*World Futures*, 60: 469–503, 2004

ISSN 0260-4027 print
DOI: 10.1080/02604020490518324

# MULTIFUNCTIONAL, SELF-ORGANIZING BIOSPHERE LANDSCAPES AND THE FUTURE OF OUR TOTAL HUMAN ECOSYSTEM

Z. NAVEH
*Faculty of Agricultural Engineering, Technion, Israel Institute of Technology, Haifa, Israel*

Solar energy powered autopoietic (self-creating and regenerative) natural and cultural biosphere landscapes fulfill vital multiple functions for the sustainable future of organic life and its biological evolution and for human physical and mental health. At the present crucial Macroshift from the industrial to the post-industrial information age, their future and therefore also that of our Total Human Ecosystem, integrating humans and their total environment, is endangered by the exponential growth and waste products of urban-industrial technosphere landscapes and agro-industrial bio-technosphere landscapes.

This danger can be prevented only by the creation of new symbiotic relations between human society and nature with the help of mutual supportive, restorative cultural and economic cross-catalytic networks in our Total human Ecosystem. This should be part of an all—embracing sustainability revolution, driven by human consciousness and its responsibility to act as stewards rather than exploiters of the complex and harmonious web of life on this planet.

*KEYWORDS: Landscape ecology, evolution, nonequilibrium thermodynamics, autopoiesis, biosphere, technosphere, cross-catalytic networks.*

## INTRODUCTION: THE TRANSITION TO THE GLOBAL INFORMATION AGE—A CRUCIAL PERIOD FOR LIFE ON EARTH

Humankind is undergoing presently closely interwoven changes, embracing all spheres of human life from the biological-ecological to the social-cultural, the economic, technological and political sphere. These global changes are driven by the rapid development of worldwide computer networks of information, allowing the rapid economic built-up expansion and globalization and have been presented by Di Castri (1998) as a multifaceted and interactive picture of globalized gears moved by information flows.

Address correspondence to Zev Naveh, Faculty of Agricultural Engineering, Technion, Israel Institute of Technology, Haifa 323000, Israel. E-mail: znave@techunix.technion.ac.il

Ervin Laszlo (1994), the renowned systems philosopher and expert on global trends, regarded these changes as a “Grand Transition” from the industrial to the post-industrial global information age, and therefore as an epochal turning point in human socio-cultural evolution. In this, global survival will be determined by the choice of human society between ensuring further evolution of life on Earth, or its final extinction.

Most recently Laszlo (2000) has further described this period of profound and irreversible changes, as a “*Macroshift.*” *This* evolutionary trajectory *is the societal variety of bifurcations in non-human systems, where the consciousness* (and therefore also the behavior) *of the system’s members will determine its outcome.*

In his own words (Laszlo, 2000, page 2);

> It is up to those who live through this Macroshift, whether the era that dawns will be true advance over the era we have been living through, or a lapse into downward spiral: more penury, greater poverty, more violence, and greater degradation of environment and the quality of life.

Some of the most recent findings show in a very convincing way that this dilemma of human society to choose between evolution and extinction, is not a far-fetched doomsday prophecy. On the contrary, as will be shown below, it has become even more urgent since the publication of his book in 1994. These findings show clearly how urgent is a human-induced radical change in the current direction of this Macroshift. However, the values, insights and behavior of all of us, in all parts of the world will decide its outcome.

In the 1999 *State of the World Report* as one of the most important and reliable source of information on critical global environmental issues, published annually by the Worldwatch Institute Brown et al. (1999) summarized this situation as follows:

> Coupled with the rapid population growth and the even faster growing consumption have undermined the ecological foundations of our natural life support systems, on which our civilization depends. Modern industrial society has become thereby a major destabilizing biological, sociological and even geological force and has reached a crucial turning point in its relations to nature.

Thanks to the extraordinary achievements of science and technology we are approaching now this new global, information-rich age. However in the creation of the rapidly expanding technosphere and its urban-industrial and agro-industrial landscapes, the technological power and skill of *Homo Industrialis* and his obsessive believe in the panacea of growth and the increase in material goods, have far exceeded his ecological wisdom, knowledge and ethics. Thus, in spite of the great advances in science and technology, the industrial society has not been able to resolve the deep ecological crisis it has created in the last century. Its leading governments have squandered the historic opportunity to reverse the accelerating speed of Earth’s environmental decline during the prosperity of the last years.

In fact, during the last century the world population has increased 4 times, the world economy has increased even 17 times and the living standard of the Western world has improved tremendously. But at the same time, the less industrialized countries have become poorer and hungrier and presently 1, 2 billion people must survive with less than one dollar per day and lack access to clean water and hundreds of millions breathe unhealthy air.

The accelerating speed of the global climate destabilization is illustrated in a most recent report of the Intergovernmental Panel on Climate Change (IPCC). It envisages that the catastrophic physical, ecological and socio-economic consequences of human-induced climatic changes will occur with greater speed as previously predicted. These warnings are supported by solid facts on the accelerating speed of global warming, indicated by the melting of ice sheets in the Arctic and the Antarctic and of mountain glaciers from the Peruvian Andes to the Swiss Alps are proceeding with more speed than expected. The Arctic Ocean ice cap has been reduced by nearly half and the ice shelves of the Antarctic Peninsula are in full retreat and lost until 1997 2,000 square kilometers, but in 1999 alone 3,000 square kilometers. As the ice on land melts and flows to the sea, this is causing not only devastating floods and landslides, like those in Venezuela, worsened by deforestation that killed more than 30,000 people, but also the rise of the sea level. Over the last century, the sea level rose by 20–39 centimeters. However during this century it could rise by as much as 1 meter, and if the Greenland ice sheet will continue to shrink with the present speed, and will melt entirely, then the sea levels could rise even by 7 meters. This will have catastrophic consequences for all Atlantic and Pacific islands and shore lands.

In recent years, the warming atmosphere has spurred already more severe and more frequent weather events, like the December 1999 storms in Central and Western Europe, that caused nearly $10 billion damage. The latest flooding in India have left more than 15 millions inhabitants in terrible distress, without shelter and almost without food. Many of these will join the millions of displaced “environmental refugees” in Asia and South America, created by extreme and disastrous climatic and events.

Natural disasters have cost the world $605 billion over the last decade—as much as in the previous four decades combined. There are also already alarming signals that global climate changes are more rapid than the rate of adaptive changes with which habitats and many of their organisms can cope. Already now 11 percent of all bird species, 25 percent of mammals and 34 percent of fish are in danger of extinction, and 27 percent of the world’s coral reefs have been lost already.

It becomes now also more and more obvious that extreme climatic events such as heavy rains, strong winds, drought, and extreme cold or hot periods are becoming more and more frequent and leading to more and more catastrophic outcomes. Their results, in turn, are becoming more and more severe, because of the exponential process of landscape degradation and its destabilizing impacts. This is especially the case in the densely populated Asian countries, in which traditional unsustainable land uses, such as overgrazing, and overcutting of wood for fuel are combined with the “modern” not less detrimental but much larger scale uncontrolled agricultural and industrial intensification. Whereas the former desertification process creates bare soil, the latter creates also large, impenetrable layers of asphalt, using many thousand times more powerful engineering devices and machines for land denudation and destruction.

The problem of desertification is especially severe in the semi-arid northwestern provinces of China. Already suffering from overgrazing and overplowing, but now, the efforts of the Chinese government to compensate for the loss of fertile croplands by plowing out marginal lands is accelerating even more wind and soil erosion.

A recent, well-documented report by Brown (2001) lends special significance to the warning by Laszlo (2000) that "China is an unsustainable catastrophe in the making." This report claims that the dust bowl, resulting from this unsustainable agricultural development is threatening the future of China. The most recent record dust storm is hitting Beijing and most of the other populous cities in North East China, obscuring the sun, reducing visibility along traffic and closing airports. These huge dust plumes from northern China have reached now also the North America, "blanketing areas from Canada to Arizona with layer of dust."

Brown (2001) concludes, that reversing desertification will require a huge effort, but if the dust bowl continues to spread, it will not only undermine the economy, but it will also trigger a massive migration eastward. He states: "The options are clear: Reduce livestock populations to a sustainable level or face heavy livestock loss as grassland turns to desert. Return highly erodible cropland to grassland or lose all of the land's productive capacity as it turns to desert. Construct windbreaks with a combination of trees and, where feasible, wind turbines, to slow the wind or face even more soil losses and dust storms."

Of special relevance for our discussion on the future of multifunctional solar-powered biosphere landscapes are the results of a recent worldwide pilot study. It has been carried out jointly by 175 interdisciplinary scientists under the auspices of the United Nations Development Program and the United Nations Environment Program, the World Bank and the World Resources Institute (World Resources, 2000–2001, available On-Line at www.wli.org/wr2000). These scientists arrived at the conclusion that a critical point has been reached in the earth's capacity to support both nature and human populations. As illustrated by many maps, the researchers studied different landscapes (but used instead only the vaguely defined and delineated ecosystem term), showing that many of these landscapes are reaching now dangerous thresholds.

Some of the major landscape functions of agro-ecosystems, and coastal-, forest-, freshwater- and grassland-ecosystems were evaluated as goods and services and scored for food/fiber production, water quality, biodiversity, carbon storage, recreation, shoreline protection and woodfuel production. The "Bottom Line" was that overall there are numerous signs that the capacity of ecosystems to continue to produce many of these goods and services is decreasing. The erosion of biodiversity is alarming, chiefly because of "loss of habitat area," and their vanishing landscapes. Amongst the most revealing indicators for the loss of crucial landscape functions is the extent of deforestation of watersheds. Almost a third of all watersheds assessed have lost 75 percent of their original forest cover and seventeen have lost more than 90 percent.

Amongst the many other recent findings on the rapidly increasing threats to these natural and semi-natural landscapes and their organic life, is the latest report by the World Wildlife Fund. It warns, that if until the end of this century the atmospheric Carbon dioxide levels will continue to rise and thus be doubled since the beginning of the industrial revolution, then 70 percent of all natural habitats in the northernmost landscapes of Canada, Russia and Scandinavia could be lost, and 50 percent of those in northern European countries altogether.

## THE ROLE OF LANDSCAPE ECOLOGY AND THE SUSTAINABILITY REVOLUTION

This acceleration of overwhelming global threats puts additional weight to the claim by Laszlo (1994) that for the choice of further biological and cultural evolution, a far-reaching ecological, social, cultural and political sustainability revolution in all spheres of life is essential. It can be achieved only by a great effort on global dimensions, driven by all those who are concerned with the future of life on earth and the welfare of all its inhabitants and who can provide the scientific and professional leadership to this revolution.

Of special relevance for this purpose are those sciences dealing with the fate of the land and seascapes, their geophysical, bio-ecological and human-ecological, socio-economic and cultural aspects with broad, integrative approaches. Amongst these sciences, landscape ecology occupies a special place. It emerged after in the sixtieths in Central and Eastern Europe as an interdisciplinary ecological-geographical, and problem-solving, holistic discipline of landscape study, planning and management, and has developed in the last twenty years as a dynamic global environmental science. The International Association of Landscape Ecology (IALE) has hundreds of members, academic researchers, professional planners, land managers and users in about 40 industrial and developing countries. A great number of landscape-ecological studies, dealing with highly diverse themes on natural and cultural, rural and urban landscapes are published in "Landscape Ecology," "Landscape and Urban Planning": and in other, related scientific journals. At the same time, the number of books published on these subjects is increasing steadily.

The fate of all these landscapes—and our global ecosphere landscape as a whole—is closely coupled through mutually amplifying feedback relations with these cultural evolutionary trends of human society and its choice between further evolution and extinction. Therefore landscape ecologists have to become involved in this choice and have to become, what Di Castri (1997) in an important editorial in "Landscape Ecology" has called "*committed actors*," but not remain only "critical but marginal spectators in this game." As pointed out by Naveh (2001), for this purpose, landscape ecology cannot be carried out anymore in the sheltered academic ivory tower of so-called "objective science," detached from people and their values and needs. This has to be reflected both in theory and action in their day-to-day work in education, research and practice. To contribute jointly with scientists from all other relevant disciplines to a sustainable future of healthy, productive and attractive landscapes should become one of the greatest challenges for future-oriented landscape ecologists. It demands first of all an understanding of the transdisciplinary scientific revolution, offering a holistic systems view of the world. It requires the recognition of the far-reaching impacts of these developments on multifunctional landscapes and their management, conservation and restoration as tangible, self-organizing Gestalt systems of our Total Human Ecosystem. This will be discussed further in more detail.

## LANDSCAPES AS TANGIBLE MULTIFUNCTIONAL GESTALT SYSTEMS OF OUR TOTAL HUMAN ECOSYSTEM

The true meaning of future-oriented and mission-driven holistic landscape ecology can be fully comprehended only in the broader context of the present holistic and transdisciplinary scientific revolution. According to Kuhn (1996), such a scientific revolution is characterized by major paradigm shifts that are generally accepted in "normal" science. We are dealing here with a far-reaching paradigm shift from conventional reductionistic and mechanistic concepts to holistic and organismic approaches of wholeness, connectedness and ordered complexity. These are grounded in systems theory, offering a unified worldview that seeks to do justice not only to the physical, biological and the socio-economical, but also to the mental, the cultural and the spiritual reality in which we live. It is leading also to a profound postmodern cultural transformation, changing many of the ideas which dominate since the industrial revolution most of science and technology and Western society, its education, economy and culture at large. As explained in more detail elsewhere (Naveh, 2000, 2001), this implies a holistic paradigm shift from perceiving landscapes as nothing but large-scale heterogeneous mosaics of physical, chemical, and biological landscape elements in repeated patterns of ecosystems, into a holistic view of landscapes as *multifunctional Gestalt systems* in their own right. The German term "Gestalt" has been introduced into psychological Gestalt theory, in which humans are perceived as whole persons, fully embedded in the world, and the world is seen more like a living person than like a nonliving mechanism of separate interacting parts. Antrop and Van Eetvelde (2000) have recently pointed out the relevance of some of the laws of psychological Gestalt theory for a holistic perception of complex landscape patterns. The scope of this theory has been broadened by the ecopsychologist Cahalan (1995) to achieve a deepened sense of the full therapeutic function of the natural environment, to which I will refer further below.

Naveh and Lieberman (1994), and more recently Naveh (2000, 2001) have presented detailed discussions on the holistic nature of landscapes and their multidimensional functions. Here it is sufficient to point out that in landscapes all natural and cultural dimensions are intrinsically related to each other by the general state of the whole and its emergent qualities from the smallest, mappable landscape cell or *ecotope*, to the global ecosphere landscape. The different landscape units and types are closely interlaced into a multi-layered, stratified hierarchy of holons, being both parts of their higher level supersystem and wholes towards their lower level subsystems. Therefore, instead of a puzzle of separate particles, forming together a mosaic, we deal with a hierarchically structured interacting network of landscapes at different scales. Together with increasing spatial temporal and perceptional scales, also the complexity of patterns and processes, and their resulting functions are increasing, and a better comprehension of the underlying ecological and historical and cultural dynamics can be reached (Naveh, 1994a).

Further insights in the unique, holistic nature of landscapes can be gained with the help of Bohm's (1980) and Bohm and Peat's (1987) groundbreaking studies on enfolded implicate and generative orders, in which human mind, consciousness and creativity play and important role. These are hidden behind the familiar notions of simple regularity and randomness, describable in landscapes by Archimedian geometry and the Cartesian grid of coordinates which has dominated the basic order of reality for the last three hundred years. Bohm and Peat (1987) showed 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 of nature through the mind. A major challenge for landscape ecologists will be to capture these new orders with the help of innovative transdisciplinary methods in their research, and to develop practical tools for an integrated appreciation of the aesthetic, ethical and intrinsic functions of landscapes as tangible bridges between human mind and nature.

In accordance with this holistic paradigm shift, humans are not apart from nature or even above nature, valuing only its instrumental functions, but they are *integral parts of nature.* They should therefore not be considered as external, "disturbance" factors or be modeled in these landscapes merely as socio-economic factors. Instead, *human aspects and dimensions have to be treated as an intrinsic part of landscape processes and functions*. As such these functions should also be holistically assessed and utilized for the sake of both natural and human systems.

For this purpose, landscapes are to be viewed, studied, and managed not only within the ecological/functional and the geographical/spatial dimensions of the natural sciences. They have to be treated within a much broader context of the of the integrated human-nature systems complex, as the larger ecological geo-bio-anthropo entity in which we live. Following the eminent, first holistic ecologist, Frank Egler (1964), we suggested naming this entity the *Total Human Ecosystem* (THE) *integrating humans and their total environment at the highest co-evolutionary level of the global ecological holarchy.* As the tangible spatial and functional matrix of all organisms, including humans, their populations, communities and ecosystems, landscapes become thereby also the concrete, space/time defined ordered wholes and unique Gestalt systems of our THE along different functional, spatial and perceptional scales and dimensions (Naveh, 1982; Naveh and Lieberman, 1994).

However, as thinking human creatures we are living not only in this physical, ecological and geographical landscape space, which we share with other organisms. We live also in the conceptual space of the human mind of the *noosphere* (from the Greek *noos* = mind).This is an additional natural envelope of life in its totality that *Homo sapiens* acquired throughout the evolution of the human neocortex from the paleo-mammalian brain, as the domains of our perceptions, knowledge, feeling, volition, and consciousness. It enabled the capacity for "*self-reflective mentation*" (Jantsch, 1980) or of "*reflective consciousness*" and self-awareness, namely the ability not only to perceive and feel things, but to know that one perceives and feels them and hence to order them in the light of his purpose (Laszlo, 1994). This led to the development of additional noospheric realms of the info-socio- and psycho-spheres that have emerged during the cultural evolution of modern man, through which he became a mighty geological agent with both constructive and destructive powers.

The Total Human Ecosystem should be regarded as the overarching conceptional supersystem for both these physical geospheric and mental and spiritual noospheric space spheres. It could serve therefore also as the unifying conceptional foundation for a very much needed holistic paradigm of for the highly fragmented environmental science rooted either in the natural or the social sciences and humanities. Such a complementary systems view enables us to view the evolution of THE landscapes in the light of the new holistic and transdisciplinary insights as a tangible bridge between nature and mind, and as an integral part of the dynamic self-organization and co-evolution in nature and in human societies. It opens the way for a better comprehension of the multifunctionality of cultural landscapes and their natural and cultural multidimensions (Naveh, 2001).

## NEW INSIGHTS INTO SELF-ORGANIZATION AND EVOLUTIONARY PROCESSES IN NON-EQUILIBRIUM SYSTEMS

Of great relevance for this conception of THE landscapes are the insights gained on the self-organization of living systems. In these, the spontaneous emergence of new order, creating new structures and new forms of behavior within network patterns is made possible by their self-regulating feedback loops. Such systems on a relatively high organizational levels, which can renew, repair, and replicate themselves as networks of interrelated component-producing processes, in which the network itself is created and recreated in a flow of matter and energy, are called *autopoietic systems* (from the Greek = self-creating or self-renewing). This is true not only for cells and organisms and ecosystems, but also for landscapes, as interacting Total Human Ecosystems of non-human and human living systems. In his last, seminal book, on the "The Self-Organizing Universe," the great transdisciplinary systems thinker and planner Erich Jantsch (page 10; 1980), has defined autopoietic systems as follows:

> An autopoietic system is in the first line not concerned with the production of any output, but with its own self-renewal in the same process structure. Autopoiesis is an expression of the fundamental complementary of structure and function, that flexibility and plasticity due to dynamic relations, through which self-organization becomes possible.

This autopoietic process is made possible by "*autocatalyis*" by which one of the products of the reaction enters a cycle that helps to reproduce itself by creating its own synthesis. In cycles of "*crosscatalyis*" two or more subsystems are linked, so that they can support each other by catalyzing each other's synthesis and thereby mutually increase their growth. This is the case with living cells, which can produce more of themselves and in the same time they preserve themselves in a changing environment. The eminent biologists Eigen and Schuster (1979) have demonstrated that entire chains autocatalytic self-reinforcing and mutually reinforcing cross-catalytic cycles and network relations are the basis of the complex structures which underlie, and make possible, the emergence of life. Their work led to the recognition of "*hypercycles*" of mutually reinforcing chemical and biological processes of systems far from equilibrium, through positive feedback loops, together with the appearance of instabilities, leading to new, and higher forms of organization.

Such hypercycles are shown on the subcellular DNA level. The major auto- and cross-catalytic cycles of the biosphere, driven by solar energy through the trophic food chains and recycling their decay products are shown in Figure 2. Here Laszlo (1987) presents the biosphere as the global system, driven by solar energy through trophic food chains and recycling their decay products. It should be realized that such energy-material flows and crosscatalytic networks can be completed fully only in natural and seminatural, solar-energy powered biosphere landscapes. However, as will be described further in more detail below, in the current global Total Human Ecosystem of the industrial society, these cycles are threatened in agro- and urban-industrial landscapes.

Maturana and Varela (1975) have broadened these findings into a comprehensive systems theory of self-organization of biosystems (Figure 1). Jantsch (1980) has carried this new paradigm of dynamic micro-and macro-co-evolution of self-organization in nature even further. He has laid the transdisciplinary foundations for a synthetic view of cosmic, geological, biological, ecological and socio-cultural evolution. It leads to an all-embracing conception co-evolution, emphasizing

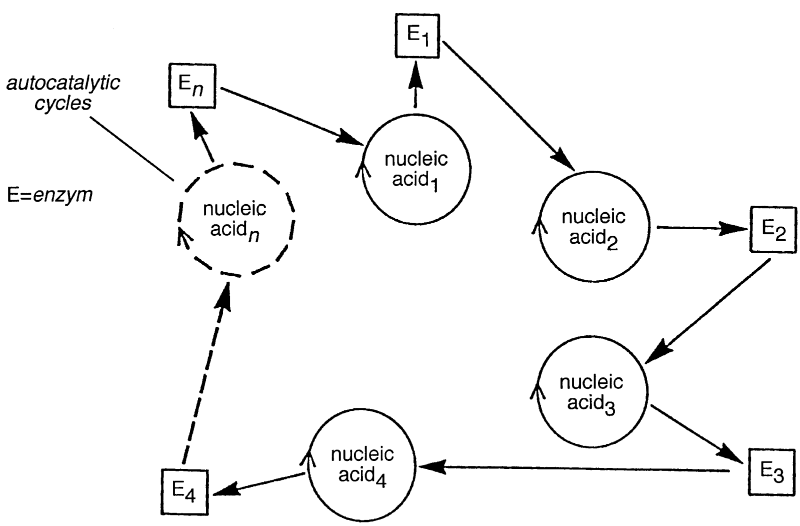



Figure 1. Autocatalytic cycles in nucleic acid molecules and their enzymes, producing a cross-catalytic cycle with another nucleic acid molecule and forming together a cross-catalytic ("Hyper") cycle, converging thereby to a higher level of cell organization (Laszlo, 1987).

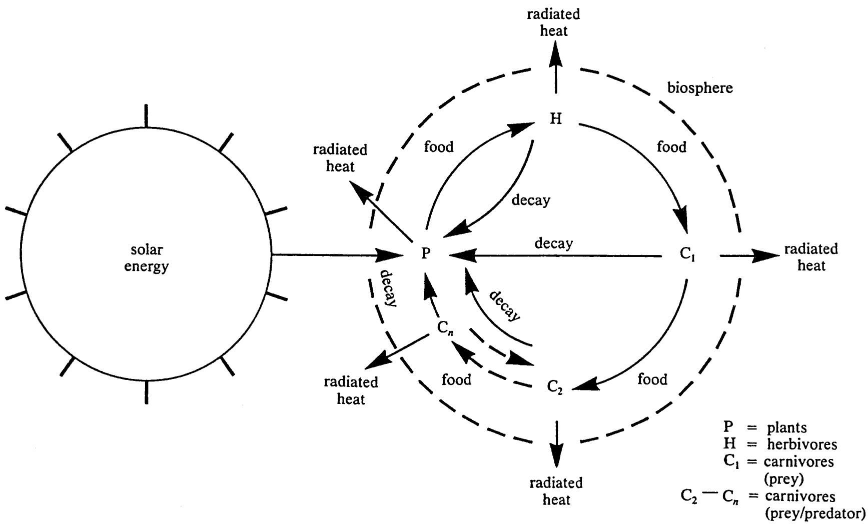



Figure 2. Major catalytic cycles in the biosphere between the different trophic levels of the food chain, driven by solar energy, "pumping out" radiated heat (Laszlo, 1987).

cooperation as the creative play of an entire evolving universe. This presents a major paradigm shift from the Cartesian and Newtonian view of a mechanistic world and reaches far beyond the still fashionable post-Darwinian and sociobiological interpretations of evolution. Jantsch (1980) achieved this by combining these evolutionary insights with the new ordering principles of self-organization in non-equilibrium systems, developed by the Nobel-Prize winner Prigogine and his Brussels team, to which I will refer further in the context of landscape evolution. Since then, his groundbreaking theories have been corroborated and further developed thanks to recent findings in the sciences of wholeness and the mathematics of complexity. They have been outlined recently by Capra (1996), the well-known author of the "Tao of Physics," in a remarkable readable and non-formal book "The Web of Life."

In his seminal study on the "Grand Evolutionary Synthesis" Laszlo (1987) further examined the co-evolutionary patterns of change and transformation in the cosmos, organisms and in modern society. In this synthetic evolutionary patterns, systems are not moving in a continuous and linear progress from the simpler to the more complex type of system, and from the lower to the higher level of organization. They leap by the sudden emergence of successive levels of organization from quarks to global socio-cultural systems and to cosmic systems.

These discontinuous developments of sudden leaps from one kind of stable state to another occur as "*bifurcations*." In systems far from equilibrium subtle "catastrophic" bifurcations can model increasing instability. These may turn chaotic or disappear or lead to a new state of metastability on a higher level of organization.

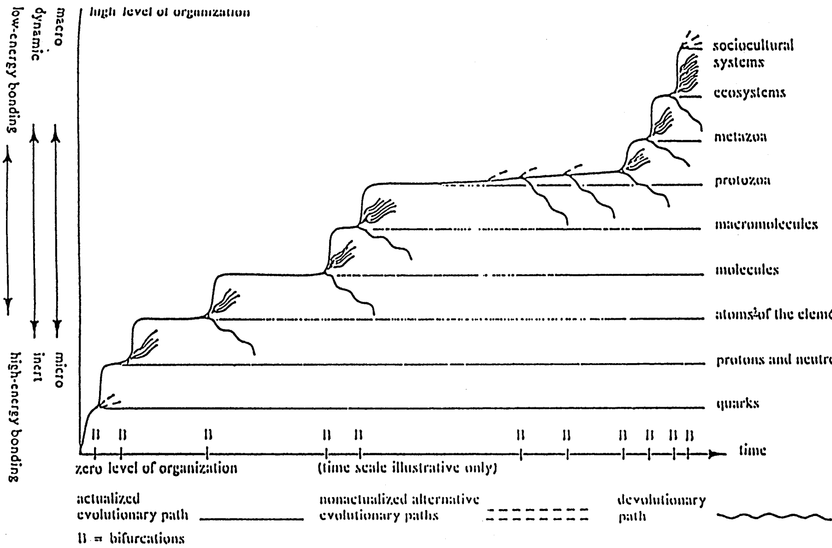



Figure 3. The sudden evolution of successive higher organization levels from physical to chemical, ecological and cultural systems (Laszlo, 1987).

All these evolutionary steps have been made possible by mutually reinforcing crosscatalytic feedback loops. According to Laszlo (1987), their formation allows dynamic systems to emerge on such successively higher levels of organization on multiple hierarchical levels. On each level the amount of information that can be handled by the cycle is greater than on the lower level, owing to a greater diversity and richness of the components and structures. In Figure 3, these sudden leaps and their bifurcations are shown on global levels from the lowest organization level of quarks up to the highest level of socio-cultural systems, and according to our conception, up to the Total Human Ecosystem.

Following the findings of Prigogine and his co-workers, these non-linear evolutionary processes can be explained from the thermodynamic viewpoint as new ordering principles that "create order through fluctuations" (Prigogine, 1976) and even "order out of chaos" (Prigogine and Stengers, 1984). They showed that nonlinear thermodynamics of irreversible processes in open systems exchanging energy and material with their environment could lead to the evolution of such new, dynamic globally stable systems. This is opposed to the belief by many physicists that non-equilibrium states are only temporary disturbances of equilibrium, not containing any interesting physical information. Prigogine proved that through the break in time and space symmetry, non-equilibrium of irreversible processes became sources of order and became a creative evolutionary process. These non-equilibrium systems are called "*dissipative structures*" because they maintain continuous entropy production and dissipate accruing entropy, not accumulating in the system, but being part of the continuous energy exchange with their environment.

Dissipative structures constitute the simplest case of spontaneous self-organization in evolution. This has opened the way for realizing that evolution toward increasing complexity and organization is the result of structural fluctuations and innovations that can appear suddenly in a previously stable systems and drive it subsequently to a new regime at a more complex state, as described above.

Jantsch (Page 307; 1980) has summarized these findings as follows:

> We stand at the beginning of a great new synthesis. The correspondence of static structures is not its subject, but connectedness of self-organization dynamics—of mind—at many levels. It becomes possible to view evolution as a complex, but holistic dynamic phenomenon of a universal unfolding of order which becomes manifest in many ways, as matter and energy, information and complexity, consciousness and self-reflection.

It is very hard to condense the great amount of information gathered from many studies in these different fields of innovation and presented mostly in highly formal specialist ways. Here I can describe them only in very general and simplified terms. However, fortunately, they have been synthesized so brilliantly by the above-cited transdisciplinary scientists that they are now much more easily accessible. It will assist greatly all those who are concerned about the future of our THE landscapes to get at the roots of these new paradigms and to find thereby new and deeper meaning with many important practical implications for the management of multifunctional landscapes.

## THE EVOLUTION AND DYNAMICS OF SELF-ORGANIZING LANDSCAPES, AS DISSIPATIVE STRUCTURES FAR FROM EQUILIBRIUM

The above-described findings enable a much more comprehensive view of landscape dynamics as part of the cultural evolution of our Total Human Ecosystem. In a very simplified way this could be described as proceeding by leaps through bifurcations from the primitive food-gathering hunting stage to the Neolithic agricultural revolution, and from there to the industrial revolution until our present, still chaotic transitional bifurcation stage leading towards information society.

As part of these cultural evolutionary processes the THE has expanded according to the rate of growth of human populations, their consumption and technological power.

This caused the expansion of their "ecological footprints" (Rees, 1995) and "colonization processes" (Fischer-Kowalski and Haberl, 1997), by which natural landscapes were modified and into semi-natural, landscapes and converted into rural, and urban-industrial cultural landscapes. However, during this socio-cultural evolutionary process, and since the industrial fossil fuel revolution with accelerating speed, a crucial symmetry break in time and space occurred. This led to a bifurcation, which has divided these entire natural and cultural Total Human Ecosystem landscapes into 3 major functional landscape classes:

1. *solar-powered, autopoietic and regenerative biosphere landscapes.*
2. *fossil fuel-powered technosphere* landscapes and their ecotopes (or in short *bio-* and *techno-ecotopes*),
3. most recently also into additional intermediate both solar and fossil fuel-powered *agro-industrial ecotopes*.

Because of the vital importance of biosphere landscapes for the development of future-oriented and holistic strategies of sustainable planning, designing, conserving and restoring of natural and cultural landscapes, these bifurcations have far-reaching implications for the safeguarding of life on earth and the sustainable future of our Total Human Ecosystem.

In all biosphere landscapes and their bio-ecotopes, high quality potential and chemical energy (and therefore low entropy producing energy) is derived from solar energy and its conversion through photosynthesis and assimilation into chemical and kinetic energy in the organismic food chain. As has been shown in Figure 2 part of this energy is dissipated into low quality metabolic heat and respiration as radiated heat. Therefore an increase in structural and spatial heterogeneity, higher species diversity and higher complexity in food chains and webs build up negentropy—as a measure of organizational order and information—in the landscape. Simultaneously entropy production—as a measure of homogeneity, and disorder—is also minimized by the protection and stabilization functions of the "living sponge" of the vegetation cover and its underlying pedosphere. These reduce the rate of kinetic energy and heat flows and their destructive and destabilizing impacts on the landscape. However, according to their human uses, bio-ecotopes have to be divided into natural and close-to natural and cultural bio-ecotopes.

The scientific breakthrough in non-equilibrium thermodynamics and its new ordering principles have also deepened our understanding of the dynamics of landscapes far from equilibrium and their capacity of continuous self-organization from lower to higher holarchical levels (Naveh and Lieberman, 1994).

As has been described elsewhere in more detail (Naveh, 1991, 1998) Mediterranean, as well as most other semi-natural and agro-silvo-pastoral landscapes, behave as such dissipative structures. They are maintained and stabilized only by permanently interchanging energy and entropy with their environment. Driven by positive feedback of environmental and internal fluctuations, they move to new regimes that generate conditions of renewal of higher internal entropy production, while undergoing short- and long-term, and chiefly cyclic fluctuations, far from a homeostatic equilibrium stage. From such an unstable and even chaotic basis, they move to a stage of dynamic stability or "metastability." By "pumping out" entropy as disorder in their autopoietic life-creating process, these landscapes increase their internal negentropy, ensuring more effective information and energy efficiency within the system.

According to Li (2000), these dynamics can be explained now also in more rigorously in thermodynamic and formal terms. With the help of "synergetics," introduced by Haken (1983) Li extended Prigogine's non-equilibrium thermodynamics into more complicated non-linear dynamic situations with which landscapes are confronted. In synergetics, the system consists of a vast number of subsystems and certain conditions of controls are changed even in a very unspecified way. The system can develop new patterns of macroscopic scale of stable states, such as bistability or multistability. The system may also undergo oscillations or random motions and chaos. Li (2000) combined Haken's theories with those of Prigogine and especially his recent study (Prigogine, 1997), for the interpretation of landscape instability or multistability as dissipative systems, in which stochastic fluctuations lead to an intrinsic instability.

In the Mediterranean Basin and elsewhere such cyclical perturbations have been introduced mostly by regular, centuries lasting rotational grazing, browsing, burning, cutting, coppicing regimes, together with cultivation and other human land uses. These human perturbations were superimposed on the seasonal and annual climatic fluctuations, and their resulting defoliation pressures were incorporated in the landscape together with these and other natural perturbations at different spatio-temporal scales. They resulted in the establishment of a human-maintained and dynamic long- and short-term flow equilibrium or "homeorhesis" (from the Greek, meaning, "Preserving the flow") between the tree, shrub, herb, and grass layers of forests, woodlands, shrublands and grasslands. For such dynamic flow equilibrium, the eminent geneticist Waddington (1975) coined the term "*homeorhesis*" (from the Greek, meaning, "Preserving the flow"). In all these landscapes, the system is not returned to a stationary state of homeostasis, like in traditional climax systems. It is going on to move along the same trajectory of change as it has in the past, as long as these cyclic perturbations are driving these changes and are continued with similar intensities and time intervals. Thereby these human perturbation-dependent systems have acquired long-term adaptive resilience and evolutionary metastability. The long-term maintenance of such homeorhetic flow equilibrium, operating within the great macro- and micro-site heterogeneity of the rocky and rough terrain and producing the fine-grained agro-silvo-pastoral land-use patterns, played apparently a major role inducing the unique combined biological, ecological and cultural landscape "ecodiversity" of these landscapes. Thereby they acquired their most important multifunctional assets.

The disruption of this homeorhetic flow equilibrium is caused not only by too intensive land use pressures, but also by the cessation of all human interference and land abandonment. It is leading to the impoverishment of structural and biological diversity of Mediterranean grasslands, shrublands, woodlands and Maquis, from the Eastern corner to the Western corner of the Mediterranean Basin (Naveh and Whittaker, 1974; Naveh, 1998; Pinto-Correira, 1998). Here, most affected are the light demanding herbaceous species, including many rare endemics and ornamental geophytes (Ruiz de la Tore, 1985), as well as many vertebrates (Warburg et al., 1978), and especially bird species, whose loss is closely coupled with the loss of over-all landscape heterogeneity and diversity (Farina, 1989).

No systematic studies have been carried out up-to-now elsewhere on these aspects. However, we can assume that also in other semi-natural biosphere landscapes outside the Mediterranean Basin a similar homeorhetic flow equilibrium has been maintained either by cyclic natural long or short-tem climatically-induced fire, windrow, flooding and other fluctuations and/or by human-induced fluctuation, such as periodic coppicing, cutting, mowing, grazing and browsing. The disruption of this homeorhetic flow equilibrium by the cessation of traditional, and mostly small-scaled agricultural activities is also one of the major reasons for the loss of some of the most attractive biological and cultural richest rural landscapes and their conversion into dense, homogeneous, secondary forests. This is true not only for Europe, but also for other temperate, as well as subtropical and tropical regions all over the world.

In North American in forests, shrublands and grasslands, such dynamic flow equilibrium has been, most probably maintained both by natural and human set fires. In the African savannas and forests, fire, together with wild and domestic ungulate grazing have fulfilled a similar function. Thus, for instance, in view of the great threats to African elephants, their vital role as a keystone species for diversifying the savannas, the forests, and the swamps is of special importance. This has been demonstrated with many examples by the eminent African wildlife ecologists David Western (1997) during his devoted, life-long work for the Masai in the Amboseli Park in Kenya and the wildlife of East and Central Africa. He reached also very similar conclusions on the need for innovative holistic and dynamic conservation strategies. These should be based on a holistic shift and "a radical departure from the western view of separateness of Man and Nature" by which nature and society should be intimately linked in our minds.

In the South American Pampas grasslands the cyclic homeorhetic flow equilibrium is apparently maintained by periodic flooding, which ensures the high productivity of these subtropical grasslands. Here it is distorted by draining and irrigation schemes for intensive agriculture. Such periodic flooding seems to be also very important for the maintenance of homeorhetic flow equilibrium in many wetlands and swamps and in maundering riverbeds. In many cases, such as in the Mississippi river, the removal of this flow equilibrium by engineering interventions to "regulate the water flow" has resulted just in the opposite, causing much more severe and damaging floods.

The importance of the re-establishment of this multifactorial homeorhetic flow process by active and dynamic conservation management, furthering the highest attainable multifunctionality of these landscapes, can be supported further by their thermodynamic behavior as dissipative structures.

In Mediterranean shrublands and Maquis, the conditions for the creation of new thermodynamic regimes, leading to their function as dissipative structures are apparently created during their regeneration after periodical perturbations of fire, grazing and cutting. But this will happen only if sufficient time has been allowed for the regeneration phase and thereby also for the import of negentropy through intensified photosynthetic growth and regeneration processes. At the same time, the system can actually use free energy to reorganize itself with increasing structural complexity, biological diversity and productivity. But if these perturbation cycles are too frequent and severe, then the external entropy exchange may become more and more positive and disorder will remain at a high level. The same is true also if these perturbations are stopped altogether, either by total protection and non-interference or by abandonment. In this case negentropy and information rises in the early regeneration phase, but with the lack of further perturbations, the rates of entropy production again increase and disorder becomes more and more positive (Naveh 1990, 1991, 1994b).

This is expressed by the monotony and low structural, floristic and faunistic diversity of undisturbed Mediterranean shrublands and Maquis thickets, and by their high inflammability. They are therefore not reaching a homeostatic climax stage of rich and stable "mature" ecosystems, because they are aging and becoming more and more stagnant and senescent, more and more inflammable and therefore also more unstable and species-poor in time.

This process can be illustrated with the help of Prigogine's dissipative function, in which entropy (s) and therefore also disorder (D) grows at the rate ds/dt: $D = ds/t$. D may be positive, negative or zero. If it is zero then the system is in a stationary state—as in the homeostatic "climax" state of natural systems. If it is positive ($D > 0$), then it is in a state of progressive disorganization, and conversely the rate of negentropy and information (info) decreases and it looses its capacity for self-stabilization and self-organization, as in the state of too frequent or no perturbations: $D > 0 = dinfo/dt < 0$. But if D is negative ($D > 0$), then the system is in a state of progressive organization and increases its negentropy and information, as in the case of optimum perturbations. Then the homeorhetic metastability and therefore the capacity of constant self-organization and stabilization can be maintained: $D < 0 = dinfo/dt < 0$. Figure 4 illustrates the results of these 3 different perturbation regimes.

The determination of management strategies for such "optimum" regimes of perturbation and enhancement of biological diversity alone (in nature reserves), or in combination with other land use goals, such as increase of economic production, recreation amenities and scenic values, requires systematic, long-term studies on different landscape scales. Such studies will have to provide the answer if and when controlled burning, both for the reduction of fuel and prevention of destructive wildfires and for dynamic conservation management can be replaced completely by chemical or mechanical means or by domestic or wild animal grazing, and which of these functions are most desired for multiple land uses. These landscape ecological considerations are beyond the now very popular "integrated dynamic ecosystem management."

Many ecologists are already aware of the need for "new paradigm in ecology", replacing the metaphor of a balance of nature maintained without human interference by "the flow of nature" through dynamic change, induced by disturbances including humans and their effects (Pickett et al., 1992). It is regrettable that this new ecological paradigm is not based on the above-described transdisciplinary evolutionary systems concepts and the breakthroughs in non-equilibrium thermodynamics. These are essential for a comprehensive theory of sustainable conservation and restoration management of biosphere landscapes as multifunctional life support systems.

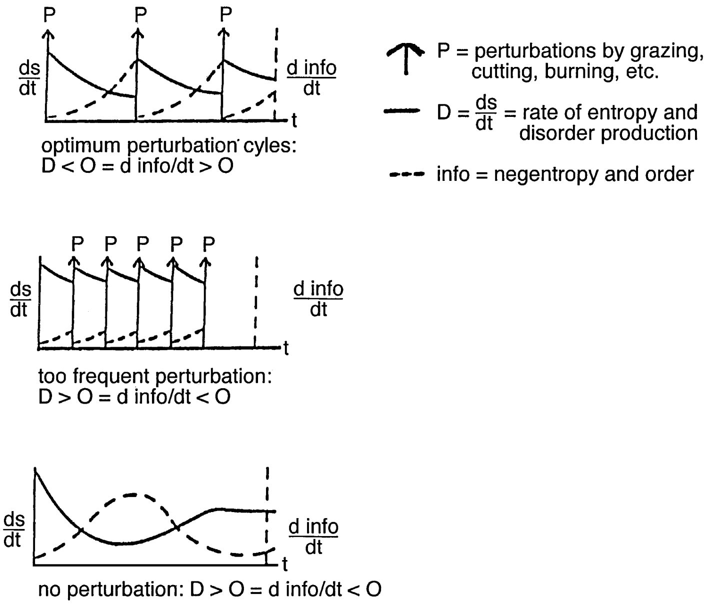


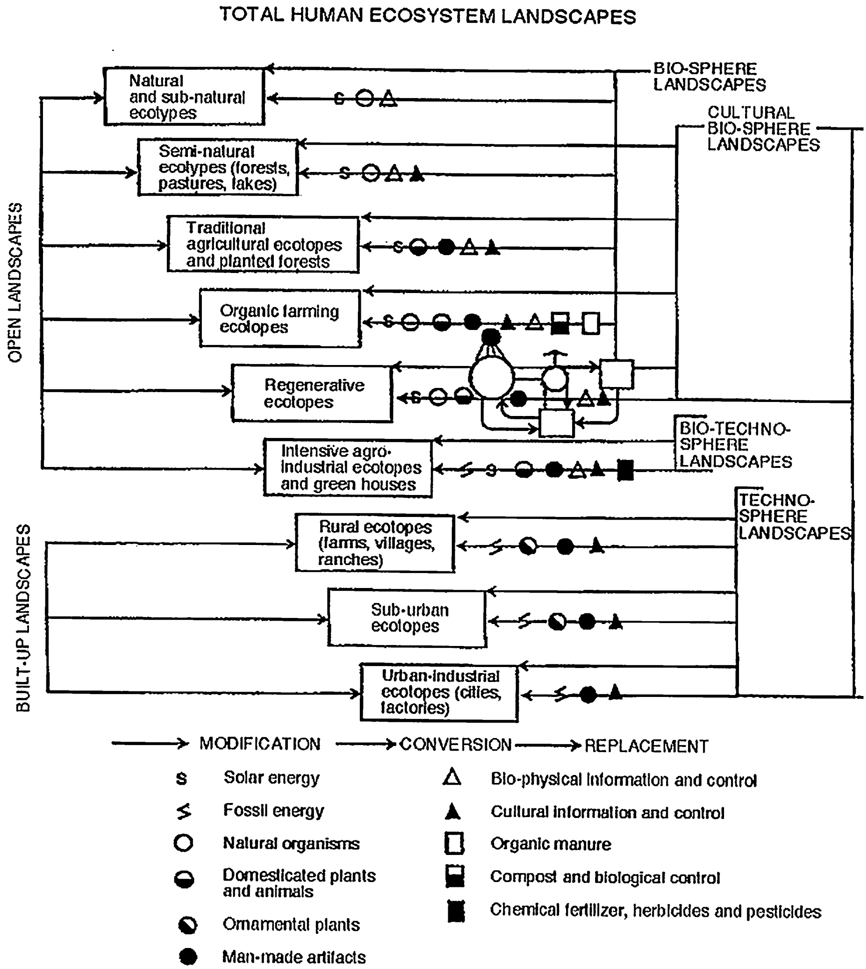

Figure 4. Mediterranean landscapes as perturbation dependent dissipative structures.

## A MULTIFUNCTIONAL CLASSIFICATION OF TOTAL HUMAN ECOSYSTEM LANDSCAPES INTO BIOSPHERE- TECHNOSPHERE- AND AGRO-INDUSTRIAL- LANDSCAPES

For the implementation of the THE landscape paradigm in practice, their classification according to their natural elements and land uses is not sufficient. Thus a new functional classification of natural and cultural biosphere landscapes and technosphere landscapes is urgently required. Its major point of departure should not be based on the degree of so-called "naturalness" of landscapes, but as a clear distinction between these above-mentioned major functional landscape classes and their basic multifunctional differences, according to the following parameters:

1. The different energy and material inputs, throughputs, and outputs
2. The differences in the kind and amount of regulation by natural or human information, as a result of these features
3. The above-described capacity of landscapes to organize themselves in a coherent way by maintaining their structural integrity in a process of continuous self-renewal. The latter determine their evolutionary regenerative capacities, had only by autopoietic natural and seminatural biosphere landscapes.

In addition, we have to take into consideration the two basic system types of internal self-organizing behavior, defined by Jantsch (1975) as follows:



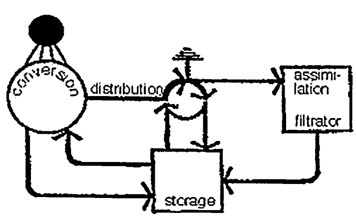




Figure 5. A functional classification of Biosphere and Technosphere landscapes, according to their energy and material flows, natural of cultural regulation and autopoietic capacities.

1. *Adaptive (or organismic) systems,* which adapt to changes in the environment through changes in their internal structure in accordance with pre-programmed information (genetic templates). This enables further biological evolution.
2. *Inventive (or human action) systems,* which change their structure through internal generation of information (invention) in accordance with their intentions to change the environment. Such information is generated within the system in feedback interactions with the environment. This enables further noospheric cultural evolution.

In Figure 5 all THE landscapes and their ecotopes are presented in a hierarchical model, ranging from the natural bio-ecotope pole to the cultural techno-ecotopes pole along a gradient of increasing degrees of modification, conversion, and replacement of natural elements, controls and functions by human-made, artificial ones. These are closely related with increasing throughputs of fossil energy and materials.

(1). *Natural and close-to-natural biosphere landscapes* contain only natural (meaning spontaneously evolving and reproducing) organisms. As adaptive self-organizing systems, natural, biological, physical and chemical information internally regulate these landscapes. Contrary to the "non-interference" climax paradigm, it is essential to ensure the undistorted continuation and/or re-introduction of all those natural ecological processes, maintaining their natural homeorhetic flow equilibrium and thereby also their biological diversity and productivity together with all other vital functions (Rickleffs et al., 1984), and hence their evolutionary future. Because of the overwhelming global human dominance, almost no truly undisturbed natural and very few close-to-natural, or sub-natural landscapes are left on earth, in the most inaccessible regions.

However even these are severely threatened both from external pressures, as well as from uncontrolled commercial exploitation of their biodiversity, agricultural encroachment, and poaching. Therefore the last and most precious and attractive protected nature refuges are losing their integrity by mass tourism, even if it is promoted as "eco-tourism." As described by de Palma (1996) for the famous World Heritage Site of the first Canadian park—the Banff National Park—this sad situation is typical for many other cases all over the world. The closely interwoven intrinsic functions and assets of bountiful natural beauty, as well as cultural and historical values are "sold off for making money": The multiple threats caused by the heavy tourist pressures, the suppression of natural fires, the building of roads to accommodate motorized traffic, the damming of rivers for a recreational lake and all other recreational and commercial developments, which disrupt the natural ecological and evolutionary processes and the normal cycles of wildlife, are destroying this unique touchstone of Canada's national identity. The prevention and reduction of these recreational over-development damages and the introduction of sounder and more sustainable management practices are essential for the future of these most valuable biosphere landscapes.

All other human modified and converted landscapes are controlled to lesser or greater degrees by cultural information. they should be considered therefore as *cultural landscapes*. These have to be subdivided further into three major classes and subclasses.

(2). The first major class consists of *Cultural biosphere landscapes.* Like natural landscapes these are all *solar-powered*. However, they are controlled by different degrees of both natural and human information, and are functioning therefore as a *mixture of internal organismic-adaptive and human-intervention self-organizing systems*. Also these landscapes are functioning as open, dynamic self-organizing systems, which are far from equilibrium. This enables the spontaneous emergence of new order, creating new structures and new forms of behavior.

(2.1). *Human modified and used semi-natural ecotopes*, such as forests, woodlands, grasslands, wetlands, and lakes, in which biological productivity and diversity are based, as in natural landscapes, on spontaneously reproducing organisms. Their productivity is used at least partly for "hard values" as marketable goods for human consumption, such as wood, fiber, forage, and fishes.

But at the same time these *multifunctional landscapes* are important life supporting and improving systems. As such they not only fulfill vital instrumental production, regulation, protection and carrier functions, but, like natural and subnatural landscapes, their ecotopes have also intrinsic "soft" spiritual, aesthetic, scientific and other cultural values. Their multifunctionality has therefore both tangible physical geospheric-biospheric and intangible mental noospheric dimensions (Naveh, 2001). This has been forcefully expressed also by Joan Nassauer (1997), a leading American landscape ecologist and landscape planner.

More recently ecological economists have suggested that to ensure their sustainable use, their "natural capital," should be presented as a counterpart to the classical "economic capital." In the conventional economic sense "capital" is accumulated by the production of marketable goods, and is evaluated by monetary values. However, there is a danger that if the conservation of this natural capital and its monetary, utilitarian values will become the only justification for conservation management and sustainable development, the other, intangible dimensions and "soft" functions and values will be neglected. Such monetary evaluations are highly doubtful, even for the loss of the most vital "natural capital" namely soil, clean air and fresh water, and they are impossible for such vital life support functions such as the aesthetic and the psycho-hygienic and therapeutic function of these biosphere landscapes. We can even assume that their value in the information society will be of greater importance than in the industrial society. Therefore they should become critical issues in the land use decision-making process.

Of greatest relevance in this context are the findings by the influential American environmental psychologist Stephen Kaplan (1995), on "*the restorative experience of nature*" against the many stresses of modern life. Of special significance in this respect for the information society is the restorative function of these landscapes after "*direct attention fatigue*" caused by continued and intensive mental work, such as performed by High-Tech workers spending many hours in creative work behind the computer.

The emerging transdisciplinary science of ecopsychology is opening new vistas for the recognition of our deeply ingrained and mostly unconscious relations to nature, as presented in all biosphere landscapes. These have been entirely overlooked in modern psychiatry as a typical modern urban-industrial science. But fortunately, now more attention is devoted to these psychotherapeutic biosphere landscape functions, especially by the emergence of the science of ecopsychology.

This has been forcefully expressed by Theodore Roszak (1995; page 5), the eminent American historian in his introduction chapter to the first anthology on ecopsychology:

> The understanding of human sanity has always stopped at the city limits" . . . "But now are signs that this is beginning to change and a new generation of psychotherapists is seeking ways in which professional psychology can play a role in the environmental crisis of our time.". . . "Unlike other mainstreams schools of psychology that limit themselves to the intrapsychic mechanisms or to a narrow social range, ecopsychology proceeds from the assumption that its deepest level of psyche remains sympathetically bonded to the Earth that mothered us into existence.

For all those committed to the conservation of biosphere landscapes it will be very important to join forces with ecopsychologists, because they can help to reach a better understanding of the deep environmental bond between human beings and the natural environment, during which we evolved and lived for millions of years. In this long period the industrial age was just a split second. But this short span of time was sufficient for the almost total urban alienation from nature and from turning so many of us into compulsive consumers. Ecopsychologists could eventually help society to find ways to overcome this modern syndrome of addiction.

Roszak (1994) has also rightly pointed out to the dangers of "the cult of information," as the most recent expression of "technophilia"—our love affair with machines. In facing the rapidly advancing computer technologies, we should be aware of the danger that, instead of dealing with real three-dimensional, healthy landscapes on which the future of life on Earth depends, the information society will be satisfied with virtual landscapes and the plastic Disney land "nature." In this respect, the comments by Robert Thayer (1994, page 100) in his important book on technology, nature and the sustainable landscapes, is of great relevance:

> Approaching sustainability will require us to alter radically the various entrenched meanings implicit in our lives, technologies, and landscapes. Just as the need for fundamental change is being felt ever more acutely, an exponential increase is occurring in the ability of information technologies to gloss over real environmental problems and create a landscape fantasy so vivid it threatens to replace reality altogether. Sustainability, I believe, springs not only from guilt associated with technology's physical impact on nature, but also from the growing tendency of technology to replace nature in our minds as well.

By far the greatest majority of all these semi-natural bio-ecotopes are presently undergoing accelerated biological and cultural impoverishment. Therefore the conservation and restoration of their ecodiversity and its resulting biological, ecological and cultural functions, is of no lesser importance than that of the biodiversity of natural and close-to-natural bio-ecotopes. For this purpose, their dynamic multifunctional conservation and restoration management should ensure their homeorhetic flow equilibrium. It can be maintained by those natural as well as cultural ecological processes which have been introduced by human land uses throughout their evolutionary history, such as grazing, cutting, prescribed burning and traditional agricultural practices (Rickleffs et al., 1984; Naveh, 1991, 1994a; Naveh and Lieberman, 1994).

In order to be able to implement such strategies, landscape ecologists, together with all other scientists and professionals involved in this challenge, have to learn as much as possible about the early land-use history not only from a biological-ecological point of view, but also from an ethno-historical and anthropological-cultural perspective. Because of the important role of fire in shaping most semi-natural landscapes, they have to become well versed in fire ecology and its application in different patterns and scales of heterogeneous natural and rural landscapes.

(2.2) *Traditional and agro-silvo-pastoral ecotopes* such as meadows, planted forest groves and traditionally cultivated fields and orchards, in which domesticated plants and animals have replaced their natural competitors and their solar-energy driven biological production is channeled into economic goods with no or very low inputs of chemical fertilizers and pesticides. Although human–controlled and maintained, these bio-ecotopes have retained still a certain amount of their self-organizing capacities and they fulfill important functions for the preservation of biological and cultural ecodiversity in the rural landscape. According to Bignal and McCracken (1996), occur more that 50% of the most valued biotopes and in these "low-intensity farmlands" and most efforts should be devoted to the prevention of their loss. However, in the process of urbanization they are undergoing intensification or being abandoned or converted into commercial monospecies conifer or eucalyptus forests. Thereby they are losing both their biological and cultural diversity and scenic attractiveness, that is deeply embedded in their structural and functional heterogeneity as their *total landscape ecodiversity*. This of no lesser importance than that of the biodiversity of natural and close-to-natural and semi-natural bio-ecotopes and should be conserved and restored (Naveh, 1994, 1998; Farina, 2000).

However, these landscapes can be rescued only if the local populations and their governments are willing to recognize them as valuable cultural heritage landscapes. For this purpose they have to invest sufficient means and manpower to conserve worthwhile examples by restoring and maintaining these traditional farming practices and their typical local crop strains and animal breeds, and thereby also their great genetic value.

To these cultural biosphere landscapes belong also two new and most promising sustainable agricultural systems and their ecotopes, namely:

(2.3). *Organic farming ecotopes, cultivated without inputs of chemical fertilizers, herbicides and pesticides*. Thanks to the application of suitable agro-technological methods, higher crop diversity and their rotation, and the building up of high soil fertility through the use of organic manure and compost, their productivity is much higher than that of traditional farming. It comes now close to that of high-input agro-industrial farming systems, but without the detrimental environmental effects caused by chemical fertilizers, herbicides and pesticides (Mansvelt and Mulder, 1993).

On one hand there is a steady proliferation of these chemicals, including those that can interfere with human and animal endocrine systems, but on the other, there are also encouraging signs of a rapidly increasing demand for healthier products, and their sales are growing by 20% a year. Farmers in Europe have doubled the area cultivated with organic methods to 4 million hectares in only three years and in Italy and Austria the share of certified organic products topped 10 percent in 1999 and are now reaching 20 percent and more. The studies by Mansvelt and van Luppe (1999) and by Tress (2000) are fine examples of the important role that landscape ecologists can play in reshaping the European agricultural landscapes in the direction of more sustainable, healthy, and attractive organic farming ecotopes.

(2.4). *Regenerative ecotopes* are the result of an even more advanced version of organic farming, in which not only the natural regenerative capacity of cultivated land is restored, but also the basic cyclic flows of energy, water and nutrients of natural biosphere landscapes, based on the inputs of solar radiation. At the same time,their biological production is channeled partly into agricultural production for human uses. Such regenerative farming systems are driven entirely by solar energy and other regenerative non-polluting energy sources. One of the most outstanding examples is realized at the Center for Regenerative Studies at the California Polytechnical State University at Pomona in a combined inter- and transdisciplinary teaching, research and demonstration project in regenerative technologies. As has been described lucidly by its chief designer (Lyle, 1994), here the natural biosphere functions of energy/material conversion, distribution, filtration, assimilation, storage are utilized for intensive agricultural production with the help of human-inventive "neotechnological" information. They provide thereby for continued replacement through their own functional processes of the energy, material and information used in their operation. The symbol for regenerative farming systems in Figure 5 stems from Lyle (1994) and will be shown in more detail in the next figure.

(3). *Intensive agro-industrial ecotopes* are an intermediate class between bio- and -technosphere landscapes that have replaced almost all other, low-input cultivated agro-ecotopes in industrial countries. Although regarded in general as "green landscapes," they should not be confused with all above mentioned, sustainable biosphere landscape. Driven by a shortsighted, over-consumptive and socially unjust market economy, they are spreading now also in many developing countries. Like in bio-ecotopes, their productivity is dependent on photosynthetic conversion of high-grade solar energy. But this energy is subsidized to a great extent by low-grade fossil energy, and the natural biological control mechanisms have been replaced almost entirely by agro-technological information, aiming at maximum production through heavy chemical inputs of fertilizers, pesticides and herbicides. Therefore, these landscapes have lost all self-organizing and regenerative properties. In this respect, and in their detrimental environmental impacts on the open landscape, its wildlife and biodiversity, and on the quality of its natural resources of soil and water, as well as on human health, they come very close to technosphere landscapes, and like these, they are "*Throughput Systems*."

The efforts to minimize these adverse impacts by slow-releasing fertilizers and integrative pest control are only palliative measures which cannot ensure in the long run a sustainable future for our agricultural landscapes and healthy food production. As stated rightly by Lyle (1994), sustainability can only be achieved by replacing these linear technosphere processes of high input and throughput flows with cyclical flows at sources, consumption centers, and sinks, as attempted in regenerative systems. Even in those countries, in which the highest agricultural production of crops and livestock has been achieved, this type of high-input and throughput of agriculture production is not only ecologically unsustainable, it also cannot be sustained economically without heavy governmental subsidies. Therefore, the time is ripe to realize that the future of sustainable, profitable and healthy agricultural production will depend on the restoration of the fertility and regeneration capacities of cultivated land by organic and especially by regenerative ecotopes. This should be the aim for all future-oriented land and land use research and education.

The major functional brake in cultural landscapes is in their difference in solar or fossil energy inputs:

(4). *Technosphere landscapes and their ecotopes* as well as their technological artifacts such as highways, bridges, mines, quarries and power lines are artificial, human-made and are maintained chiefly by fossil and nuclear energy and their technological conversion into low-grade energy and materials. They lack the multifunctionality and self-organizing and regenerative capacities of biosphere landscapes and are regulated solely by cultural information of the internal self-organization systems behavior of human inventive actions. This results in high outputs of entropy, waste and pollution with far-reaching detrimental impacts on the remaining open landscapes and their biological productivity and ecological diversity and stability and human health. Their subclasses differ in these detrimental environmental impacts, but these differences are vanishing rapidly in the process of urbanization.

(4.1). *Rural ecotopes*, such as farms, ranches, villages, are closely interwoven with the cultural semi-natural and agricultural landscapes. In Europe and all other industrialized countries they are undergoing a rapid transformation into the other techno-ecotopes. As has been shown by successful examples in Great Britain by Green (1995), and also elsewhere by Lucas (1992) this can be prevented at least partly by sound countryside planning and management in which landscape ecologists are actively involved.

(4.2). *Sub-urban ecotopes* can still contain larger biosphere islands, such as lakes, riverbeds, parks and forest groves. These can contribute much to the improvement of the quality of city life and, like rural landscapes, they are therefore of great value. This is also true of recent tendencies to establish low-maintenance gardens, based chiefly on indigenous plants, provided that these gardens are maintained without inputs of chemical fertilizers, herbicides and pesticides.

(4.3). *Urban-industrial ecotopes* are the fastest-growing, fuel-powered technosphere landscapes, with the most pronounced adverse environmental impacts. This is indicated by the huge amount of energy that flows annually through western urban-industrialized centers such as New York or Tokyo. They can be measured in millions of kcal per square meters, as compared to only thousands of kcal in solar-powered biosphere landscapes. Fischer-Kowalski and Haberl (1997) have shown that in the transfer from a traditional, chiefly agrarian society into the modern fossil-powered urban industrial society, the social metabolism, as measured by the energy input in GJ/capita/year in Austria, has risen from about 65 to 223 GJ, and that of material input, measured in t/capita/year, from about 4 to 21.5 t. These figures are a very good index for the quantitative measurement of the impact of the technosphere on our THE biosphere landscapes and on the destabilizing of the geosphere and atmosphere. They show clearly the energetic differences between the regenerative natural and cultural biosphere landscapes and the throughput agro- and urban-industrial technosphere landscape systems. As illustrated in Figure 6, this results in high outputs of entropy, waste and pollution with far-reaching detrimental impacts on the remaining open landscapes and their biological productivity and ecological diversity and stability, as well as on human health.

Rees (1995), applied an innovative index of "*Ecological Footprints*" as the total area of productive land and water required to produce all the resources required

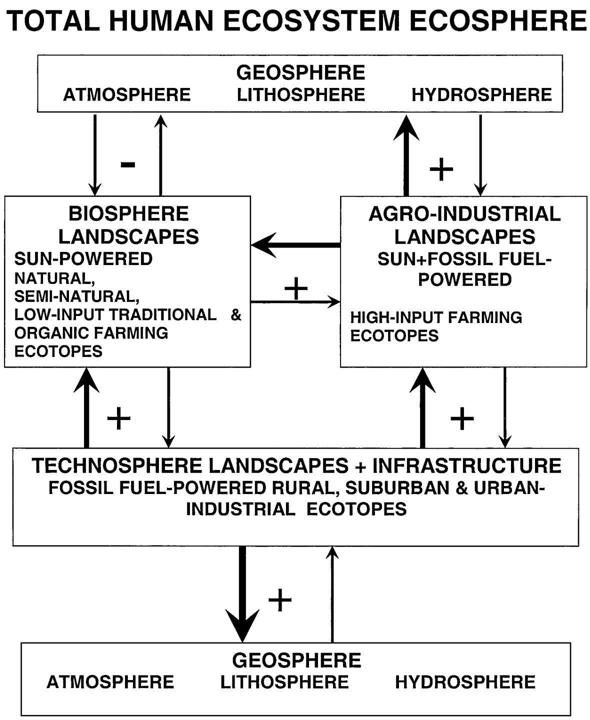



Figure 6. The disorganized Total Landscape of the industrial Total Human Ecosystem–Ecosphere, and its destabilization by the Technosphere.

by the population of city or a region and to assimilate all its waste produced. He found that in 1991 the population of the city of Vancouver used the productive output of a land area nearly 200 times larger than its political area to maintain its consumer lifestyle.

The improvement of rural and urban life quality is closely coupled with the reduction of these huge throughputs and outputs. This will require far-reaching functional and structural changes in the "metabolism" of the cities and their design, as part of the sustainability revolution, in which landscape ecologists should take an active part. According to UN projections, by 2025 60% of the world's 8.3 billion global citizens will be living in towns and cities and presently half of the world's poorest people, or some 420 million are living in urban settlements and chiefly in "megacities." This "urbanization syndrome" represents clearly one of the most important social, political and ecological challenges for the sustainable future of our Total Human Ecosystem and its landscapes.

The internal self-organizing behavior of technosphere landscapes is dependent entirely on our human inventive actions, driven by our consciousness as a feedback reaction on the information gained from the environment. Therefore there is hope that human society will change these threatening trends before local and global ecological catastrophes will force us to do so. It is up to landscape ecologists and planners to accept this challenge. They have to prove to the decision-makers and the people at large that the creation of biosphere oases in the biological deserts of our cities is by far the cheapest and most efficient way for over-all urban environmental improvement. It does not require fossil energy like all man-made engineering devices and therefore does not add any further burdens of waste, pollution and entropy on the urban landscapes. But is has also much more far-reaching effects: It reduces the soul and body crippling threats of urban stresses and draws the estranged city dwellers closer to a new I-Thou dialogue with nature. It brings thereby a richer dimension to his life, which cannot be measured by dollars or Yen values and material goods, but it will pay high dividend in non-economic richness and urban life-quality.

## CONCLUSIONS: THE NEED FOR A POST-INDUSTRIAL SYMBIOSIS BETWEEN HUMAN SOCIETY AND NATURE

Although all these bio-agro- and techno-ecotopes are spatially interlaced into larger regional landscape mosaics, they are antagonistically related because of these overwhelming adverse and destabilizing impacts of the techno- and agro-industrial landscapes and their entropic and wasteful fossil-powered throughput metabolism. They form a disorganized conglomerate that the German landscape historian Sieferle (1997) has called "The Total Landscape." This industrial Total Landscape will be able to function as a coherent, sustainable THE ecosphere landscape only after these antagonistic relations between the biosphere and the technosphere have been reconciled through the creation of an urgently needed post-industrial cultural symbiosis between human society and nature. Such a symbiotic relation should lead, above all, to the structural and functional integration of bio- and techno-sphere ecotopes into a coherent, sustainable ecosphere, in which both biological and cultural evolution can be ensured.

As illustrated in a simplified cybernetic model of the Total Human Ecosystem ecosphere. (Figure 6), with exception of the stabilizing negative feedback couplings, maintaining a dynamic flow equilibrium between the biosphere landscapes and the geosphere, all other interactions are ruled by destabilizing positive feedback loops. Because of the rapidly vanishing intact biosphere landscapes and these overwhelming decoupling effects of the technosphere landscapes, the "Gaia hypothesis "(Margulis and Lovelock, 1974), regarding the biosphere together with the atmosphere as a global co-evolutionary self-regulating and self-renewing system, may loose gradually its validity, endangering thereby the future of life on Earth.

A first essential step towards this symbiosis will be the establishment of new, better balanced, complementary relations between healthy, livable and attractive technosphere landscapes and its "hinterland" of vital, attractive and productive biosphere landscapes. This can be achieved through comprehensive landscape planning, conservation, restoration, and design, together with environmental management for sustainable development towards information society.

One of the most important stabilizing feedback couplings is the function of biosphere landscapes as a biological filter and living sponge, absorbing the emissions from the technosphere, including the greenhouse gases and carbon dioxide. At the UN Marrakech meeting on November 7, 2001, some pf the major findings of a cluster of eight research EU sponsored projects on the carbon cycle, called "Carbon Europe," were summarized as follows:

1. The European biosphere is a carbon sink that can absorb about 20–30% of the annual European carbon emissions.
2. The European biosphere has additional potential to absorb carbon emissions through forestation projects and improved management methods. This is an important message, since sinks can be used in part to fulfill the reduction commitments as laid down in the Kyoto protocol.

However, on global scales this symbiosis can be realized only as part of an all-embracing cultural and technological sustainability revolution, initiated by the transition from the "fossil age" to the "solar age" of the new economy, based on the limitless power of the sun as the non-polluting and renewable energy source. In one year the sun provides 15,000 time more energy than that of the total annual consumption of fossil and nuclear energies, and the annual photosynthetic output of the world's vegetation is 10,000 greater than the chemical industry's annual global output. According to reputable studies, such as those conducted by the British Shell concern—which is investing already many millions of dollars in preparation of the emerging shift towards solar energy—by 2050 half of the world's energy needs will be supplied from these renewable sources (Scheer, 2000).

As envisaged by Laszlo (1994), this cultural evolutionary process will guide the bifurcation on the leap towards a higher organizational level of the emerging sustainable information society. But it will be driven not only by the widespread adoption of technological innovations of regenerative and recycling methods and the efficient utilization of solar and other non-polluting and renewable sources of energy: It must to be coupled with more sustainable lifestyles and consumption patterns, caring for nature and even investing in nature.

The former president of the Club of Rome, Ricardo Diez Hochleitner (1999) has expressed these demands in his optimistic vision for the future of the information society as follows: "Humanity's future will only be secured when we are more careful with nature and we shape our interaction with it in a more sustainable way. This will require not only doing everything to increase efficiency of how we use resources; it also implies sustainable lifestyles which will entail giving something up."

An important step to achieve these goals in regional sustainable development will be the replacement of the ruling neo-classical market-economy incentives for quantitative growth, by a more far-reaching and more just integrated socio-ecological approach, based on the Total Human Ecosystem paradigm. This development should be aimed chiefly towards qualitative growth by fostering positive synergies between people, their economy and their open and built-up landscapes.

Thanks to the above-described, recent insights in self-organization of autopoietic systems and their cross-catalytic networks, 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 sustainable development.

In Figure 7, the major auto- and cross-catalytic cycles and cybernetic feedback loops of our Total Human Ecosystem are presented. In biosphere landscapes, the

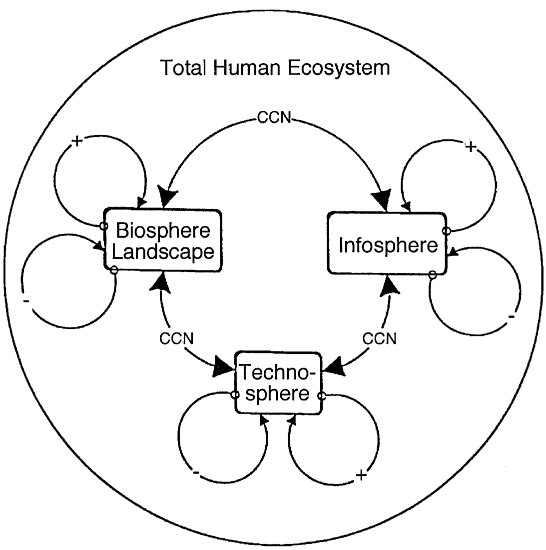



Figure 7. Major auto- and cross—catalytic cycles and feedback loops in the emerging information society of out Total Human Ecosystem.

negative self-stabilizing loops are indicated by a minus sign, and the positive autocatylitic loops symbolizing also autopoiesis and evolution are indicated by a plus sign. The letters CNN in both directions of the arrows indicate the potentials for mutually supporting and amplifying relationships through cross-catalytic networks. However in contrast to the biosphere landscapes, in technosphere landscapes, the plus signs symbolize the "run-away," destabilizing feedbacks of exponential expansion, which can be restrained only by cultural negative feedbacks of sustainable planning and environmental management. These are channeled via the information sphere as the noospheric cultural information pool playing a rapidly growing role in the emerging information society.

This conceptual THE model has been applied in a recently completed interdisciplinary and multinational project EU project on "Modeling Sustainable Regional Development in the European Information Society" (EU-Project "MOSES" (2000), carried out under the leadership of Wolf Grossmann in 5 regional case studies. With the help of dynamic systems simulation models, combining a recursive systems-dynamic simulation model with cross–catalytic networks (ISIS) and other innovative methods and tools we could show that we are able to create new cultural, information-rich cross-catalytic and synergistic feedback loops in the emerging information society. In this model we attempted to link natural, ecological, socio-cultural and economic processes of our Total Human Ecosystem, and to create the scientific basis for new cross-catalytic and synergistic feedback loops. These should reduce the destabilizing effects and help to ensure lasting mutually reinforcing—that means synergistic—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.

The project coordinators W. D. Grossmann, M. Lintl, and H. Kasperidus prepared a very simplified version of the basic structure of this complex holistic model. It is presented in Figure 8.

This model revealed mutual supportive cross-catalytic network relations in the dynamics of the emerging information society, initiated by the development of younger companies, their innovators and key people, which are comparable to the autopoietic dynamics driving ecological systems and natural and semi-natural biosphere landscapes.

With the help of this model we could further show that the contribution of nature to regional attractiveness is crucial for regional upswing. Thereby the citizens will gain from nature, namely the "soft" intangible and intrinsic values, and the "hard" and marketable values of the regional green" biosphere landscapes.

The model resembles a CCN, because both partners are capable of autocatalytic growth but because of the unbalanced relationship between the biosphere landscapes, and the technosphere landscapes, only the regional economy gains from nature, increasing its attractiveness. At the same time the destructive feedback of the regional economy is increasing because of unrestricted growth and unsustainable development. This is shown in Figure 9.

Our study showed that the new successful economy could create the missing vital symbiotic CCN link of a "double G"—"give and gain" symbiotic relation by

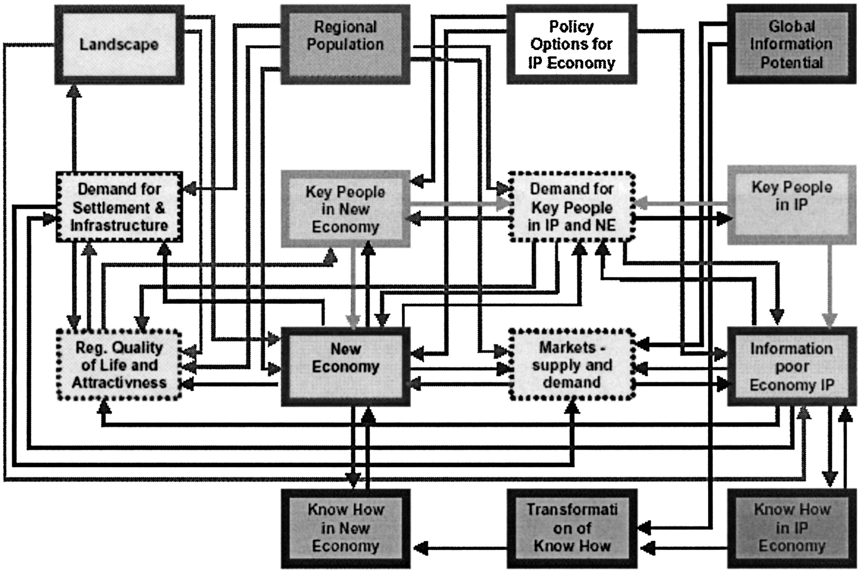



Figure 8. Overview of the structure of the Information Society Integrated ISIS Model (Prepared by W. D. Grossmann, M. Lintl, and H. Kasperidus, for E-U Project Moses 2000).

"investing in Nature" through paying an adequate fixed share of the tax income dedicated to the conservation and restoration and the sustainable design and management of attractive biosphere landscapes. The new link could even allow to purchase and restore more land that becomes available because of the lower

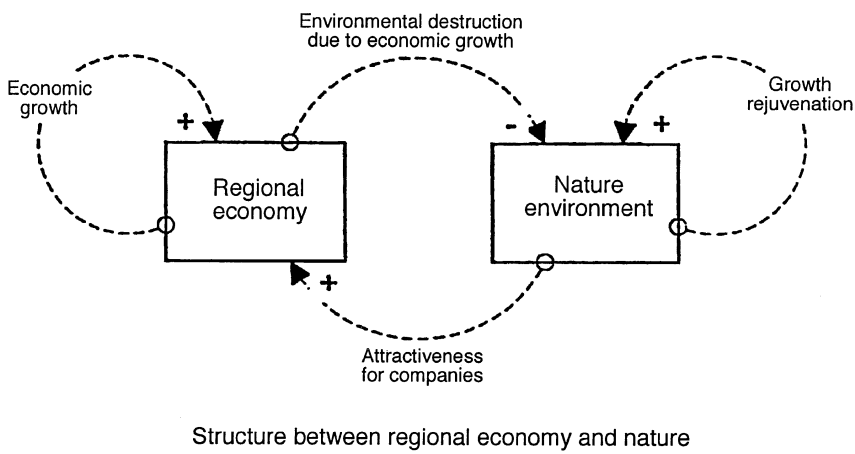



Figure 9. The unbalanced relationship between the regional economy and nature in the industrial society, leading to its destruction.

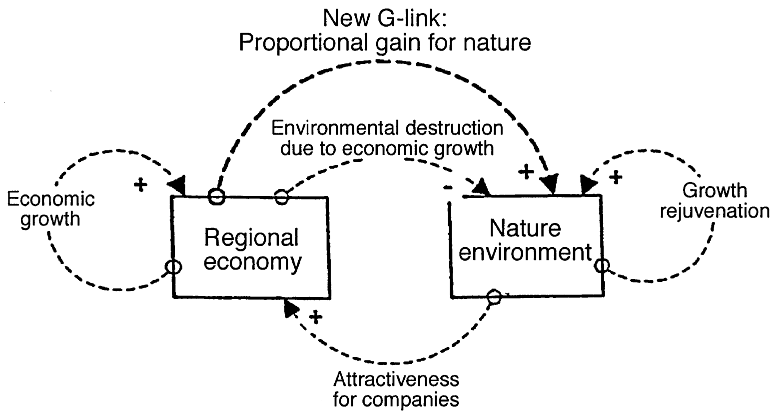



Figure 10. The conversion of the human-nature systems in the information society into synergistic CCN relations by the creation of symbiotic Double G link of "give and gain" (Grossmann and Naveh, 2000).

demands and negative impacts by human activities of the post-industrial technosphere of the information society (Figure 10).

If such symbiotic relations could be realized in actual sustainable development projects, they will constitute an important step towards the environmental sustainability revolution.

That this is not an utopian dream can be learned from the encouraging examples provided—in addition to many others—in the 1999 *State of the World report* (Brown et al., 1999) indicating the beginning of such an environmental sustainability revolution. To contribute jointly with scientists from other relevant disciplines to these developments should become one of the greatest challenges for future-oriented landscape ecologists. Guided by the holistic worldview and its practical implications they could eventually provide leadership not only as educators, researchers and professional experts, but also as integrators in transdisciplinary teamwork for sustainable development.

In concluding, our hope for a sustainable future for our biosphere landscapes of our post-industrial Total Human Ecosystem as a whole, has been expressed lucidly by Laszlo (2000, page 114) in the final sentences of his "Macroshift 2000-2010" book:

> 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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