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Ten major premises for a holistic conception of multifunctional landscapes

Zev Naveh*

Faculty of Agricultural Engineering, Technion, Israel Institute of Technology, 32 000 Haifa, Israel

Abstract

The object of this paper is to present 10 major premises serving as a holistic conception for research on multifunctional landscapes (MFLs). Such a theory should become an integral part of the conceptual foundation of transdisciplinary goal-oriented and mission-driven landscape research. Based on a dynamic systems view, emerging from the recent paradigm shifts and insights from findings on complexity and wholeness, MFLs should be conceived as tangible, mixed natural and cultural interacting systems. They are the concrete, self-transcendent and self-organizing Gestalt systems of our total human ecosystem. Ranging from the smallest mappable ecotope to the global ecosphere landscape, they should be studied, upscaled, managed and evaluated with a biperspectivable systems view. For this purpose MFLs have to be treated simultaneously as products of material, natural biogeophysical systems and as mental, cognitive noospheric systems. This can be achieved with the help of innovative transdisciplinary approaches and research methods, in close cooperation among landscape researchers from natural sciences, social sciences, the humanities and the arts, as well as the professionals involved in all phases of land use decision. By adopting such a transdisciplinary and integrative approach towards the landscape as a whole, landscape ecologists could take part in such joint studies and projects, not only as narrow specialists in their own field of expertise as ecologists or geographers. They could help bridge the gaps between all biological and human ecological aspects, related to land use. Thereby they could play a useful role in ensuring the future of healthy, attractive and stable MFLs as part of the creation of post-industrial symbiotic relations between human society and nature. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

The object of my paper is to suggest 10 major premises, which should serve as the holistic conception of multifunctional landscapes (MFLs), with a clear vision for the necessity of transdisciplinary goal-oriented landscape research. For this purpose we have to abandon the reductionistic and positivistic assumptions, which are still widely accepted in the natural sciences. Namely that we can achieve complete scientific objectivity and predictability in the transdisciplinary study of MFLs.

The presently occurring rapid changes in most human-influenced landscapes on earth are unpredictable. Therefore, instead of clinging to the classical scientific model of a predictive science, it is essential for landscape research to become an anticipating science, and like medicine, to become also a *prescriptive science*. As pointed out by Holling (1996) and Bright (2000), we have to anticipate environmental surprises and we have to learn to deal also with uncertainties and unpredictability.

* Tel.: +972-4-824-5029; fax: +972-4-822-1529.
E-mail address: znave@hotmail.com (Z. Naveh).

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We cannot predict the future of our landscapes, but we can help shape their future. We can only attempt to anticipate their fate and the risks involved in their further misuse and degradation and the prospects for their further sustainable development. We can illustrate these anticipations in different scenarios, based on the principle of "if . . . then". We could further help in realizing the most desirable scenarios, both for human society and nature, and prescribe the best remedies for their management, conservation, and restoration. For this purpose a landscape theory cannot be bound down by a rigid, human detached and mechanistic predictive theory, for which classical Newtonian physics has served as a model. It must be guided by a much broader and flexible, future-oriented and holistic view of the world systems and its present deep ecological and cultural crisis.

Humanity has reached a crucial turning point in its relations to nature. The fate of our natural and semi-natural landscapes plays a vital role in these relations. Increasing pressures on their natural resources as well as on their biological and cultural assets, driven by the vicious circle of exponential growth of population and consumption, gravely endanger our sustainable future.

These processes are an integral part of the dramatic transition from the industrial to the post-industrial global information society and its globalized economy. Laszlo (2000) has called these encompassing changes in all spheres of life and systems levels a "macroshift". In these cultural evolutionary trends, our only choice is between further evolution of sustainable life on earth, or its further exponential degradation until its final extinction (Laszlo, 1994).

Transdisciplinary research and education implies an overarching scientific and practical approach, transcending and crossing disciplines and professions, creating a common conceptual base and aiming together towards a common systems goal (Jantsch, 1970). Such a joint, transdisciplinary goal is essential in this context (cf. Naveh, 1995a; Naveh and Lieberman, 1994; Grossmann and Naveh, 2000). It should lead to the creation of new, mutually beneficial symbiotic relations between nature and human society, as realized in healthy, productive, attractive and livable MFLs. Research and action towards this goal have to be based on a sound holistic conception of landscapes and their role in this process (Li, 2000a; Naveh, 2000a).

2. The meaning of transdisciplinarity for landscape research

Such a transdisciplinary challenge does not mean that landscape researchers have to neglect their own unique disciplinary expertise of dealing with the land as a whole. Rather they will have to share it with others, such as economists, anthropologists, environmental psychologists, and sociologists. This requires overcoming the "disease of specialized deafness" for anything outside our own competence. As noted by Allesch (1990, p. 171): "we need specialists that know how special their knowledge is. We need the biologist and the anthropologist, but the biologist who knows that man's nature is more than biology, and the anthropologist who knows that man is part of the ecological circuits".

By opening such a broader integrative "window" for our landscape perception, transcending that of our own discipline, we will not only benefit from knowledge outside our own expertise. We will be able to act both as experts and help to integrate our knowledge with that of the other participants, bridging the gaps between bio-ecology and human ecology (Naveh, 1990). This is essential for achieving our common goal.

From a recent IALE Mission (1998), one can get the impression that the major core theme of landscape ecology is nothing more than studying spatial variations and landscape heterogeneity at different scales on a vaguely defined interdisciplinary level. Instead of retreating to the isolation of a disciplinary academic ivory tower, landscape ecologists have to participate actively at the implementation level. Levin (1999) recently presented such participation as an "integrative science of ecological management". They must become "committed actors", and not only "critical but marginal spectators in this game" (Di Castri, 1997). The Dutch Association for Landscape Ecology (WLO, 1998) expressed forcefully this need to face the challenges of safeguarding and creating sustainable healthy, productive and attractive landscapes for the next millennium. This should be achieved with the help of a broader holistic, conception, applied to transdisciplinary landscape research.

In her final statement at the first IALE conference on cultural aspects of landscape, Nassauer (1990, p. 173) demanded that ". . . we must be courageous in innovating around the conventions of our own disciplines. We must dare to borrow from what is useful in the approaches and knowledge of our colleagues in the arts, social sciences and physical and biological sciences. We cannot afford to be sidetracked into critiques of old, traditional paradigms. Rather, we should move on to invent what works now''.

This requires also an appropriate transdisciplinary educational program, to be enriched by a broad evolutionary literacy (Laszlo, 1994) and according to Orr (1992), above all by a new, ''life-centered post-modern education'' (see also Naveh, 1990, 2000a).

3. Ten major premises for a holistic conception of multifunctional landscapes (MFLs)

A holistic theory of landscapes cannot be considered in isolation. It has to be based on a hierarchical systems view of the world, rooted in general systems theory (GST) and in its recent holistic and transdisciplinary insights in organized complexity, self-organization and co-evolution in nature and in human society. Presented recently in more details (Naveh, 2000b), these issues will be included in the 10 major premises serving as the core theory for such a holistic theory of MFLs.

3.1. First premise: MFLs are part of the dynamic synthetic evolution of self-organizing non-equilibrium dissipative structures

The true meaning of contemporary holistic landscape conception can be fully comprehended only in the broader context of the recent holistic and transdisciplinary ''scientific revolution'', senso Kuhn (1996). Such a revolution was initiated by a major paradigm shift from parts to wholes and from entirely reductionistic and mechanistic approaches to more holistic and organismic ones. It shifted from breaking down, analyzing and fragmenting wholes into smaller and smaller particles towards new trends for integration, synthesis, and complementarity. It meant the need to replace the reliance on exclusively linear and deterministic processes by non-linear, cybernetic and chaotic processes, based on systems thinking of complexity, networks and hierarchic order. It leads from a belief in the objectivity and certainty of the scientific truth towards the recognition of the limits of human knowledge, the need for a contextual view of reality, and the need for dealing with uncertainties. Presently, this scientific revolution leads beyond multidisciplinarity and interdisciplinarity to transdisciplinarity.

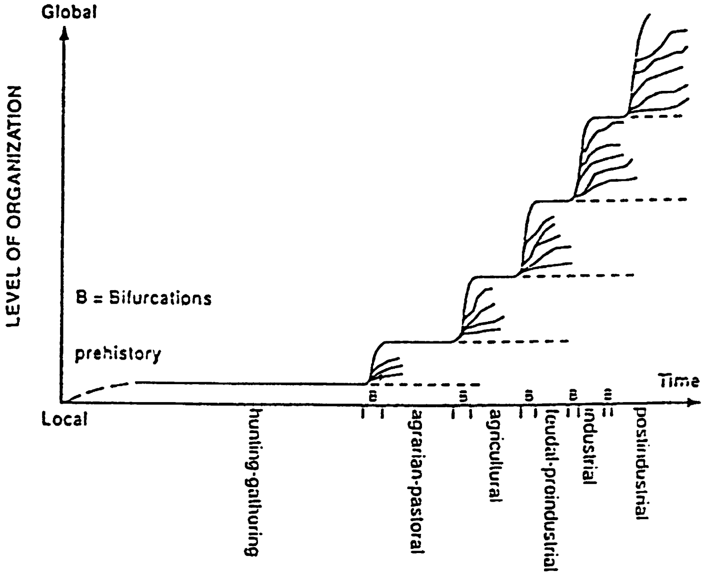
According to Holling et al. (1999) such a holistic paradigm shift is changing already the science and practice of adaptive resources management. It recognizes the limits of our ecological knowledge and the validity of human wisdom and traditional commonsense and its deep cultural values. It has to change also our view of landscapes from a multidisciplinary and interdisciplinary picture of physical, chemical, biological, and other landscape elements and processes into a transdisciplinary view of the landscape and its multifunctional natural and cultural dimensions.

Probably the greatest achievement of the transdisciplinary scientific revolution has been inspired by a great number of new research findings and especially those by Prigogine and his collaborators on the self-organizing properties of non-equilibrium ''dissipative structures''. These new ordering principles of self-organization occur in non-equilibrium systems with the help of ''dissipative structures''. These dissipate entropy as part of the continuous energy exchange with their environment. They create ''order out of fluctuations'' (Prigogine, 1976), and ''order out of chaos'' (Prigogine and Stengers, 1984) by increasing negentropy within the system. Negentropy is the opposite of entropy and disorder. It is characterized by the increase of effective information and energy efficiency, greater flexibility and creativity, higher structural complexity at each higher organizational systems level.

These should be also the properties of sustainable societies, their economy and landscapes in the emerging post-industrial information society. It constitutes a major transdisciplinary paradigm shift from the neo-Darwinian conception of evolution to an all-embracing conception of synthetic cosmic, geological, biological and cultural co-evolution. This new holistic evolutionary conception has been described in comprehensive ways first by Jantsch (1980) as the ''self-organizing universe'' and by Laszlo (1987) as the ''grand synthesis''. Emphasizing cooperation as the creative play of an entire evolving universe, this paradigm is opposed to the Newtonian paradigm of an atomistic world, operating by mechanistic laws of the clockwork-like universe and its more modern view as a bio-chemical and physical machine.

The synthetic evolutionary process should be conceived, as a discontinuous development of sudden leaps by "bifurcations" (from the Greek *furca* means fork) to a higher organizational level. As shown by Laszlo (1994) in Fig. 1, in the cultural evolution these were leaps from the primitive food gathering—hunting to the more and more advanced agricultural and industrial stages. They culminated in societies globally integrated in the emerging information age. Each of these bifurcations is driven mainly by the widespread adoption of basic cultural and technological innovation, such as symbolized presently by the computer. Landscape evolution is an integral part of this cultural evolutionary process.

Systems on a relatively high organization level that can continuously renew themselves and regulate this process in such a way that the integrity of their structure is maintained, are called *autopoietic systems* (from the Greek *autopoiesis* means self-production or self-renewal). They achieve this by *self-organization* as cross-catalytic networks (CNN) of interrelated component-producing processes in a flow of matter and energy and information.



Throughout the span of recorded history, human societies have converged to progressively higher organizational levels. The process began with the hunting-gathering tribes of the Stone Age and currently culminates in the coming of societies globally integrated in the emerging information age. Each bifurcation, driven mainly by the widespread adoption of basic technological innovations, has impelled societies toward more complex, more embracing levels of organization. Today, the widespread adoption of the new information and communication technologies drives the process to the global level.

Fig. 1. The convergence of human societies to higher organization levels during cultural evolution by bifurcations (after Laszlo, 1994).

The integration of the structure-oriented model of self-organization of dissipative structures, rooted in non-linear thermodynamics, and the organization-oriented model of catalytic networks of autopoiesis, has culminated in a coherent theory of living systems, ecosystems and social systems (Jantsch, 1980; Laszlo, 1987; Capra, 1996). It can be adopted also for solar-powered biosphere landscapes, such as natural and semi-natural forests, shrublands, grasslands, wetlands, river-, lake-, and seascapes (Naveh and Lieberman, 1994; Naveh, 2001). This has far-reaching implications for MFLs, which will be discussed further in Section 3.10.

3.2. Second premise: MFLs are more than the sum of their parts, they are unique Gestalt systems

This holistic systems paradigm is rooted in GST and should serve also as the major theoretical foundation for a MFL theory. It requires that we regard each landscape on its own right as an open, concrete, space–time defined ecological system. Landscapes serve as the spatial matrix and living space for all organisms, including humans, their populations, and ecosystems. Because of their emergent organizational system properties, landscapes are more than the sum of their measurable components. They become an entirely new entity as an ordered whole of a "Gestalt" system. In these like in an organism (or a melody) all their parts are related to each other by the general state of the whole. Not only the natural but also the cultural components of a regional landscape, its forests, grass- and shrublands, its wetlands and rivers, its agricultural fields, its residential and industrial areas, its roads, traffic- and power-lines, and their history contribute to this truly holistic Gestalt character of the landscape. These elements comprise its various biological- and human-ecological, social, economic, psychological, spiritual, aesthetic and functional aspects. We experience and use these in the landscapes as concrete wholes. Their complex network interactions and their implications for resolving the pressing problems of our present ecological and cultural crisis cannot be comprehended merely by analysis, but only by synthesis within the context of the organization of the whole.

Weiss (1969) demonstrated these essential holistic features as expressed by the invariance of the system, in comparison with the more variant fluctuations of its constituents by a simple mathematical formula. He pointed out that this is the result of systems behavior under the internal degrees of freedom of its components by coordination and control. It is realized by the capacity of cybernetic adaptive self-regulation through negative feedback loops. Thereby the system—and in our case the landscape—becomes more than its parts, not in a quantitative–summative way but in a qualitative-structural way. Li (2000a) has recently illustrated this holistic landscape paradigm in a more formal way with the help of mathematical set theory and non-equilibrium thermodynamics.

3.3. Third premise: MFLs are part of the hierarchical organization of nature and of the global ecological holon hierarchy (or "holarchy")

Inspired by GST, hierarchy theory has become an important part of the systems approach, and as Simon (1962, 1973), Jantsch (1970) and Weinberg (1975) have shown also a cornerstone for transdisciplinarity. The basic GST paradigm is the view of a hierarchical organization of nature as ordered wholes of multi-leveled, stratified open natural systems. These range from the lowest, physical levels of space–time fields and quarks up to the astronomic entities of planets, stars, galaxies and their clusters. In this macro-hierarchy of the cosmos, the micro-hierarchy of our planet Earth constitutes the biological levels of organismic complexity and the ecological levels of above-organisms complexities, integrating living systems with their environment (Laszlo, 1972).

In the hierarchical organization of any natural system, each higher level contains the lower one and acquires thereby newly emerging qualities, and is more complex than its lower subsystems. It organizes the level below it and serves as the context of the lower level. At the same time, its lower subsystem gives the function of each system and the purpose is given by its supersystem.

For the representation of a holistic and dynamic systems view of the real world we have to take into consideration its hierarchical structure and to adapt our means of measurement and evaluation to each level. Each higher level displays lower frequency behavior. Classical ecology and ecophysiology have dealt mainly with the fast response loops between the atmosphere and the surface vegetation. Until recently it has been assumed that at the landscape scale we have to deal chiefly with the slower and weaker loops of landscape modifications through anthropogenic activities and their effects on biogeochemical cycling and climate change. But because of the exponential rates of these modifications, and ''the acceleration of history'' (Brown, 1996), their time scales become faster and faster and their loops become more and more strongly coupled. Therefore the prevention of their adverse effects has become also more and more urgent. This has to dictate our priorities for landscape research and has far-reaching implications on the ways in which the usable ''pragmatic'' information—senso Naveh and Lieberman (1994)—should be brought to the attention of the stakeholders and decision-makers, to induce their immediate response.

An important development for the recognition of the dichotomic Janus-faced nature of each hierarchy level being at the same time both whole and part, was the introduction of the ''holon'' concept by Koestler (1969). Holon is a composition of two Greek terms: *holos* means whole and *proton* means part. On each intermediary hierarchic level such holons function as self-contained wholes toward their subordinated subsystems, but at the same time they act also as dependent parts toward their super-systems. In other words, depending on our point of view each holon in the systems hierarchy behaves either as a part or as a whole.

In the universal holon macro-hierarchical organization of natural, multileveled and stratified open systems, MFLs should be considered as part of the global ecological micro-holarchy. Serving as the tangible matrix for all organisms, they form their own holon hierarchy or ''holarchy'', with *ecotopes* as the smallest structural and functional holons and the *ecosphere* as the largest, global holon (Naveh and Lieberman, 1994).

Accordingly, MFLs should be studied and managed in a complementary way. They should be considered as being at the same time parts of a higher super-level of the space–time and perceptional hierarchy, and as wholes toward their lower sub-level of this landscape holarchy. Thereby we are overcoming the contradiction between entirely one-sided holistic or reductionist perceptions of landscapes. However, we have to realize that their organizational complexity cannot be treated as a rigid one-dimensional spatially structured physical and biological hierarchy. They should be treated only as dynamic, multidimensional space–time, conceptual and perceptual holarchies, from the largest and most complex global ecosphere landscape to the smallest landscape cell or ''ecotope''. Their upscaling from the lower to the higher holarchy levels is a special challenge for landscape ecologists.

The ecotope can be considered as the smallest, more or less homogeneous and clearly discernible and mappable building block of nature, with all its subordinated landscape elements and fluxes. They have been defined and delineated as concrete systems in much more concise ways than landscape ''patches'', and are mapped in general on scales of 1:10,000–25,000 (Leser, 1991; Zonneveld, 1995). Their boundaries are determined in a pragmatic way, according to the object and the needs of the study. In this respect such landscape cells differ also from ecosystems. They are functional and therefore diffuse in space and more or less intangible (Allen and Hoekstra, 1992; Naveh and Lieberman, 1994).

3.4. Fourth premise: MFLs are complex nature–culture interaction systems

Landscapes, together with living systems and ecosystems are belonging to a special class of ''ecological interaction systems'' whose elements are coupled with each other by mutual, mostly non-linear and cybernetic relations. Such ''middle-numbered'' systems, senso Weinberg (1975), are characterized by intermediate numbers of diverse natural biotic and abiotic and (anthropogenic) cultural components with greatly varying dimensions and structural and functional relationships among these components. For the organized complexity neither mechanical nor statistical approaches are satisfactory and innovative approaches and methods are required. This is especially the case with highly fragmented and heterogeneous human modified MFLs, in which natural and cultural patterns and processes are closely interwoven. Whereas their natural elements have evolved and are operating as parts of the geosphere and biosphere, their cultural landscape elements are the creations of the *noosphere* (from the Greek *noos* means mind). This is the sphere of our human mind and consciousness. It should be regarded as an additional natural envelope of life in its totality that *homo sapiens* has acquired throughout the evolution of the human cortex. As the domain of our perceptions, knowledge, feeling, and consciousness, it enabled the development of additional noospheric realms of the info-socio- and psycho-spheres that have emerged during our cultural evolution (Jantsch, 1976).

In the following premises, the unique features of middle-numbered autopoietic MFLs will be further elaborated. These will also explain further the major differences between ecosystems and landscapes as middle-numbered systems and the need for more far-reaching innovative methods for their study.

3.5. Fifth premise: MFLs are the concrete Gestalt systems of our total human ecosystem

Landscapes are to be viewed not only within the ecological/functional and/or geographical spatial context. They have to be treated within a much broader context of the integrated human-nature systems complex, as the larger ecological entity in which we live. I suggested naming this entity the total human ecosystem (THE). It integrates humans and their total environment at the highest co-evolutionary level of the global ecological holarchy. Landscapes are the concrete, space–time defined ordered wholes and unique Gestalt systems of our THE, within different scales of the above described landscape holarchy (Naveh, 1982; Naveh and Lieberman, 1994).

The conventional ecological conceptions consider natural ecosystems as the highest organization level of this ecological hierarchy, above organisms, populations and communities. This is to view humans merely as external factors to natural ecosystems. As such they should create their own social and economic hierarchies outside those of the natural ecological hierarchy.

Human-modified landscapes make by far the majority of the total open landscape area at global scales (Pimentel, 1992). Even the few remaining natural and close to natural landscapes and their terrestrial and aquatic networks are affected directly and indirectly by humans and are shrinking rapidly. Their fate—like that of all other land- and seascapes on earth—depends for good or worse almost solely on the decisions and actions of human society (Vitousek et al., 1997).

If we disregard the close links between natural and social systems, we will not be able to divert the global change trajectory from extinction into future sustainable biological and cultural evolution. The THE concept intends to overcome this disregard at the conceptual level. It perceives humans and their ecological, cultural, social, political and economic dimensions as an integral part of this highest co-evolutionary geo-bio-anthropo level of the ecological hierarchy *above* the ecosystem level. Recognizing the deeply embedded evolutionary connectedness between humans and the rest of the natural world, this holistic THE concept could serve also as the basic cornerstone for an overarching holistic metatheory for landscape science in the broadest sense.

This co-evolutionary connectedness in our THE is closely related to self-transcendent openness (Naveh and Lieberman, 1994). Self-transcendence means reaching beyond the boundaries of one's own existence. According to Jantsch (1980), and his self-organization paradigm, evolution is the result of self-transcendence at all levels.

For a better comprehension of the unique self-transcendent openness of MFLs, we can adopt the example of Frankl (1969), the founder of the psychotherapeutic school of logotherapy. To demonstrate the uniqueness of the human Gestalt system and its intrinsic and self-transcendent openness, he used the projection of three-dimensional models into lower dimensional ones. This is contrary to the still prevailing reductionist tendencies through which human phenomena are reduced to ‘‘nothing but’’ chemical or psychological reactions. Once we have projected humans out of their own dimension into the lower dimensions of biology or psychology this multidimensional self-transcendent openness necessarily disappears.

Thus, as shown in Fig. 2, if we project a drinking cup or an open cylinder out of their three-dimensional space into the two-dimensional plane of the outline of their layout or the side view of their profile, we receive only a circle or a rectangle. In addition, neither of these lower dimensional projections reveals the fact that the drinking cup is an open container and not a closed figure.

The same is happening if we project MFLs out of their unique multidimensional Gestalt wholeness into ‘‘nothing but’’ their lower geophysical, biological, or

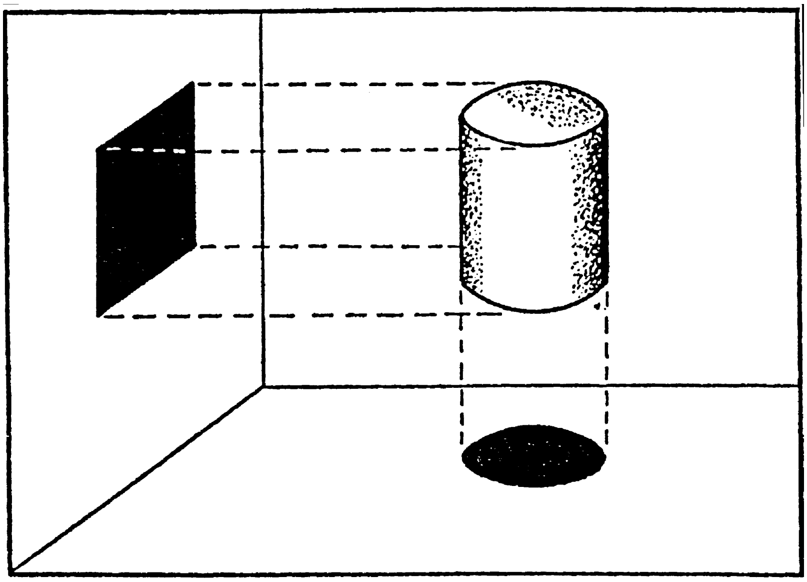


Fig. 2. Projecting of the three-dimensional space of a drinking glass or of an open cylinder into the two-dimensional planes of the layout of its profile (after Frankl, 1969).

socio-economical, or mental or artistic dimension. It can be compared to drawing these landscapes only with a pencil, and thereby loosing the unique qualities of the interplay of their colors. These are an intrinsic part of their Gestalt nature, like the rhythm of a melody.

MFLs have not only "formal" openness (Pankow, 1976) to energy/matter and information flow of ecosystems. They have not only the formal structural configurations of the geometrical landscape configurations of patches, corridors, mosaics, and the spatial organization of landscapes. All these features can be measured only with the help of formal languages, such as mathematical equations, models or graphical symbols and maps. Such formal languages cannot represent themselves, but only other objects. To these they are related only by analogy. However, MFLs have also self-transcendent openness. This means they have the capability to represent themselves or to be described adequately by homology with the help of another natural, self-organizing Gestalt system. This is our natural language. It is the organ of consciousness and therefore serves us as our major cultural exchange of personal experience and information. It must therefore be used for a fuller landscape description (Naveh and Lieberman, 1994).

This does not mean that these lower dimensions should be studied and treated in scientifically sound ways as unidimensional realities, as long as they are recognized as such. The systems view of landscapes can be compared to a perceptional and scientific window through which we are able to look at complex ecological and societal phenomena in their realistic way within the observed context. Such a "contextual window view" is of greatest relevance for transdisciplinary landscape research. Viewed through such a conceptual multidimensional window, these lower dimensions have to be re-interpreted, re-evaluated and represented as parts of the higher whole landscape-ecological Gestalt multidimension. It does also not belittle the great advances achieved in the field of quantitative spatial and functional landscape ecology, based on such formal landscape openness. It only illuminates their perceptional and epistemological limitations for gaining full comprehension of our THE landscapes. If we are aware of this fact, we will never draw inappropriate conclusions from such analytical tools which study landscapes only with these formal language methods, to the same extent that the two-dimensional circle or rectangle are only projections of the open, three-dimensional cylinder. But, as a truly transdisciplinary science, bridging bio-ecology and human ecology, landscape research has to deal also with this self-transcendent openness of our THE landscapes, both in research and education. This is, in my opinion, the only way to account in a comprehensive way for their uniqueness as the tangible meeting point between nature and mind. Some of these unique THE Gestalt features will be elaborated further in the next premises.

3.6. Sixth premise: in MFLs, a transdisciplinary parameter could measure biological diversity together with cultural diversity and ecological heterogeneity, as a common index of "total landscape ecodiversity"

As a consequence of the above-described holistic features of MFLs, biodiversity has to be complemented by new, more inclusive and broader transdisciplinary parameters. These should measure biological and cultural diversity together with ecological heterogeneity as "total landscape ecodiversity", as explained further by Naveh (1991b, 1995b, 1998).

Total landscape ecodiversity can be used as the tangible expression of the dynamic interplay between the biological, ecological and cultural landscape dimensions and their effects on landscape functions. These could be determined by biological diversity, ecological micro- and macro-site heterogeneity and human land uses and their cultural artifacts. These are either enriching or impoverishing both biodiversity and overall landscape heterogeneity at the different scales measured. As shown in Fig. 3, they are coupled by positive, mutually amplifying and self-augmenting feedbacks. The greater the ecological landscape heterogeneity, the greater the chance for biological diversity while at the same time floristic, faunistic and structural vegetation diversity enhances ecological heterogeneity. The opposite is also true. Therefore landscape homogenization, fragmentation, and despoliation diminish biodiversity that in turn reduces further landscape heterogeneity.

3.7. Seventh premise: gaining further holistic insights of MFLs beyond the Archimedian and Cartesian orders

Bohm (1980), Bohm and Peat (1987), and Peat (1997) have opened new vistas for holistic and transdisciplinary scientific paradigms. These are also of greatest relevance for the holistic nature of MFLs as autopioetic middle-numbered systems and as unique self-transcendent Gestalt systems. Bohm (1980) has used the advances of the lensless holograph photography for the development of these exciting new holistic ideas and theories, known also as the "Bohm hologram paradigm". In a holograph the light from each part of the object falls onto the entire photographic plate. Therefore, each part of the plate contains information about its interrelated patterns. It is relevant for the perception of the whole by reflecting the whole that, in a sense, becomes enfolded across the holograph. This has served Bohm (1980) as a powerful analogy for a new metatheory of a dynamic holistic whole and undivided order of the universe. To describe the deeper reality, he proposed a "new notion of order" which he named "implicate order" or enfolded order. It is still hidden and lies beneath the regular "explicate order". In this order the fundamental equations are written, using the coordinates of space and time. It gives rise to it in a universal "holomovement". For Bohm, what happens on the plate is simply a momentary frozen version of what is occurring on infinitely vaster scales in each landscape on earth and in each space of the universe. In this "everything is enfolded into everything".

Bohm and Peat (1987) have carried this holistic paradigm even further. They claimed that no one order would fully cover the human experience. As contexts change, orders must be constantly created and modified. This is true also for the Cartesian grid of coordinates, which has dominated the basic order of physical and geographical landscape reality for the last 300 years. They questioned its general appropriateness and arrived at notions of different degrees of order. The flowing river gives a good image of how a simple order of low degree can gradually change to chaotic order of high degree, and eventually to random order. But they show that between the two extremes of simple regular order and chaos there is a rich new field of creativity, as a state of high energy making possible a fresh perception, generally through the mind. Full creativity requires also free play in communication in science.

Bohm and Peat (1987) recognized implicate order as a special case of *generative order*. This order is fundamentally relevant in nature, as well as in human

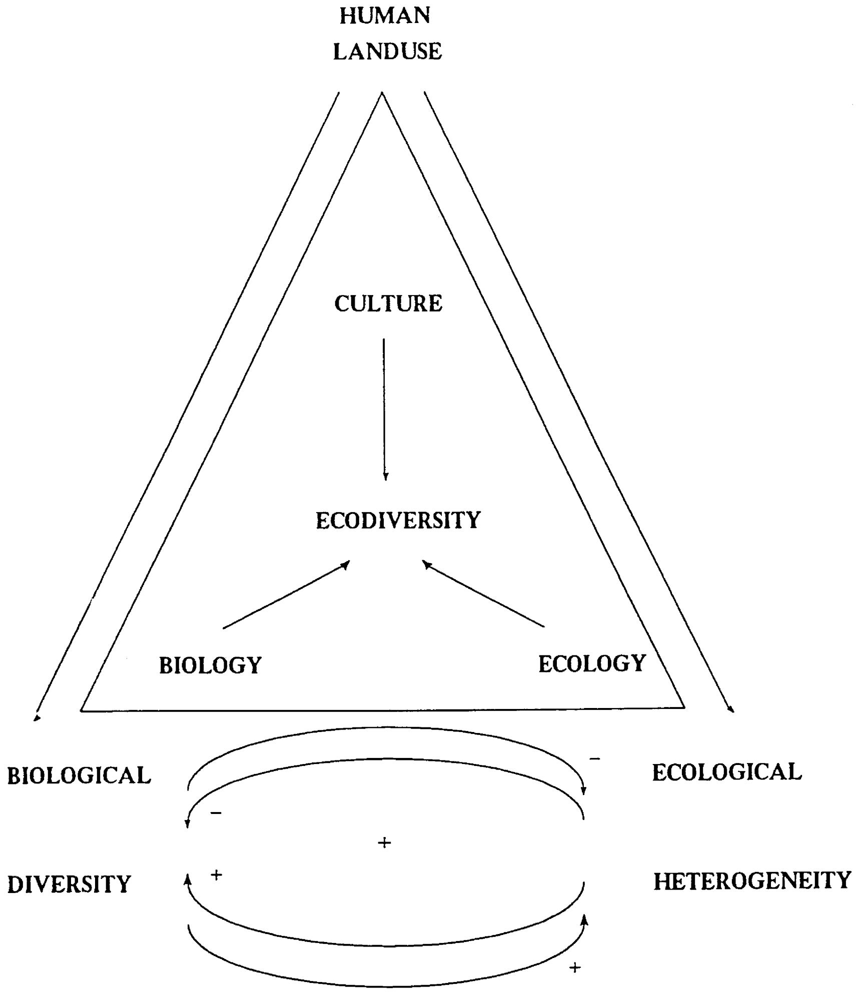


Fig. 3. Total landscape ecodiversity as the result of the interactions between biological, ecological and cultural landscape shaping forces.

consciousness and in our creative perception and understanding of nature. It is therefore also very important for MFLs. With its help we may be able to reach an entirely new view of consciousness as a generative and implicate order that throws light on nature, mind and society. If such an overall common generative order will bring together science, nature, society and consciousness, this can have also far-reaching implications for our transdisciplinary landscape paradigms.

In a recent comprehensive biography of Bohm and his work, his close collaborator Peat (1997, p. 263) stated that "the implicate order is a door into new ways of thinking and the eventual discovery of new and more appropriate mathematical orders. It is both a philosophical attitude and a method of inquiry".

For landscape research this means that further and deeper insights into the holistic nature of landscapes can be gained if we are ready to free our minds of rigid commitments to familiar notions of order. Only then, we may be able to perceive new hidden orders behind the simple regularity and randomness: "it is possible for categories to become so fixed a part of the intellect that the mind finally becomes engaged in playing false to support them" but clearly, "as context changes so do categories" (Bohm and Peat, 1987, p. 115). Such a change in context occurs when landscapes will no longer be treated as ''nothing but'' formal, spatial geometric structures and mosaics, describable by Archimedian geometry, and by the Cartesian grid of coordinates. Instead they will be conceived as unique self-transcendent autopoietic THE Gestalt systems. These are imbedded in a hierarchy of subtle, generative, implicate orders, in which human mind, consciousness and creativity play an important role.

The first important steps in this direction beyond the regular Archimedian order are *fractal dimensions*, which occupy already an important role in many landscape studies. Their multiple functions for landscapes have been described recently and very comprehensively by Li (2000b). However, it should be realized that the order of fractals is related to a local order of space, whereas in the implicate and generative order the process of development should be related to the THE landscape as a whole.

For landscape research it will become a major challenge to capture these implicate and generative orders. One possibility could be the combination of the holistic Gestalt interpretation of aerial photography, presented recently by Antrop and Van Eetvelde (2000) as a visual image interpretation of suburban landscapes, with holograph photography. Further new orders may also hopefully emerge through the collaboration of landscape researchers with others in relevant scientific and professional fields. They are essential for the development of practical tools to provide a more integrated appreciation of the aesthetic, ethical and intrinsic functions of nature and their values in the decision making process, beyond narrow economic cost/benefit calculations.

3.8. Eighth premise: the dualistic perception of MFLs can be overcome by treating them simultaneously as biperspectivable natural and cognitive systems

A major challenge for our transdisciplinary vision is to overcome the great epistemological barriers erected between scientists from the natural and humanistic scientific ''cultures'' by their contrasting perceptions of landscapes as either entirely physical or entirely mental phenomena. This dichotomy originated from the deeply ingrained Cartesian dualistic view of nature and mind. It has resulted in the positivist and reductionist dualistic interpretations, by which the mental phenomena ''do not count'', because they cannot be counted, measured and quantified by conventional mathematical and/or biophysical means. However, as shown above, there are many landscape features and functions that cannot be counted by these measures, but they ''count'' very much in reality. On the other hand, not all those landscape elements which can be counted are worth counting because they do not count at all in reality.

Laszlo (1972) developed an alternative to this dualistic view with the help of a biperspectivable systems view of two major classes of natural systems and cognitive systems. He defined natural systems as ''a random accumulation of matter/energy, in a region of physical space–time, organized into co-acting inter-related subsystems or components'', and cognitive systems as, ''systems constituted by mind events, including perceptions, sensations, volition, feelings, dispositions, thoughts, memories and imaginations, i.e. anything present in the mind''.

Both natural and cognitive systems are single, self-consistent mind-events of cognitive systems and natural, physical space–time events of concrete systems. But they are internally and externally observable *simultaneously* as integrated *natural cognitive* and *psychophysical systems*.

As thinking human creatures we are living not only in the physical, and geographical space of these concrete natural systems of the geosphere and the biosphere, which we share with all other organisms. We also live in the conceptual space of the cognitive systems of the human mind, in the noosphere. The MFLs of our THE are the products of both of these internally and externally viewable natural and cognitive systems and their interactions. Therefore they can serve as the ''tangible bridge between nature and mind'' (Naveh, 1995b). As such they can be perceived by our contextual window view, as well as studied, managed and evaluated simultaneously with such a biperspectivable systems view. Only such a complementary approach allows us to grasp fully the self-transcendent notion of these MFLs. That such a biperspectivable view is essential for any meaningful transdisciplinary research and its practical implementation is shown also in the next premise.

3.9. Ninth premise: "hard" and "soft" values of MFLs should be appraised jointly by transdisciplinary teams

Living systems are driven solely by chemical, physical and biological processes. Thereby they maintain their multifunctionality of life. In ecosystems, the relations between organisms and their biotic and abiotic environment have created additional ecological processes. These lead to a great number of vital regulation, production and protection functions. However, their multifunctionality is only *monodimensional*. It is based solely on natural, material processes of flow of energy/matter and biophysical information. These are investigated by basic and applied disciplines of the natural sciences with the help of formal languages. On the other hand, the multifunctionality of our natural and cultural THE landscapes is *multidimensional* with important reciprocal effects on human society. It is deeply imbedded in their holistic, biperspectivable nature as self-transcendent mixed natural and cultural middle-numbered systems. Their functions are driven both by natural, material–ecological processes of geospheric and biospheric origin, and by cognitive mental processes of noospheric origin. The former processes are transmitted by biophysical information, whereas the latter are transmitted by cultural information chiefly with the help of our natural language.

The evaluation of these multidimensional functions has to include both the *anthropocentric dimensions* of their instrumental values, as measured by their benefits for human society, and the *ecocentric* and *ethical dimension* of the intrinsic existence values of landscape. These are non-instrumental and do not depend on utilitarian values. As explained by Smith (1998, p. 14), "these intrinsic values refer to the natural thing not as a means to an end but as an end in itself". Therefore we have to study landscape functions not only as a mere commodity to be exploited as a resource on which we project our economic interest. They are also a source of value on their own right, even if we cannot put any monetary and social value on their services. It is a grave mistake to assume that we will be able to prevent their extinction by stressing only their socio-economic functions in which the human role is reduced to that of a "homo economus" keystone species (O'Neill and Kahn, 2000). This is true also for the attempts to express nature values in terms of "natural capital". In the conventional economic sense "capital" is accumulated by the production of marketable goods and measured only by monetary values. Such measures can be very misleading, even for the value of the most vital life support functions provided by fertile soil, clean air and water. They are impossible for all these "soft", and intangible values whose importance for the quality of life in the information society will be even greater than in the industrial society (Naveh, 2001).

Instead, we have to mount a common, transdisciplinary effort with scientists from other natural, social and human disciplines, as well as with artists, planners, architects and with ecopsychologists to study, evaluate and promote landscape multifunctionality based on a much broader holistic view of landscapes and their reciprocal relations with humans.

3.10. The tenth premise: the antagonistic relations between biosphere, agro-industrial and urban-industrial technosphere, threatening life and further evolution can be overcome only by a post-industrial symbiosis between nature and human society

In Section 3.1, I presented cultural evolution as leaps by bifurcations to higher organization levels with the help of mutually reinforcing auto- and cross-catalytic feedback loops. These new insights will be related now to the fate of our THE landscapes.

As the THE expanded throughout human history, along with the growing human population and its increasing consumption and technological power, natural landscapes were converted gradually into human-modified cultural landscapes. Since the industrial fossil fuel revolution a crucial bifurcation has divided these THE landscapes into *biosphere* and *technosphere* landscapes and their ecotopes into *bio-ecotopes* and *techno-ecotopes*, and most recently also into intermediate *agro-industrial ecotopes*.

In contrast to the biosphere autopioetic "regenerative systems", urban-industrial techno-ecotopes are human-made "throughput systems" (Lyle, 1994), driven by fossil and nuclear energy and their technological conversion into low-grade energy. Lacking the self-organizing and regenerative capacities of biosphere landscapes they result in high outputs of entropy, waste and pollution with far-reaching detrimental impacts on the remaining open landscapes and on human health. More recently, high-input agro-industrial ecotopes have replaced almost all low-input cultivated agro-ecotopes in industrial countries and are spreading now also in many developing countries. These agro-industrial ecotopes are much closer to technosphere landscapes than to biosphere landscapes. Although their productivity still depends on photosynthetic conversion of high-grade solar energy, this energy is subsidized to a great extent by low-grade fossil energy. At the same time, their natural control mechanisms have been replaced almost entirely by heavy chemical inputs and throughputs. In this respect, and in their detrimental environmental impacts on the open landscape, its wildlife and biodiversity, and the quality of its natural resources of soil and water, as well as on human health, they come very close to technosphere landscapes. In spite of their high productivity, without heavy financial subsidies, even those agro-industrial systems, that reached highest yields and agro-technological sophistication (e.g. those in Israel and California), are undergoing a deep economic crisis. They have lost thereby not only their ecological sustainability but also their economic sustainability. In this unstable industrial "total landscape" (Sieferle, 1997) all these ecotopes do not function together as a coherent, sustainable ecological system of the global THE ecosphere, like in the pre-industrial biosphere. Their antagonistic relations are a major cause for ecological and economical land use conflicts.

The rapidly growing technosphere and agro-industrial landscapes have caused the destabilization of the geosphere and biosphere by their one-sided, adverse outputs on the biosphere landscapes and their atmosphere, lithosphere and hydrosphere envelope. With the exception of the stabilizing negative feedback couplings, that maintain a dynamic flow equilibrium between the biosphere landscapes and the geosphere, all other interactions are ruled by destabilizing positive feedback loops. This situation not only has far-reaching impacts on the biological and cultural impoverishment of the ecosphere and its landscape ecotopes but also is manifested in threatening global climate changes and in the disruption of the protective ozone layer in the stratosphere. As predicted by Laszlo (1994) this could lead to final extinction, if these threatening trends are not counteracted by cultural regulative controlling and stabilizing ones in all natural and human dimensions of life. This shows clearly that our present environmental crisis has to be recognized and resolved as an all-embracing cultural revolution. Only in this way can we establish a proper balance between productive and attractive biosphere and healthy and livable technosphere landscapes. Their present antagonistic conflicts can be reconciled through the creation of new symbiotic relations between human society and nature. Such an urgently needed post-industrial symbiosis should lead to the structural and functional integration of bio- and technosphere ecotopes into a coherent sustainable ecosphere, in which both biological and cultural evolution can be ensured. In this symbiotic process, the scientific input of landscape research in collaboration with other mission-driven transdisciplinary environmental sciences in restoring, reclaiming, and rehabilitating landscapes as part of comprehensive planning and management for sustainable development towards the information society, could become a driving force.

Thanks to recent insights in self-organization of autopioetic systems and their cross-catalytic networks (CCN), we are now able to express these new symbiotic relations between nature and society in much more robust and even mechanistic terms and translate them into strategies for sustainable development. It would be illusionary to assume that we can restore some of the symbiotic natural feedback loops that existed in the pre-industrial society. However, we are now in a position to create new cultural, information-rich CCN feedback loops, linking natural, ecological, socio-cultural and economic processes of our THE. As a recent multinational and interdisciplinary EU study on modeling sustainable regional development (MOSES, 2000) has shown, such CNN links could be established in the information society between the regional economy and its biosphere landscapes through special taxes devoted to landscape restoration and management. The mathematics of these CNN says that a lasting synergistically acting improvement could arise for humans, nature and economy. This can be achieved in projects with the help of dynamic transdisciplinary systems simulation models and other innovative holistic methods and tools. In these, ecologists, economists and other environmentally concerned scientists collaborate to ensure lasting mutually reinforcing benefit for the people and their physical, mental, spiritual and economic welfare, together with the creation of healthy, productive and attractive landscapes for the emerging information society (Grossmann, 2000; Grossmann and Naveh, 2000).

4. Conclusions

With the help of a holistic landscape conception, well grounded in systems theory and its recent insights, we will be able to better comprehend and deal with MFLs as an integral part of the natural and socio-cultural processes determining the fate of our THE and overall global survival. The biperspectivable systems view of landscapes, functioning simultaneously as natural and cognitive systems, and therefore as a tangible bridge between nature and mind, opens the way for close cooperation among landscape researchers and scientists from all other relevant disciplines and professions. These have to work together for the joint overarching transdisciplinary vision of a sustainable future of our THE and its landscapes. Equipped with these conceptions, landscape researchers can fulfill an important role by serving in the dual position of experts in their own field and by helping to integrate innovative, future-oriented research and action.

Such research must take into consideration that the recent adoption of new information and communication technologies has caused the rapid development of the infosphere, driving human society through unstable and even chaotic transitional stages towards this global information rich age with all its positive and negative implications, dangers and opportunities. It will depend on the readiness and ability of human society to follow the road toward further evolution and sustainability of our global THE, by choosing the bifurcation, converging towards a higher level of complexity and organization and toward further evolution of life on a higher level of quality. This can be ensured only by the creation of a postindustrial symbiosis between nature and human society, turning the antagonistic relations between the biosphere and the technosphere into mutually beneficial ones, in sustainable, healthy and information-rich biosphere and technosphere landscapes.

This is not an utopian dream that is evident from the many encouraging examples, such as provided in the 1999 State of the World report (Brown et al., 1999), in addition to many others, indicating that we are at the threshold of such a post-industrial environmental sustainability revolution.

Our hope for a sustainable future for the macroshift 2000–2010 lies in the final sentences of Laszlo (2000, p. 114): ‘‘endowed with the highest forms of consciousness in our regions of the universe, we are the only species that not only acts, but can also foresee the effects of its actions. As members of a species capable of foresight, we must live up to our responsibility as stewards rather than exploiters of the complex and harmonious web of life on this planet’’.

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References

Allen, T.F., Hoekstra, T.W., 1992. Toward a Unified Ecology. Columbia University Press, New York.

Allesch, C.G., 1990. The space of landscape and the space of geography. In: H. Svoboda (Ed.), Cultural Aspects of Landscape. Pudoc, Wageningen, pp. 17–23.

Antrop, M., Van Eetvelde, V., 2000. Holistic aspects of suburban landscapes: visual image interpretation and landscape metrics. Landscape Urban Plann. 50, 43–58.

Bohm, D., 1980. Wholeness and the Implicate Order. Routledge and Kegan, London.

Bohm, D., Peat, D.F., 1987. Science, Order, and Creativity. A Dramatic Look at the Roots of Science and Life. Bantam Books, New York.

Bright, C., 2000. Anticipating environmental surprises. In: Brown, L.R., Flavin, C., French, H. (Eds.), State of the World 2000. A Worldwatch Institute Report on Progress Toward a Sustainable Society. Norton & Company, New York, pp. 22–38.

Brown, L.R., 1996. The acceleration of history. In: Brown, L.R. et al. (Eds.), State of the World 1996. A Worldwatch Institute Report on Progress Toward a Sustainable Society. Norton & Company, New York, pp. 9–26.

Brown, L.R., Flavin, C., French, H. (Eds.), 1999. State of the World 1999. A Worldwatch Institute Report on Progress Toward a Sustainable Society. Norton & Company, New York.

Capra, F., 1996. The Web of Life. A New Understanding of Living Systems. Anchor Books Doubleday, New York.
Di Castri, F., 1997. Editorial: landscape ecology in a changing globalized environment. Landscape Ecol. 12, 3–5.
Frankl, V.E., 1969. Reductionism and nihilism. In: Koestler, A., Smithies, J.R. (Eds.), Beyond Reductionism: New Perspectives in the Life Sciences. Hutchinson of London, London, pp. 396–408.
Grossmann, W.D., 2000. Realizing sustainable development with the information society—the holistic double-gain-link approach. Landscape Urban Plann. 50, 179–193.
Grossmann, W.D., Naveh, Z., 2000. Transdisciplinary challenges for regional sustainable development toward the post-industrial information society. In: Proceedings of the Third International Conference of the European Society for Ecological Economics, Vienna, 3–6 May, pp. 1–3.
Holling, J., 1996. Surprise for science, resilience for ecosystems and incentives for people. Ecol. Appl. 6, 733–735.
Holling, J., Berkes, C.S., Folke, F.C., 1999. Science, sustainability and resources management. In: Berkes, F., Folke, C., Colding, J. (Eds.), Linking Social and Ecological Systems. Cambridge University Press, Cambridge.
IALE Mission, 1998. IALE Mission statement. IALE Bull. 16, 1–3.
Jantsch, E., 1970. Inter- and transdisciplinarity university: a systems approach to education and innovation. Policy Sci. 1, 403–428.
Jantsch, E., 1976. Self-transcendence: new light on the evolutionary paradigm. In: Jantsch, E., Waddington, C.W. (Eds.), Evolution and Consciousness: Human Systems in Transition. Addison-Wesley, Reading, MA, pp. 9–10.
Jantsch, E., 1980. The Self-Organizing Universe. Scientific and Human Implications of the Emerging Paradigm of Evolution. Pergamon Press, Oxford.
Koestler, A., 1969. Beyond atomism and holism—the concept of the holon. In: Koestler, A., Smithies, J.R. (Eds.), Beyond Reductionism: New Perspectives in the Life Sciences. Hutchinson of London, London, pp. 192–216.
Kuhn, T.S., 1996. The Structure of the Scientific Revolution, 3rd Edition. University of Chicago Press, Chicago.
Laszlo, E., 1972. Introduction to Systems Philosophy: Toward a New Paradigm of Contemporary Thought. Harper Torchbooks, New York.
Laszlo, E., 1987. Evolution: The Grand Synthesis. New Science Library, Shambhala, Boston.
Laszlo, E., 1994. The Choice: Evolution or Extinction. A Thinking Person's Guide to Global Issues. Putnam, New York.
Laszlo, E., 2000. Macroshift 2001–2010. Creating the Future in the Early 21st Century. San Jose, NY.
Leser, H., 1991. Landschaftsoekologie. Eugen Ulmer, Stuttgart.
Levin, S.A., 1999. Towards a science of ecological management. Conserv. Ecol. 3, 6–9.
Li, B.-L., 2000a. Why is the holistic approach becoming so important in landscape ecology? Landscape Urban Plann. 50, 27–47.
Li, B.L., 2000b. Fractal geometry applications in description and analysis of patch patterns and patch dynamics. Ecol. Model. 132, 353–361.
Lyle, J.T., 1994. Regenerative Design for Sustainable Development. Wiley, New York.
MOSES, 2000. Modeling Sustainable Development in the European Information Society (MOSES). EU Programme Environment and Climate 1994–1998, Area 4. Human Dimensions and Environmental Change, Brussels.
Nassauer, J.I., 1990. In: Svoboda, H. (Ed.), Cultural Aspects of Landscape. Proceedings of the Statements at the Closing Session of the First International Conference on Cultural Aspects of Landscape. Pudoc, Wageningen, p. 173.
Naveh, Z., 1982. Landscape Ecology as an Emerging Branch of Human Ecosystem Science. Academic Press, London. Adv. Ecol. Res. 12, 189–237.
Naveh, Z., 1990. Landscape ecology as a bridge between bio-ecology and human ecology. In: Svobodova, H. (Ed.), Cultural Aspects of Landscape. Pudoc, Wageningen, pp. 45–58.
Naveh, Z., 1991b. Biodiversity and ecological heterogeneity of Mediterranean uplands. Economica Montana: Linea Ecologica 24, 47–60.
Naveh, Z., 1995a. Transdisciplinary landscape-ecological education and the future of post-industrial landscapes. Bolletino del Museo dir Store Naturale della Linigiana, 9. Supplemento, Allau, pp. 13–26.
Naveh, Z., 1995b. Interactions of landscapes and cultures. Landscape Urban Plann. 32, 43–54.
Naveh, Z., 1998. Culture and landscape conservation—a landscape ecological perspective. In: Gopal, B., Pathak, P.S., Saxena, K.G. (Eds.), Ecology Today: An Anthology of Contemporary Ecological Research. International Scientific Publications, New Delhi, pp. 19–48.
Naveh, Z., 2000a. Transdisciplinary challenges for education towards regional development. In: Braunegg, S., Narodoslawsky, M. (Eds.), Proceedings of Conference on Higher Education for Sustainable Regional Development. SUSTAIN, Graz, pp. 42–71.
Naveh, Z., 2000b. What is holistic landscape ecology? A conceptual introduction. Landscape Urban Plann. 50, 7–26.
Naveh, Z., 2001. Multifunctional, self-organizing biosphere landscapes and the future of our total human ecosystem—a new paradigm for transdisciplinary landscape ecology, submitted for publication.
Naveh, Z., Lieberman, A.S., 1994. Landscape Ecology Theory and Applications, 2nd Edition. Springer, New York.
O'Neill, R.V., Kahn, J.R., 2000. Homo economus as a keystone species. BioScience 50, 333–338.
Orr, D.W., 1992. Ecological Literacy. Education and the Transition to a Postmodern World. State University of New York Press, New York.
Pankow, W., 1976. Openness as self-transcendence. In: Jantsch, E., Waddington, C.W. (Eds.), Evolution and Consciousness: Human Systems in Transition. Addison-Wesley, Reading, MA, pp. 16–36.
Peat, D.F., 1997. Infinite Potential. The Life and Times of David Bohm. Addison-Wesley, Reading, MA.
Pimentel, D., 1992. Conserving biological diversity in agricultural systems. BioScience 42, 354–362.

Prigogine, I., 1976. Order through fluctuations: self-organization and social systems. In: Jantsch, E., Waddington, C.W. (Eds.), Evolution and Consciousness: Human Systems in Transition. Addison-Wesley, Reading, MA, pp. 93–130.

Prigogine, I., Stengers, I., 1984. Order out of Chaos. Man's Dialogue with Nature. New Science Library, Shamabala, Boston.

Sieferle, R.P., 1997. Rückblick auf die Natur. Eine Geschichte des Menschen und seiner Umwelt. Luchterhand Literaturverlag, München.

Simon, H.A., 1962. The architecture of complexity. In: Hierarchy Theory. George Braziller, New York, pp. 3–27. Proc. Philos. Soc. 106, 467–482.

Smith, M.J., 1998. Ecologism Towards Ecological Citizenship. University of Minnesota Press, Minneapolis.

Vitousek, P.M., Mooney, H.A., Lubchenco, J., Melillo, J.M., 1997. Human domination of Earth's systems. Science 277, 494–499.

Weinberg, G.M., 1975. Introduction to General Systems Thinking. Wiley, New York.

Weiss, P.A., 1969. The living system: determinism stratified. In: Koestler, A., Smithies, J.R. (Eds.), Beyond Reductionism: New Perspectives in the Life Sciences. Hutchinson of London, London, pp. 3–55.

WLO, 1998. A new identity for landscape ecology in Europe. A research strategy for the next decade: outlines formulated at the European congress. Landscape ecology: things to do, Amsterdam, 6–10 October. The Dutch Association of Landscape Ecology, Wageningen.

Zonneveld, I., 1995. Land Ecology. An Introduction to Landscape Ecology as a Base for Land Evaluation, Land Management and Conservation. SPB Academic Publishing, Amsterdam.

Zev Naveh (1919), PhD, is Professor Emeritus in landscape ecology at the Technion, Israel Institute of Technology, Haifa. Until 1965 he worked as range and pasture specialist in Israel and in Tanzania. His research at the Technion was devoted to human impacts on Mediterranean landscapes, fire ecology and dynamic conservation management, introduction of drought resistant plants for multibeneficial landscape restoration and beautification. Presently he is involved chiefly in studying theoretical aspects of holistic landscape ecology and sustainable development for the information society. He was the founder and director of the Ecological Garden of the Technion and the co-founder and scientific director of the first Environmental Teaching Project in Israel, and the head of a IUCN working group for landscape conservation. He has been visiting professor and guest lecturer in many universities and keynote speaker in international conferences and is member of the editorial board of Landscape Ecology, Restoration Ecology and Mediterranean Ecology. Professor Naveh has published over 200 scientific publications and is author and co-author of several Hebrew and English books, including the first English monography on landscape ecology.