided in our book on landscape ecology (Naveh and Lieberman 1984 and 1989). We used a bio-cybernetic approach for the comprehension of the complex mutual-causal feedback interactions between open and built-up landscapes and their atmospheric, hydrospheric, and lithospheric mantle. This approach was conceived by Vester (1976) and applied by Vester and Hasler (1980) as part of the German 'Man and the Biosphere' (MAB) program in sensitivity models for ecological planning of the densely populated Untermain Region. But it can be adapted also to semi-arid and arid, open landscapes and their specific ecological and socio-economic conditions (Naveh 1989b). At the global Total Human Ecosystem level, these perspectives have to be broadened into a geo-bio-cybernetic approach (Naveh 1987).

Figure 3 is an example of the hierarchical landscape-ecological approach to the global coupling among the atmosphere and terrestrial ecosystems and the time scales involved in these closely interwoven processes. Classical ecology and eco-phys-

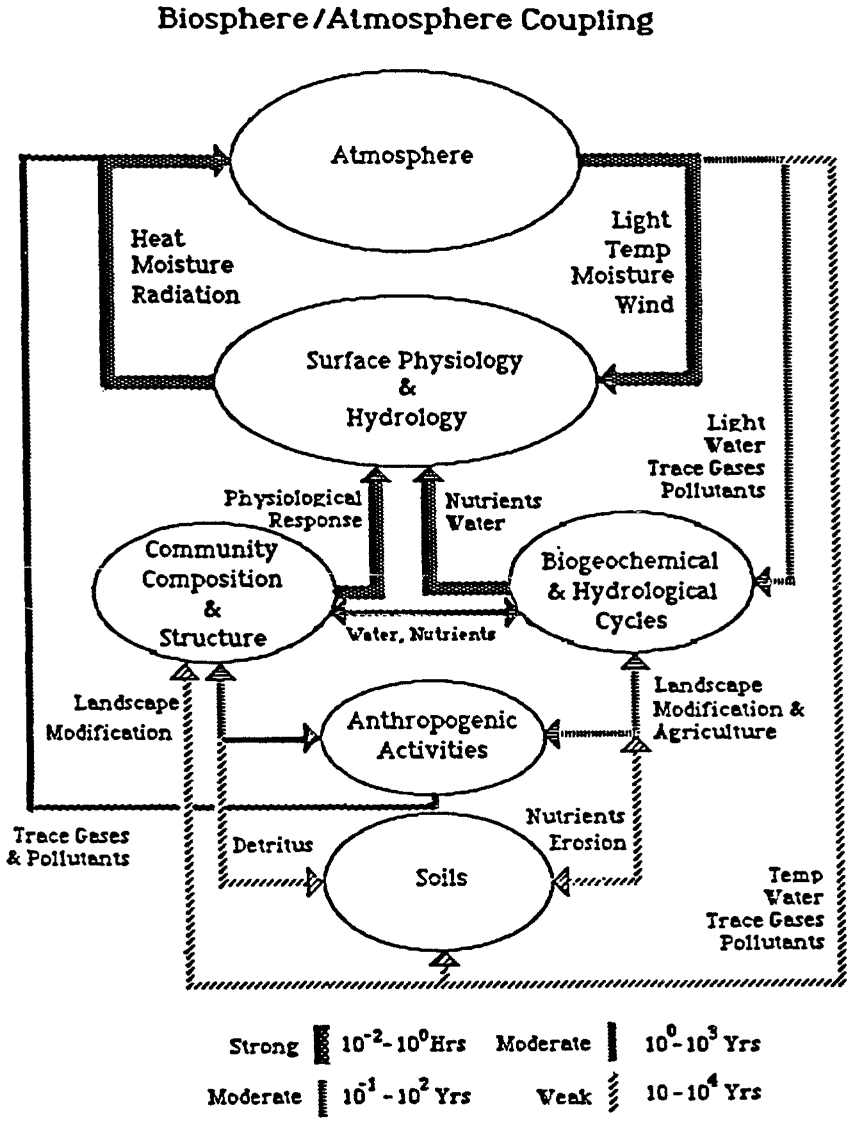

Fig. 3. Major elements in the coupling among the atmosphere and terrestrial ecosystems. This simplified diagram emphasizes the time scales involved in the various couplings. The lower atmosphere and surface vegetation are coupled with a fast-response loop through the partitioning of incidents solar radiation at the land surface and subsequent circulation of moisture and heat in the lower atmosphere which affects the physiology of the surface vegetation. The atmosphere is also coupled through weaker responses at longer scales by climate modifications to biogeochemical and hydrological cycles, soils and community composition and structure. (Hall *et al.* 1988).

iology have dealt mainly with the fast response loops between the lower atmosphere and the surface vegetation. But at the landscape scale of the ecosphere we have to deal also with the slower and weaker loops of landscape modifications through anthropogenic activities and environmental pollution and their effects on biogeochemical cycling and climatic changes.

Figure 4 shows the lack of closed feedback couplings, caused by the one-sided inputs and destabilizing feedbacks of the urban-industrial technosphere landscape ecotopes on the open biosphere landscapes. Although all these ecotopes are spatially integrated in the regional and global landscape matrix, they lack functional and structural integration. Amongst the most alarming syndromes of this

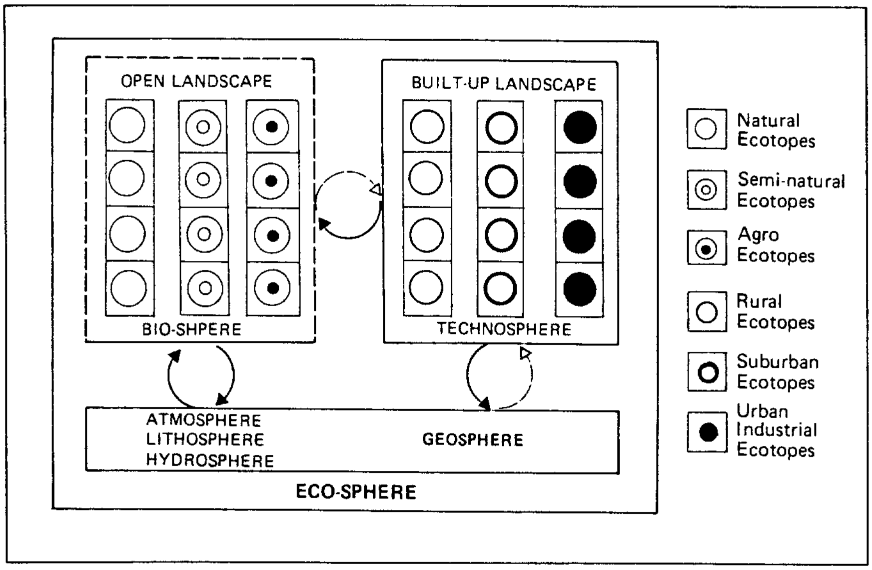

Fig. 4. The threats to homeorethic regulation of the ecosphere by the overwhelming impact of the technosphere on the biosphere and geosphere. This regulation and thereby the full geo-biocybernetic integration of the biosphere and technosphere with the geosphere can be ensured only if the destabilizing impact of the technosphere on the biosphere and geosphere are counteracted by the cultural regulation. (Naveh 1988).

lack are the decline of temperate forests, the death of remote lakes and – above all – the global, accelerating decline of biological, ecological and scenic landscape diversity.

This vital structural and functional integration of the biosphere and technosphere landscapes in the Total Human Ecosystem, as the highest level of the global ecological hierarchy can be achieved only by introducing new cultural, stabilizing and regulating feedbacks. Landscape ecologists can contribute to this process by the provision of scientific and educational information. Both kinds of information could help to induce the urgently needed changes in attitudes and actions which could lead to a new cybernetic synthesis between man and nature.

This can be achieved if we are able to develop innovative, quantitative methods which could cope in a more comprehensive way with the complex interactions between natural systems and human systems on multidimensional landscape scales. They should include not only tangible and quantifiable parameters, but also intrinsic values and intangible cultural, spiritual, aesthetic and other landscape functions and attributes and their 'non economic richnesses'.

Promising advances in this direction are the development of integrated hierarchical feedback models, such as the dynamic Pollution and Forest Collapse 'POLLAPSE' model for the forest die-off in the MAB 6 Programs in Bavaria (Haber *et al.* 1984) and the regional socio-economic ecological systems models in the Swiss Mountain Regions (Messerli and Brugger 1984). This hierarchical system approach to complex systems has been proposed by W.D. Grossman (1983) of the International Institute of Applied System Analysis and is described in more detail by Haber (1990). It can be regarded as a further development and practical application of the system concepts, introduced in our book in a non-formal way (Naveh and Lieberman 1984).

A further step required, is the transformation of this semantic information, as presented in words in lectures and published in books, articles and reports, into pragmatic information, which becomes meaningful through its feedback action by the receiver (von Weizsaecker 1974). For this purpose we have to offer practical solutions for decision makers in land use planning, management, restoration and conservation and find efficient ways for their representation and help in their implementation. A useful educational tool for this purpose is the preparation of Redbooks of threatened landscapes with different scenarios of their future fate under different management and land-use practices. I am presently leading an IUCN taskforce, composed of a multinational and interdisciplinary team for the preparation of models of such Redbooks of threatened landscapes, based on case studies in different Mediterranean countries.

Conclusions

There are, without doubt, many other worthwhile advances in the conceptualization and methodology of landscape ecology which I have not mentioned in my lecture. My main intention was to present to you some of the salient features in the development of landscape ecology as the scientific basis for the study of landscape units in their totality, from the smallest, mappable ecotope to the global ecosphere, integrating all natural and human caused patterns and processes.

In conclusion, Landscape ecology deals with landscapes as the total spatial and functional entity of natural and cultural living space. This requires the integration of the geosphere with the biosphere and the noospheric human-made artifacts of the technosphere. Thereby it transcends the purely natural realm of biological, geographical and physico-chemical sciences into the realm of human centered fields of knowledge, involved in landscape study, appraisal, planning, management, conservation and restoration.

In my opinion, the greatest challenge, for landscape ecology, is to cope with these higher levels of organized complexity and their emergent qualities, transcending those of populations, communities and ecosystems.

If we conceive landscape ecology with such a holistic approach, then landscape-ecological studies have to be carried out along multidimensional, spatio-temporal, functional, conceptual and perceptional scales by multidisciplinary teams, using innovative interdisciplinary methods and having a common systems approach and transdisciplinary conception of landscape ecology.

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