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# The Paradigm of Landscape and the Paradigm of Ecosystem - Implications for Land Planning and Management in the Mediterranean Region

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**Abstract**

Two central concepts in ecology, the concept of ecosystem and the concept of landscape, are presented as distinct paradigms, i.e. convenient approaches around which to organizing one's view of the world. In view of insights gained from the General Systems Theory, we discuss these two concepts as middle number systems, elucidating similarities as well as vast differences between them. Recent studies of the Mediterranean ecological system of Mt. Meron are presented to exemplify the way each of these concepts affects our perceptions, research, and models, and especially our prescriptions for land planning and management.

The ecosystem approach focuses on organisms, populations, and on energy/matter cycles only. Humans and anthropogenic elements are viewed as external, disturbing factors. Ecosystem borders are vaguely defined. In contrast, our landscape concept is transdisciplinary, and focuses on the entirety of biotic elements, including humans and their culture. Its basic elements are concrete pieces of land, well defined in space, along various scales. Currently, the landscape approach (as we describe it) is seldom reflected in planning and management prescribed by ecologists. It has, however, unique advantages for land planning and management. Ecological models of landscape are inherently spatially-explicit, and typically incorporate anthropogenic impacts as integral parts of the model. Recommendations relate to specific areas (as opposed to general reference to optimal habitat composition). This approach emphasizes the conservation of cultural elements as well as ecological values. Each one of the two approaches to land planning and management has its own indispensable value in applying wise management to the intricate natural systems. What is needed today is a transdisciplinary cooperation of ecologists and landscape planners for the progression of ecological planning as a new, hybrid realm combining ecology and planning, nature and culture, holistic and analytic approaches.

## Preface

Ecology is increasingly being asked to address environmental issues, and in particular, those related to land planning and management. When advising on these issues, ecologists rely on two central concepts in ecology, the concept of ecosystem and the concept of landscape. Each of these concepts represents a distinct approach, a paradigm (O'Neill 2001), and emphasizes different elements in our view of the environment. Yet, the understanding that these two central concepts are translated into two separate approaches for land planning and management is new. Most ecologists use these terms interchangeably, and even when constructing a management program based largely on the concept of landscape (exemplified below), may still call it 'the larger ecosystem approach' (Noss 2001).

First, we describe the concept of ecosystem and the concept of landscape in light of recent understandings gained from General Systems Theory. This discussion sets the stage for contrasting these two paradigms and their current role in ecology. Next, the translation of these ecological paradigms into distinct approaches for land planning and management is discussed. Case studies in which these approaches are expressed are then presented. The transdisciplinary landscape approach as presented by us, while frequently used by landscape planners and architects, is rare among ecologists. A discussion of this issue and its implications leads us to propose base lines for a trans-disciplinary approach to land planning and management that would combine elements from several disparate realms of the natural sciences, the social sciences and the humanities.

**Ecosystems and landscapes as medium numbered systems.**

The complexity of systems is determined not only by the number of components, but also by the number of interactions and their nature ("structural complexity"), and by their functional complexity, defined by the number and character of the distinct functions carried out by these system (Jorgensen 1997). In contrast to the *disorganized complexity* of *"large numbered systems"* (Weinberg 1975), composed by many identical and randomly interacting components such as gas molecules, ecosystems and landscapes have *organized complexity.* They are essentially highly diverse *"medium-numbered systems"* (Weinberg 1975), with structural and functional network interrelationships. The greater the organized complexity of a system, the greater its uncertainty and the lesser its predictability (Weinberg 1975, Jorgensen 1997). However, as we will show below, there are some basic differences between ecosystems and landscapes. The latter have greater organized and functional complexity and therefore their predictability is even lower.

Regarding the ecosystem concept, O'Neill et al. (1986 page 3) state that "despite its widespread use, the concept remains diffuse and ambiguous". De Leo and Levin (1997) support this claim, stating that "ecosystems are neither uniquely identified entities nor are they defined by sharp boundaries. Instead they are loosely defined assemblages that exhibit characteristic patterns over a range of scales of time and space and organization complexity". Sagoff, an environmental philosopher, reacts to this in a critical essay of ecological theories (Sagoff 2001 p. 69): "The oxymoron 'loosely defined' may be taken as a euphemism for undefined or constructed *in silico* (on a computer) to illustrate or vindicate a particular theory."

Noss (2001 p. 105) simplifies the ecosystem definition of Odum in his influential book (Odum 1971): "open systems, exchanging matter, energy, and organisms among them. Where to draw the lines between them appears largely arbitrary." Although he uses the term "ecosystem management" in some of his models, Noss (2001) devoted his discussion and practical conclusions on conservation entirely to landscapes and ecoregions (which are, actually, landscapes on broader regional scales).

O'Neill (2001) devotes the Macarthur award lecture to the severe limitations of the ecosystem paradigm. Among those, the spatial dimensions of the ecosystem pose two serious problems (O'Neill 2001). Firstly, the implicit assumption that interactions and feedback loops necessary and sufficient to explain dynamics occur within the ecosystem boundaries, while in fact the spatial distributions of component populations may be much larger. Second, spatial **homogeneity** within the ecosystem is typically assumed (O'Neill 2001). This simplification overlooks some of the essential properties of the system; it is the **heterogeneity** of the system that maintains the full range of populations within the system. Another crucial limitation of the ecosystem paradigm is that it typically considers human activities as external disturbances (O'Neill 2001).

A thorough study of ecosystem complexity and its formalization has been provided recently by Jorgensen (1997). He based his holistic approach chiefly on principles of thermodynamics and its recent insights into self-organization of dissipative structures. Attempting to integrate the contrasting views of ecosystems regarded either as biotic assemblages or as functional systems, he defined ecosystems "as both biotic and functional system, able to sustain life and including all biological variables, but their spatial and temporal scale are not specified *a priori* , but entirely based upon the objects of the ecosystem study" (Jorgensen and Muller 2000 p. 10). However, all his models of ecosystem networks relations are only functional models, dealing with different cycling functions, driven by energy. He restricted his discussion only to the biological-ecological and chemo-physical dimension and treated these ecosystems as if they are all natural ecosystems, devoid of humans and the resulting human ecological dimensions.

In the classical Hubbard Brook ecosystem study (Likens et al. 1977) a typical functional ecosystem approach was applied, measuring inputs and outputs from tangible landscape units of watersheds within the larger experimental forested sites. Yet, Likens et al. (1977) indiscriminately refer to these watersheds and study sites sometimes as ecosystems and sometimes as landscapes. A general trend of emphasis on biological, chemical, and physical elements, while omitting human-cultural elements, is obvious in most prominent ecosystem studies (e.g. Noy-Meir 1975, Tilman 1982, Pickett and White 1985, Connell et al. 1987, Pacala et al. 1993, Pickett and White 1985, Riley and Vitousek 1995, Levin 1998, Oksanen and Oksanen 2000, Power 2001, Burke and Lauenroth 2002).

Forman (1995) defines ecosystems as "relatively homogenous areas of organisms interacting with their environment". However, his examples of "local ecosystems" refer to patches, corridors or a matrix of a landscape". In this way he has come very close to our use of the term "*landscape ecotope"* as the smallest, more or less homogenous landscape unit, and clearly discernible and mappable building block of nature with all its subordinated landscape elements and fluxes (Naveh 2001). Ecotopes could be considered also "*concrete ecosystems*" (Naveh and Lieberman 1994).

To avoid these ill-defined and confusing applications of the ecosystem concept and to overcome this ambiguity in definition, we suggest conceiving **ecosystems as functional interacting systems, characterized by the flow of energy, matter and information between organisms and their abiotic environment and as a set of interlinked, different scale properties.** As such they are **intangible** with vaguely defined borders. This is in clear contrast to **landscapes, which are concrete pieces of land, or water or both, well defined in space and time along different scales. As such, they serve as the spatial and functional matrix and as the living space for all organisms (including humans), their populations and ecosystems** (Naveh and Lieberman 1994, Naveh 2000). These definitions of ecosystems and landscapes are rather similar to those proposed by Allen and Hoekstra (1992).

Landscapes, as well as ecosystems, 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. Because of their emergent organizational systems properties, landscapes are more than the sum of their measurable components. They become an entirely new entity as an ordered whole or "Gestalt" system, in which, like in organisms (or a melody) - all their parts are related to each other by the general state of the whole.

Neither mechanical nor statistical approaches nor their description and analysis as geometrical configurations can accurately grasp these *medium numbered systems* and their organized complexity. Innovative transdisciplinary approaches and methods are required for their study. This is especially the case with highly fragmented and heterogeneous human modified, used and managed Mediterranean landscapes. In these landscapes, natural and cultural pattern and processes have been closely interwoven for thousands of years.

## Landscape complexity as part of a general systems view of the world

As explained elsewhere in more detail (Naveh 2000, Naveh 2001), our holistic conception of landscape complexity cannot be considered in isolation but has to be part of a broader integrative system view of the world. This is the view of a hierarchical organization of nature as ordered wholes of multileveled open systems, ranging from quarks to galaxies. This world view is rooted in General Systems Theory and its recent insights in self-organization and self-creation or *autopoiesis*. It is the result of a major shift from reductionistic and mechanistic scientific paradigms to an all-embracing conception of synthetic cosmic, geological, biological and cultural evolution as a non-linear but coherent process (Jantsch 1980, Laszlo 1987, 1994, 1996). It has been enriched by the exciting findings of the Nobel Prize winner Prigogine and his collaborators on the self-organizing properties of non-equilibrium dissipative structures. These systems dissipate entropy as part of their continuous energy exchange with their environment, and by increasing negentropy within the system they create "order through fluctuation (Prigogine 1976) and "order out of chaos" (Prigogine and Stengers 1984). This results in an increase of effective information and energy efficiency, greater flexibility and creativity, and higher structural complexity at each higher organizational level.

## Cultural evolution and landscape evolution

This synthetic evolutionary process should be conceived as a discontinuous development of sudden leaps by *"bifurcations"*

to a higher organizational level. As shown by Laszlo (1994) in Fig. 1, in the cultural evolution of humankind these were leaps from the primitive food gathering-hunting to the more advanced agricultural and industrial stages. These are culminating presently in societies globally integrated in the emerging information age. Each of these bifurcations is driven mainly by the widespread adoption of cultural and technological innovations. Landscape evolution is an integral part of this cultural evolutionary process. The rapidly expanding urban-industrial and agro-industrial landscapes are a result of such a crucial bifurcation (Fig. 1).

These leaps have been made possible by mutually amplifying *cross-catalytic feedback loops* of whole chains of catalytic "*hypercycles*", which underlie the emergence of life. Such auto- and cross-catalytic processes drive the autopoiesis by which complex organized systems can renew, repair and replace themselves as interacting networks. This is the case in our natural and semi-natural biosphere landscapes, such as forests, woodlands, grassland, wetlands and lakes, driven by high quality solar energy and its biological and chemical conversion into photo

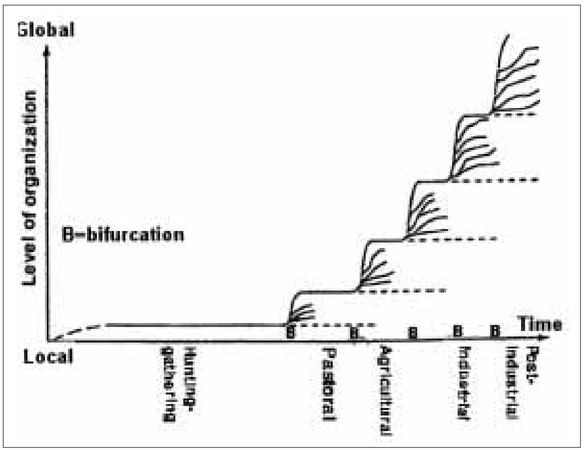



*Fig. 1.* The convergence of human societies to higher organization levels during cultural evolution by bifurcations (after Laszlo 1994). Throughout the span of recorded history, human societies have converged to progressively higher organizational levels the process began with the hunting-gathering 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. After Laszlo 1987.

synthesis and assimilation into chemical and kinetic energy in autotrophic organisms. They are self-organizing autopoietic "**regenerative**" systems that ensure further biological evolution. At the same time negentropy – a measure of organizational order and complexity – is built up in these landscapes by an increase in structural and spatial heterogeneity, higher species diversity and higher food web complexity. Simultaneously entropy production – as a measure of homogeneity and disorder – is also minimized by the protection and stabilization function of "the living sponge" of the vegetation cover and its underlying soil. This reduces the rate of kinetic energy of wind, water and soil, and their destructive impacts on the landscapes, and raises their multifunctionality as life supporting systems.

The scientific breakthrough in non-equilibrium thermodynamics and its new ordering principles have deepened further our understanding of the complexity and dynamics of these landscapes far from equilibrium and their capacity of continuous self-organization from lower to higher hierarchical levels. As explained in more detail elsewhere (Naveh 1991, 1994, 2002) Mediterranean biosphere landscapes behave like dissipative structures, resulting from short- and long-term cyclic perturbations of natural climatic fluctuations and of long and short-term grazing, browsing, cutting and burning rotations. These lead to the establishment of a human-maintained dynamic long-and short term flow equilibrium - or "*homeorhesis*" (from the Greek meaning " preserving the flow") between the layers of trees, shrubs, herbs and grasses, ensuring their high biological and ecological complexity and diversity.

## Landscapes of our Total Human Ecosystems, their Multidimensional functional complexity and its evaluation

This holistic view of landscape complexity, embedded in the web of life as a micro-hierarchic level in the macro-hierarchy of the self-organizing universe culminates in the recognition that **humans are not apart from nature, neither are** they above nature. At the highest level of the global ecological hierarchy, above ecosystems, humans form together with their total environment an indivisible co-evolutionary geo-bio-anthropological entity. Following Egler (1964), we suggested to call this supersystem the TOTAL HUMAN ECOSYTEM because of the overwhelming human domination on Earth (Naveh 1982; Naveh and Lieberman 1994). Landscapes are its concrete space-time defined ordered wholes. Thus, the Total Human Ecosystem should be regarded not only as the overarching conceptual supersystem for the physical space and geographical space of the biosphere, but also as the conceptual space of the cognitive systems of the human mental and spiritual realm. Such a complementary systems view enables us to perceive and treat our landscapes as **the tangible bridge between nature and mind.** It opens the way for a better comprehension of multifunctional landscape complexity and its natural and cultural multidimensions.

For this purpose we have to overcome the deeply ingrained dualistic view of the positivistic natural sciences "culture" by which mental phenomena " do not count" because they cannot be counted, measured and quantified by conventional mathematical models and biophysical means of our formal scientific language. This requires a "*biperspectivable systems view*", as formulated first by Laszlo (1972). With this holistic view single, self-consistent mind events of human cognitive systems and natural, physical space-time events of concrete systems are internally and externally observable and manageable **simultaneously** as integrated natural-cognitive and psychophysical systems (Naveh 2001, Naveh 2002). This is in sharp contrast to the ecosystem concept and its monodimensional scope of multifunctional complexity, based solely on the na tural dimensions of material processes of flow of energy/matter and biophysical information, and investigated by basic and applied ecological disciplines with the help of above-mentioned formal languages, like in the above-mentioned study by Jorgensen (1997). On the other hand in our mixed natural-cultural medium numbered landscapes we deal both with the functional dimensions of natural- bioecological processes, transmitted by biophysical information, as well as with the cognitive mental and perceptual dimensions, transmitted by cultural information with the help of the natural system of our language and its visual means. The biperspectivable approach can translate this multidimensional functional complexity into actual landscape appraisal, planning and management practices.

Consequently, the evaluation of these multidimensional functions has to measure not only the anthropocentric, 'hard" instrumental values and their direct benefits for human society, but also the "soft" ecocentric and ethical dimensions grasped with our cognitive and perceptual dimensions. It is a grave mistake to assume that the ongoing exponential landscape degradation can be prevented by treating landscapes merely as a commodity to be exploited as a resource on which we project our economic interest, and not also as a source of intrinsic existence values on their own right, although we cannot measure them by monetary parameters and marketable products. Even the term "natural capital" introduced by ecological economists cannot account fully for the most vital life supporting functions provided by fertile soil, clean air and water, and not at all for the intangible aesthetic, cultural, spiritual and re-creative values of healthy and attractive biosphere landscapes. Their importance for our quality of life and mental well-being in the emerging information society is greater now than ever.

Such a biperspectivable application for the utilization of multifunctional landscape complexity is a precondition for integrated ecological, socio-economical and cultural sustainable development. It requires a common effort by landscape ecologists with scientists from relevant natural, social and human disciplines as well as with artists, planners, architects and eco-psychologists, land use managers and decision makers. One of the most urgent transdisciplinary challenges is the development of practical tools for integrated assessment of the closely connected biodiversity, cultural diversity and ecological macro- and micro-site heterogeneity by joint indices of *"Total Landscape Eco-diversity"* that can be easily applied by land managers and users (Naveh 1998).

As O'Neill et al. (1986) have shown in the context of ecosystems, hierarchy theory provides an efficient measure to deal with organized complexity. This is certainly the case also with landscapes. The hierarchical systems view of landscapes can be compared to a "*contextual window*" (Naveh 2001) through which we can look at the different hierarchical levels of landscape organization. These are decreasing in their process rates and frequencies from the lower to the higher levels, serving as the context for the level below, but at the same time, they are increasing in their ecological, cultural and perceptional complexity and their mutual dependence, together with new, emergent systems qualities.

The introduction of the "*holon*" concept by Koestler (1969) as a composition of the Greek terms *holos* =whole+ *proton*= part has contributed much to a better comprehension of the hierarchical relation between the lower and higher levels. Thus the lower holon level depends on its upper Holon level, but at the same time also a self-contained whole towards its lower subsystem holon. This means that according to our contextual window view, each holon in the systems hierarchy (or *holarchy)* behaves either as a part or as a whole. Thus, the holon macro-holarchy landscapes are parts of the global ecological micro-holarchy. Ecotopes are the smallest structural and functional holon and the ecosphere is its largest one. Landscapes should be studied and managed in a transdisciplinary manner as dynamic multidimensional space-time and conceptual and perceptual holarchies. Their upscaling from the lower to the higher holarchy levels is a special challenge for landscape ecologists. According to Koestler (1969) these holons are intermediate structures on a series of levels of ascending complexity.

In concluding: landscapes are more than puzzles of mosaics in repeated patterns of ecosystems. They are irreducible wholes, interlaced as spatial and functional networks and their multidimensional complexities.

## The concept of 'landscape' and the concept of 'ecosystem' applied to conservation and management

In view of the above discussion, it becomes clear that when ecologists produce conservation and land management programs, the paradigms of 'landscape' and 'ecosystem' are reflected in their products. In what follows, we describe the 'ecosystem approach' and the 'landscape approach' to nature conservation and to land planning and management as two distinct trends (Table 1).

*Table 1.* Characteristics of the ecosystem approach and the landscape approach with respect to conservation, planning and management.

| Ecosystem approach | Landscape approach |
|---|---|
| Based solely on bio-ecological aspects, dealing with "natural" organisms populations and communities | Including also human-ecological aspects, dealing with all biotic components, including humans |
| Vaguely defined borders | Clear borders |
| Spatially indifferent models | Spatially explicit models |
| Biodiversity | Ecodiversity (yet to be developed) |
| 'Natural landscape' components only | Natural and cultural components |

The ecosystem approach to land planning and management emphasizes the conservation of the biotic components in the system (populations, communities, and recently strong highlight on biodiversity) and the processes carried out by these components (primary production, competition, etc.). As a consequence of the vague border lines of ecosystems, ecosystem studies are typically not spatially explicit. Nature conservation and land planning based on those studies view the entire area as composed of several habitat types (Watson et al. 2001). Management recommendations often relate to the required composition of habitats (Lesica 1992, Murphy and Noon 1992), or the required total area of a specific habitat type (Cowling and Bond 1991, Lamberson et al. 1994), rather than to actual, specific land parcels. Most important, the ecosystem approach views anthropogenic elements in the land as unwanted, disturbing and disrupting nature's harmony. Therefore, in most ecosystem models anthropogenic elements are typically omitted (Pacala et al. 1996, Jorgensen 1997).

The landscape approach, being holistic, regards the land as a whole, and seeks to conserve the integrity of its components, including the a-biotic, biotic and anthropogenic elements. The landscape is essentially a concrete piece of land, and as a consequence, studies and models are spatially explicit. Most important, the landscape approach regards humans and their impact as an integral part of the system. As a consequence, landscape approach modeling incorporates human impacts in the building of the model and in scenario-testing. This incorporation may take the form of quantitative socio-economic factors within the model (Wear and Bolstad 1998). Alternatively, systems dynamic simulation models in combination with cross-catalytic networks, assess the interrelations between anthropogenic processes and landscape dynamics for regional sustainable development (Grossman and Naveh 2000).

Ecological knowledge and such models are translated to conservation and management programs. A landscape-based program should be oriented towards the conservation of cultural components as well as natural components. In particular, indigenous cultures and traditional agricultural "biosphere" landscapes (Naveh 1982, 2002) are of special value for conservation, for three main reasons: (1) they harbor both ecological values and cultural values (2) they represent the many faces of the coexistence of nature and culture, product of long history of co-evolution, and (3) the mere existence of these values is endangered: many such cultures are assimilated into the western culture, and lands of traditional agriculture are abandoned or give rise to industrial agriculture. Another unique element that should characterize landscape approach, and is yet to be developed, is the holistic concept of Total Landscape Eco-diversity, mentioned above, that should be the focus of conservation effort. The common measure of biodiversity, important as it is, is only one of the aspects of eco-diversity.

## The case study of Mount Meron

In order to exemplify the ways in which these paradigms affect our science and practical management, we use Mount Meron Nature Reserve as a case study. Mount Meron is the highest mountain in the Galilee, located at the Northern part of Israel. It has eight summits above 1000 m, and a sub-humid Mediterranean climate, with average annual precipitation of more than 900 mm (Markus 1994). With an area of 100 square km, its nature reserve is the largest reserve in the Mediterranean part of the country. It is relatively remote and undisturbed, with the richest Mediterranean vegetation formations found in Israel, with a fine mosaic of different regeneration and degradation stages from dwarf shrub, "Batha", to taller Maquis shrublands and dense oak forests (Naveh and Whittaker 1979). Two conservation-oriented studies were conducted in this region recently, each representing different blend of the two concepts of landscape and ecosystem. The first study (Carmel and Safriel 1998), concerned with conservation of the community of bat species, represents a typical example of the ecosystem approach. The second study deals with vegetation dynamics, reflecting elements of both the ecosystem approach and the landscape approach.

The goal of the first study was to assess habitat

*Fig. 2.* Habitat use of bats in Mount Meron. On the Y axis, Percent activity in total sample time is shown for each habitat. SCR - scrub, BAT - batha, WAT - water, RIP - riparian vegetation, AGR - agriculture, SET - settlements.

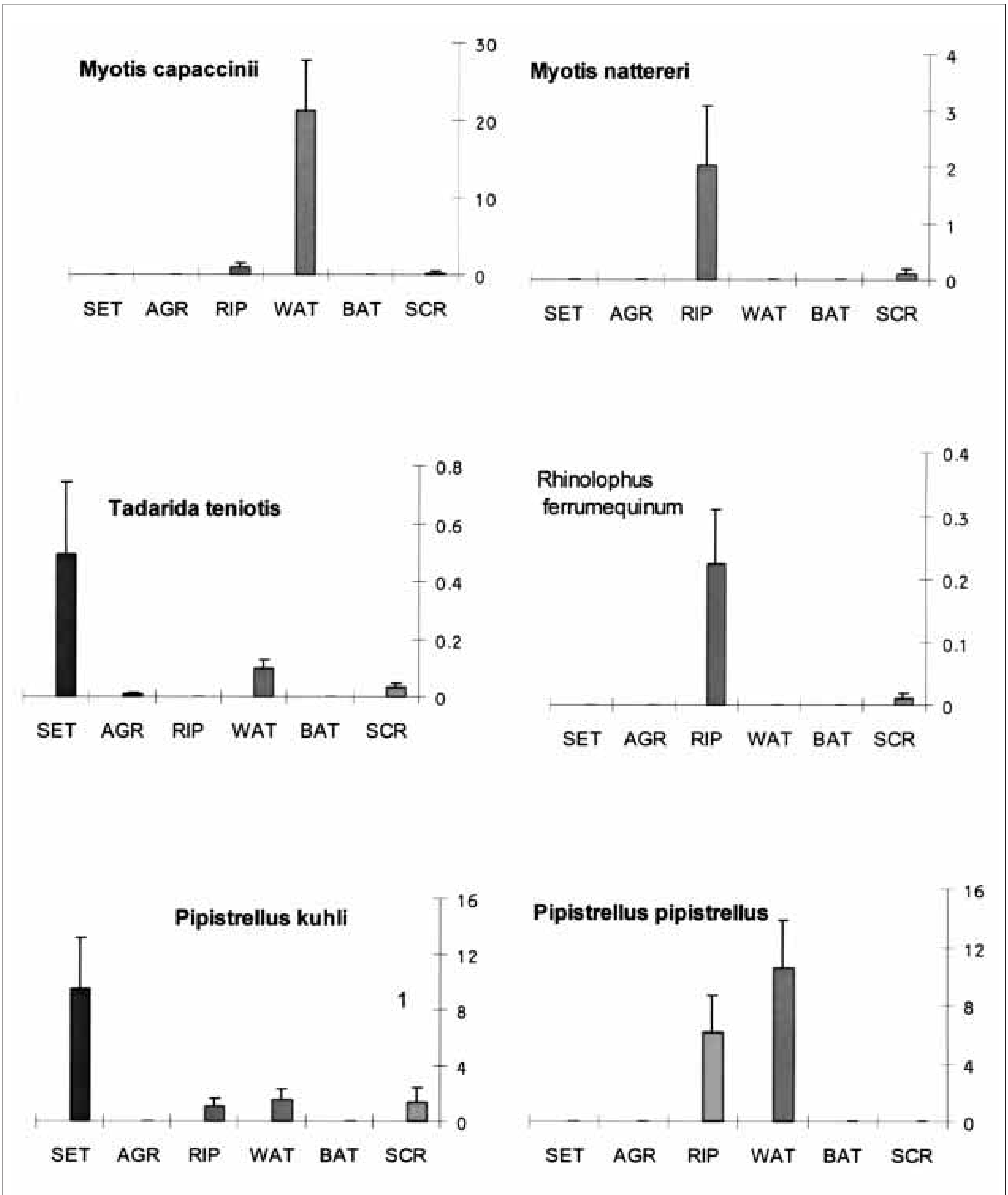
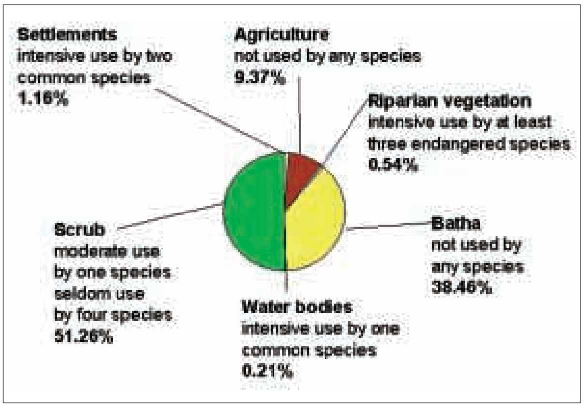
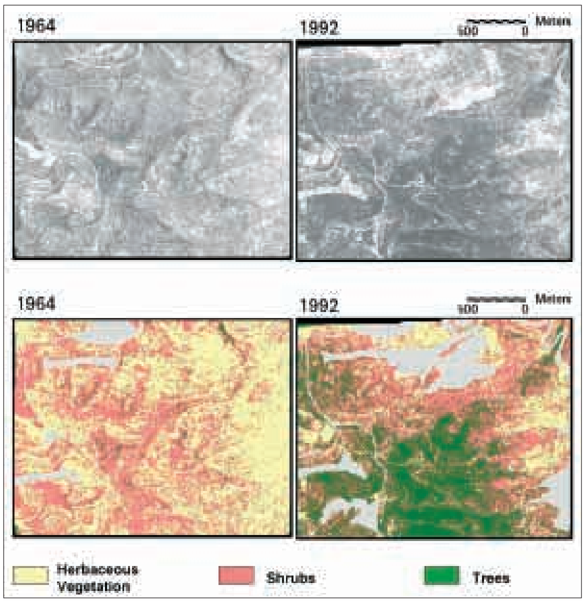


*Fig. 3.* Habitat composition in Mount Meron Nature Reserve, and the importance of each habitat for foraging bats. After Carmel and Safriel 1998.




use for an entire bat community, in order to construct a management program for a nature reserve designed to protect its endangered bat species (Carmel and Safriel 1998). We used a bat detector combined with a tape recorder to record all bat callings during many sampling nights – for later identification of species specific calls. 52 locations, representing the 6 major habitat types in the reserve, were sampled repeatedly. A total of 224 samples were taken, each sample lasting 5 to 45 minutes. In this way, using the bootstrap method for statistical analysis, we found distinct pattern of habitat use for six bat species (Fig. 2). Integrating this information with information on the conservation status of bats and information on the composition of habitat types in the reserve, we were able to characterize the relative importance of each habitat for foraging bats (Fig. 3). When this was done, it became clear that large portions of the reserve are not used at all by any bat species (agriculture and Batha, together comprising 0.4 of the reserve), while small portions (water bodies and riparian vegetation, together comprising less than 1% of the reserve area) are intensively used by several bat species, some of them endangered. This finding led us to propose a conservation program for Mount Meron Nature Reserve, aimed at enhancing the protection offered to bats by the reserve. This program included several recommendations, of which the major ones involved re-designing of its habitat composition. We proposed to let treated waste water flow year-round in the ephemeral streams of the reserve, in order to increase the area of riparian habitat. Similarly, planting trees within the Batha would make it more attractive to bats, and offer them additional food sources.

*Fig. 4.* Air photos and the respective vegetation maps for the study area in Mount Meron, in 1964 and 1992. Spatial resolution (pixel size) is 0.3 m. Location error (RMSE) between the two maps is 1.13 m. For attribute accuracy, PCC, (Percent Classified Correctly) is 0.82 for 1964 and 0.89 for 1992. After Carmel and Kadmon 1998.




Analyzing this study under the perspective offered here, we find several elements of the ecosystem approach. These include the conservation of species, the conservation of communities, and the fact that space is not explicitly expressed in the model. Cultural and human-ecological elements of the landscape approach are not existing.

The second is a study of vegetation changes at the landscape scale, that involves the mapping of

*Fig. 5.* Topography and disturbance history (grazing, fire, logging) of the study area. Contour intervals represent 10 m in elevation. Shaded areas are agricultural, or villages. (1) - Kibbutz Sasa. (2) – Mt. Meron field study center. After Carmel and Kadmon1999.

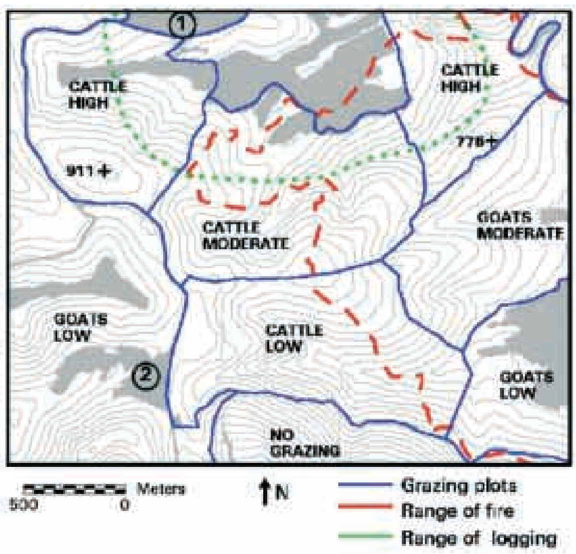


*Fig. 6.* Actual and model-prediction maps. (a) Actual 1964 vegetation map, that was the model input, (b) Actual 1992 vegetation map, (c) model map. The double line separates between model area (east) and validation area (west).

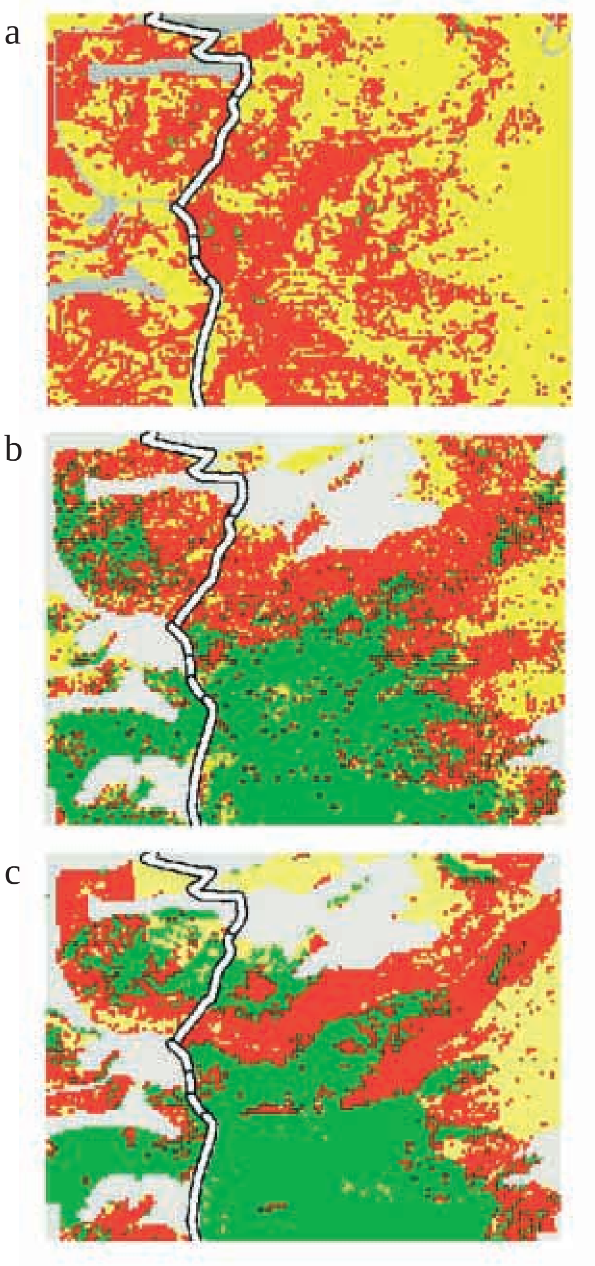
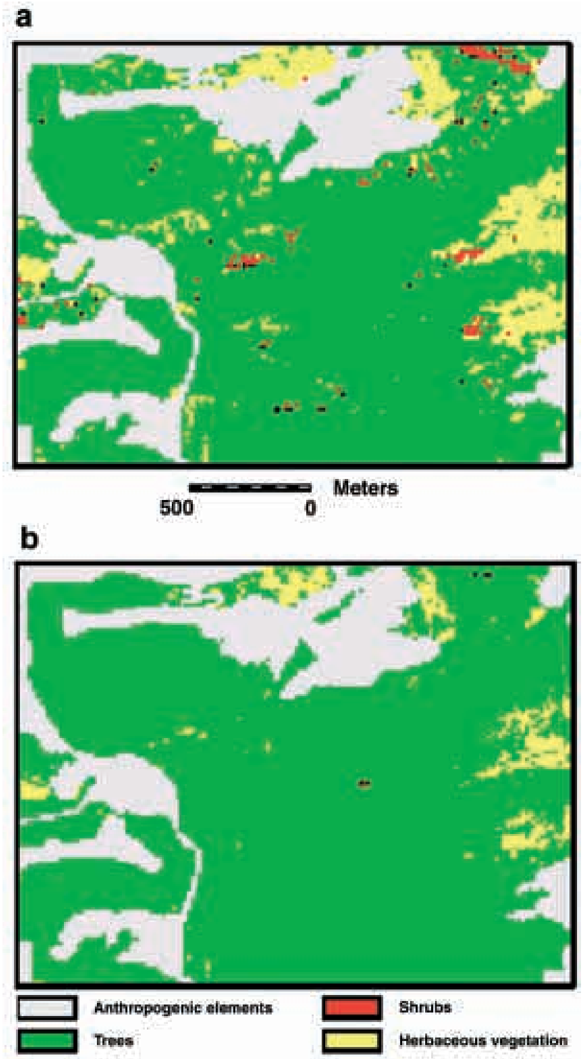



*Fig. 7.* Predicted vegetation maps for 2020. Maps were constructed based on the actual 1992 vegetation map and regression coefficients. Two scenarios were considered: (a) grazing regimes would be the same as in the last 30 years, across the study area, and (b) both goats and cattle grazing are halted in the whole area. Both scenarios assume that no other disturbance (e.g. fire, logging) occurs in the area in the period 1992 – 2020. After Carmel and Kadmon 2001.




vegetation dynamics (Carmel and Kadmon 1998), analysis of the environmental factors affecting the processes (Carmel and Kadmon 1999), and modeling of historic, current and future dynamics (Carmel et al. 2001), with the goal of predicting future vegetation structure under various scenarios.

The study consisted of four successive components: (a) Two aerial photographs (1964, 1992) of a test area at the edge of the reserve were scanned, geo-rectified and classified to trees, shrubs and openings (Fig. 4). (b) Incorporation of digital maps of relevant environmental factors (topography, grazing intensity etc., Fig. 5) together with the vegetation maps into a GIS database allowed the subsequent statistical analysis of effects of environmental factors on vegetation changes to quantify their impact. Anthropogenic elements (roads, agriculture, settlements, depicted in gray in Fig. 5) were omitted from the analysis. These vegetation changes were affected significantly by grazing intensity, slope, and aspect. Altogether, 0.76 and 0.54 of the variability in tree cover and in herbaceous cover, res pectively, were explained by the models. (c) Parameters derived from the statistical analysis were then used to calibrate a spatially explicit model of vegetation dynamics. Using the 1964 vegetation map as initial conditions, this model yielded a predicted vegetation map for 1992. These predictions corresponded well to the actual map, even for an external area (Fig. 6). (d) The model's potential for predicting future vegetation changes and relating to actual management problems was exemplified using two different scenarios: no change in grazing regimes versus a cessation of grazing over the whole area. Implications of each of these management decisions were portrayed in the form of vegetation maps predicted for 2020 (Fig. 7).

In this study, elements of both approaches can be traced. The continuation of natural processes is a major theme in the ecosystem approach, and the basic subject of this study is the continuation of vegetation dynamics. The exclusion of anthropogenic elements from the analysis and from the model, is a clear sign of the ecosystem approach. 'Vegetation dynamics can be fairly well predicted using few biologically important factors' (Carmel and Kadmon 1999) is a nice conclusion, but it is valid only when one restricts analysis to natural vegetation, and omits areas subject to recent human activity. Spatially explicit models, which refer to an actual space within clear borders, are indicators of the landscape approach. The spatially explicit model is the essence of the present study, and the scenario-testing predictions are based on this model. Another indicator of this approach is the incorporation of human elements into the study. Many of the anthropogenic elements in the study area are not an integral part of the model. Yet, livestock grazing, an important aspect of the impact of land uses, is included in the model; it plays an important part in the scenario-testing procedure. The management recommendations derived from this study emphasize the role of livestock grazing as a management tool (Carmel et al. 2001), along the lines pointed out by Naveh (1991, 1998) for human-perturbation-dependent Mediterranean landscapes.

## Conclusions

The concept of ecosystem and the concept of landscape are paradigms, i.e. products of our mind and its limited ability to grasp complex reality (O'Neill 2001). Each one of these paradigms reduces the enormous complexity of our environment differently, focusing on a small subset or a narrow aspect. The ecosystem paradigm focuses on the cycling of matter and energy, and perhaps to a lesser degree, on populations and communities. The landscape paradigm focuses on an actual space (typically a piece of land or sea and their environment), its physico-chemical properties, biological components (populations, communities, habitats) and cultural components.

The landscape approach to land planning and management can be defined as a trans-disciplinary process that responds to natural and cultural processes while incorporating economic and political aspects (Farina 1998, Burmil 2002). As such, most ecological research as well as planning and management prescribed by ecologists, do not reflect this approach. Many ecologists, trained within the discipline of natural sciences, tend to employ rather narrow reductionistic and analytic approaches in their science and its applications. Thus, reflecting the ecosystem approach, the majority of conservation programs and land planning seek to draw clear borders between natural areas and human domains, and to minimize interactions between nature and culture.

The landscape approach, described above, is still used sparsely among ecologists, but it is often implemented by landscape planners with a landscape-ecological conception (e.g. Makhzoumi 2000, Burmil 2002). As shown by Makhzoumi and Pungetti (1999), the nature of the realm encourages imagination, intuition and creativity, pre-adaptations for adoption of the landscape approach. On the other hand, most landscape planners are trained only within the discipline of humanistic and social sciences, and few landscape planners have a strong background in ecology. Land planning projects by landscape planners often lack the firm scientific basis of quantification of components and processes, critical for ecological assessment of the land (A. Farina, personal communication).

The above discussion points to the necessity of transdiciplinarity in land planning and management. Each one of the two approaches to land planning and management, derived from the paradigms of ecosystem and of landscape, respectively, has its own indispensable value in applying wise management to the intricate natural systems. What is needed today is a transdisciplinary cooperation of ecologists and landscape planners for the progression of ecological planning (Noss 2001) as a new, hybrid realm combining ecology and planning, nature and culture, holistic and analytic approaches as a new "eco-discipline" (Naveh 2002) of a problem-solving oriented landscape science.

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## References

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

Burke, I. C., and W. K. Lauenroth. 2002. Ecosystem ecology at regional scales. Ecology **83**:305-306.

Burmil, S. 2002. Holistic landscape planning: a seasonal pond as a case study. Journal of Mediterranean Ecology **3**:55-64.

Carmel, Y., and R. Kadmon. 1998. Computerized classification of Mediterranean vegetation using panchromatic aerial photographs. Journal of Vegetation Science **9**:445-454.

Carmel, Y., and R. Kadmon. 1999. Grazing, topography, and long-term vegetation changes in a Mediterranean ecosystem. Plant Ecology **145**:239-250.

Carmel, Y., R. Kadmon, and R. Nirel. 2001. Spatio-temporal predictive models of Mediterranean vegetation dynamics. Ecological Applications **11**:268-280.

Carmel, Y., and U. N. Safriel. 1998. Habitat use by bats in a Mediterranean ecosystem in Israel - Conservation implications. Biological Conservation **84**:245-250.

Connell, J. H., I. R. Noble, and R. O. Slatyer. 1987. On the mechanisms producing successional change. Oikos **50**:136-137.

Cowling, R. M., and W. J. Bond. 1991. How small can reserves be? an empirical approach in Cape Fynbos, South Africa. Biological Conservation **58**:243-256.

De Leo, and S. A. Levin. 1997. The multifaceted aspects of ecosystem integrity. Conservation Ecology (online) **1**.

Farina, A. 1998. Principles and methods in landscape ecology. Chapman and Hall, London.

Forman, R. T. T. 1995. Land Mosaics. Cambridge University Press, New York.

Grossman, W. D., and Z. Naveh. 2000. Transdisciplinary challenges for regional sustainable development toward the post-industrial information society. Pages 1-3 *in* Third International Conference of the European Society for Ecological Economics, Vienna.

Jantsch, E. 1980. The Self-Organizing Universe. Scientific and Human Implications of the Emerging Paradigm of Evolution. Pergamon Press, Oxford.

Jorgensen, S. E. 1997. Integration of Ecosystem Theories: A Pattern. Second edition. Kluwer Academic Publishers, Dordrecht.

Jorgensen, S. E., and F. Muller. 2000. Handbook of ecosystem theories and management. Lewis Publishers, Boca Raton.

Koestler, A. 1969. Beyond atomism and holism.- the concept of the holon. Pages 192-216 *in* J. R. Smithies, editor. Beyond Reductionism: New Perspectives in the Life Sciences. Hutchinson, London.

Lamberson, R. H., B. R. Noon, C. Voss, and K. S. McKelvey. 1994. Reserve design for territorial species: the effects of patch size and spacing on the viability of the northern spotted owl. Conservation Biology **8**:185-195.

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. Shambhala, New Science Library, Boston.

Laszlo, E. 1994. The Choice: Evolution or Extinction. A Thinking Person's Guide to Global Issues. C.P. Putnam & Sons, New York.

Laszlo, E. 1996. The Systems View of the World: A Holistic Vision for Our Time. Hampton, Cresskill, New Jersey.

Lesica, P. 1992. Autecology of the endangered plant Howellia aquatilis: Implications for management and reserve design. Ecological Applications 2(4), 411-421.

Levin, S. A. 1998. Ecosystems and the biosphere as complex adaptive systems. Ecosystems **1**:431-436.

Makhzoumi, J. 2000. landscape ecology as a foundation for landscape architecture: application in Malta. Landscape and Urban Planning **50**:167-178.

Makhzoumi, J., and G. Pungetti. 1999. Ecological landscape design and planning: the Mediterranean context. E & F Spon, London.

Markus, M. 1994. Meron Mountain - a landscape survey. Nature Reserve Authority, Jerusalem. In Hebrew.

Murphy, D. D., and B. R. Noon. 1992. Integrating scientific methods with habitat conservation planning; reserve design for northern spotted owls. Ecological Applications **2**:3-17.

Naveh, Z. 1982. Landscape ecology as an emerging branch of human ecosystem science. Advanced Ecological Research **12**:139-287.

Naveh, Z. 1991. Mediterranean uplands as anthropogenic perturbation dependant systems and their dynamic conservation management. Pages 544-556 *in* O. A. Ravera, editor. Terrestrial and aquatic ecosystems: perturbation and recovery.

Naveh, Z. 1994. The role of fire in the Mediterranean landscape of Israel. Pages 163-185 *in* J. M. Moreno and W. C. Oechel, editors. The role of fire in the Mediterranean-type ecosystems. Springer-Verlag, New York.

Naveh, Z. 1998. From biodiversity to ecodiversity - holistic conservation of the biological and cultural diversity of Mediterranean landscapes. Pages 23-54 *in* P. W. Rundel, G. Montenegro, and F. M. Jaksic, editors. Landscape disturbance and biodiversity in Mediterranean-type ecosystems. Springer-Verlag, Berlin.

Naveh, Z. 2000. What is holistic landscape ecology? A conceptual introduction. Landscape and Urban Planning **50**:7-26.

Naveh, Z. 2001. Ten major premises for a holistic conception of multifunctional landscapes. Landscape and Urban Planning **57**:269-284.

Naveh, Z. 2002. Multifunctional, self-organizing biosphere landscapes and the future of our Total Human Ecosystem. World Futures **In Press**.

Naveh, Z., and A. Lieberman. 1994. Landscape ecology - theory and application, second edition. Springer-Verlag, New York.

Naveh, Z., and R. H. Whittaker. 1979. Structural and floristic diversity of shrublands and woodlands on northern Israel and other Mediterranean areas. Vegetatio **41**:171-190.

Noss, R. F. 2001. Maintaining ecological integrity of landscapes and ecoregions. Pages 191-208 *in* D. Pimentel, L. Westra, and R. F. Noss, editors. Ecological integrity: integrating environment, conservation, and health. Island Press, Washington, D.C.

Noy-Meir, I. 1975. Stability of grazing systems: an application of predator-prey graphs. Journal of Ecology **63**:459-481.

Odum, E. P. 1971. Fundamentals of Ecology, 3 edition. W.B Sounders, Philadelphia.

Oksanen, L., and T. Oksanen. 2000. The logic and realism of the hypothesis of exploitation ecosystems. American Naturalist **155**:703-723.

O'Neill, R. V. 2001. Is it time to bury the ecosystem concept? (with full military honors, of course!). Ecology **82**:3275-3284.

O'Neill, R. V., D. L. DeAngelis, J. B. Waide, and T. F. H. Allen. 1986. A hierarchical concept of ecosystems. Princeton University Press, Princeton, NJ.

Pacala, S. W., C. D. Canham, J. Saponara, J. A. Silander, R. K. Kobe, and E. Ribbens. 1996. Forest models defined by field measurements: estimation, error analysis and dynamics. Ecological Monographs **66**:1-43.

Pacala, S. W., C. D. Canham, and J. A. Silander. 1993. Forest models defined by field measurements: I. The design of a northeastern forest simulator. Canadian Journal of Forest Research **23**:1980-1988.

Pickett, S. T. A., and R. S. White. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, London.

Power, M. E. 2001. Field biology, food web models, and management: Challenges of context and scale. Oikos **94**:118-129.

Prigogine, I. 1976. Order through fluctuations: Self-organization and social systems. Pages 93-130 *in* C. W. Waddington, editor. Evolution and Consciousness: Human Systems in Transition Reading. Addison-Wesley, Massachusetts.

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

Riley, R. H., and P. M. Vitousek. 1995. Nutrient dynamics and trace gas flux during ecosystem development in Hawaiian montane rainforest. Ecology **76**:92-304.

Sagoff, M. 2001. Ecosystem design in historical and philosophical context. Pages 61-78 *in* D. Pimentel, L. Westra, and R. F. Noss, editors. Ecological integrity: integrating environment, conservation, and health. Island Press, Washington, D.C.

Tilman, D. 1982. Resource competition and community structure. Princeton University Press.

Watson, J., D. Freedenberg, and D. Paul. 2001. An assessment of the focal-species approach for conserving birds in variegated landscapes in southeastern Australia. Conservation Biology **15**:1364-1373.

Wear, D. N., and P. V. Bolstad. 1998. Land-use changes in Southern Appalachian landscapes: spatial analysis and forecast evaluation. Ecosystems **1**:575-594.

Weinberg, G. 1975. An Introduction to General Systems Thinking. Willey, New York