THE EVOLUTION OF THE CULTURAL MEDITERRANEAN LANDSCAPE IN ISRAEL AS AFFECTED BY FIRE, GRAZING, AND HUMAN ACTIVITIES

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Abstract: The early evolution of the cultural Mediterranean landscape in Israel, with special reference to Mt. Carmel, is described with a holistic landscape-ecological systems approach as the coevolution of the paleolithic food gatherer-hunter and his landscapes. In addition to archeological findings and our research on fire ecology and the comparative dynamics of Mediterranean landscapes in Israel and California, we made use of new insights into the self-organization of living systems and landscapes and the theory of nonlinear general evolution. From the Middle Pleistocene onward, this process occurred in two major bifurcations; one in which the pristine forest landscape was converted by human land uses and by natural and intentional set fires into a more open subnatural landscape, and then from the Upper Pleistocene onward into a grass-rich, seminatural, landscape mosaic. The final stage of this coevolution was reached more than 10,000 years ago by the advanced epipaleolithic, pre-agricultural Natufians, whose rich culture and intensive land use have a striking resemblance with those of the pre-European central coastal California Indians. During the third major bifurcation of the Neolithic agricultural revolution, arable seminatural landscapes were converted into agropastoral ones. The coevolutionary symbiotic relationship was replaced by human dominance leading to intensive land uses including burning and grazing. This period is missing from Californian landscapes, 'jumping' almost directly into the agro-industrial age and, therefore, apparently also lacking the great regeneration capacities and adaptive resilience acquired by Mediterranean landscapes.

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1. INTRODUCTION

No bioclimatic region in the world other than the Mediterranean region has endured so long and intensive a period of human-induced perturbations. Nor has any other bioclimatic region suffered so much from the unfortunate combination of a fragile environment and a long history of land abuse and negligence with adverse effects on the land and its people. However, at the same time, no other region has shown, in a more striking way, the resilience and the soil-building capacities of the native vegetation, than the denuded Mediterranean uplands. Probably nowhere else has it been more demonstrated that the people of this region have the power not only to destroy their habitat and deplete their flora and fauna, but they are also able to reclaim them with sufficient motivation and skill, utilizing their biological productivity and preserving their organic and cultural variety (Naveh and Lieberman, 1994; Naveh, 1998a).

Grove and Rackham (2001) rightly stated in their comprehensive and lucid account of the ecological history of European Mediterranean landscapes that the pervasive “ruined landscape theory” in the Mediterranean is far too simplistic and should not be taken literally. It is supportive of this theory that in his review of the environmental history of the Mediterranean mountains, Mc Neill (1992) has called these “skeleton landscapes” in which there is no return from their present human-caused degradation.

Grove and Rackham (2001) have also refuted the deterministic, preconceived theory of a Mediterranean forest “climax”, which is automatically degraded by human interference into lower-woody successional stages of maquis, garrigue and batha (or phrygana) and finally into steppe grassland. This follows along the lines of our findings on the dynamics of Mediterranean landscapes in Israel (Naveh, 1971; Naveh and Kutiel, 1990) and in the Mediterranean region in general (Naveh, 1991; Naveh and Lieberman, 1994).

Blondel and Aronson (1999) have attempted to deal with humans as “sculptures of Mediterranean landscapes”. They accepted our thesis, by showing many examples of how the long human occupation in the Mediterranean basin had profound consequences on the distribution and dynamics of many organisms and on the current biodiversity. Their report on the results of recent studies showing that organisms may evolve life history traits as a response to human induced habitat changes corroborates our claim on the evolutionary significance of long-term human perturbations. These may have important fitness consequences and can evolve even within few generations if they are submitted to strong selection pressures both by natural and human-induced forces of intensive vegetation management and land uses.

For these issues the Mediterranean landscapes of Israel - and especially those of Mt. Carmel on which we will focus most of our attention - can serve a most suitable example. Here, we have ample archeological evidence of human habitations from the Middle Pleistocene onward. As part of the southern Levant and the “Fertile Crescent” Israel was also one of the first locations for the transition from food collection to food production, marking the beginning of the domestication of plants and animals and the creation of permanent farming communities and settlements during the so-called Neolithic agricultural revolution. As one of the older and better-known human cultural centers, it served also as the cradle for the monotheistic Judeo-Christian religions and Western civilization. Human imprints on the land can be traced back in Israel for longer periods than in any other Mediterranean country.

However, contrary to Blondel and Aronson (1999) mentioning only the evolutionary impact of livestock grazing and burning in the last 10 millennia by pastoralists and agriculturists, we claim that humans started to “sculpture” these landscapes much earlier. They even coevolved together with them, during their biological and cultural evolution in the Pleistocene and together with geological, climatic, and other natural forces and stresses, and especially those caused by fire and foraging of wild herbivores. They converted them gradually from pristine natural landscapes into subnatural, seminatural, agricultural, and rural cultural landscapes. The ensuing closely interwoven natural and cultural processes and patterns contributed much to the great ecological heterogeneity, biological diversity and adaptive resilience of the still remaining nonarable Mediterranean uplands.

As outlined in earlier publications on this subject (Naveh, 1984, 1990; Naveh and Vernet, 1991), we will not restrict ourselves only to those evolutionary and ecological perspectives for which sufficient archeological and geomorphologic evidence is available in the narrow conventional sense of these sciences. Therefore, we will not treat probable ancient human impacts as linear, one-directional cause-effects of human disturbances, but as nonlinear and partly chaotic mutual-causal and reciprocal processes of the coevolution of Mediterranean people and their landscapes.

To support our contentions on the evolutionary significance of the history of human habitation and land use we will refer to the ethno-ecological equivalence in the use of fire for vegetation management by the pre-agricultural Coastal Californian Indians comparable conditions to those of the pre-agricultural Epipaleolithic Natufians of Mt. Carmel. We will also provide indications for the higher resilience and regeneration capacities of the Mediterranean vegetation as compared with its Californian counterparts supporting our claim on the lack of evolutionary convergence between both countries because of the great discrepancies in the duration and intensity of these human impacts.

2. SOME MAJOR THEORETICAL PREMISES

The holistic and transdisciplinary approach to landscape evolution, on which this essay is based, can be fully comprehended only within the broader context of the present post-modern “scientific revolution”. The famous science historian, Kuhn (1970), first coined this term. It takes place when the existing theories no longer adequately explain reality and new paradigms of conceptional schemes have to gradually replace those conventional and well-established paradigms of so-called “normal science”. This holistic and transdisciplinary scientific revolution occurred in the last part of the 20th century with the scientific paradigm shift from reductionistic and mechanistic approaches to more holistic and organismic ones. Replacing reliance on exclusively linear and deterministic processes by nonlinear, cybernetic and chaotic processes, this scientific revolution is based on systems thinking of complexity, networks and hierarchic order. It stems from a belief in the objectivity and certainty of the scientific truth towards the recognition of the limits of human knowledge, the need for a contextual view of reality and the need for dealing with uncertainties. It causes the turning away from breaking down, analyzing, and fragmenting wholes into smaller and smaller particles toward wholeness, connectedness, integration, synthesis, and complementarity of ordered complexity, and from mono- and multidisciplinarity to inter- and transdisciplinarity. This scientific revolution is offering a unified worldview that seeks to do justice not only to the physical, biological and the socio-economical, but also to the mental, cultural, and spiritual reality in which we live. It is also leading to profound postmodern cultural transformation, changing many of the ideas dominating Western society since the industrial revolution, and in science and technology - its education, economy, and culture at large.

As described in detail by Naveh and Lieberman (1994) and more recently by Naveh (2000, 2003) and by Carmel and Naveh (2002), we attempted to provide an overarching conceptional framework for a transdisciplinary conception of landscape ecology and its theoretical and practical implications. These concepts are rooted in the General Systems Theory and its recent insights in complex systems and their dynamic self-organization and coevolution in nature and in human societies, enriched by nonequilibrium thermodynamics and chaos theory. Li (2000) has illustrated this holistic landscape paradigm in a more formal way with the help of the mathematical set theory and nonequilibrium thermodynamics. Here, we briefly outline only its most relevant premises.

2.1 A holistic view of landscapes and nature-human relations - the total human landscape of our total human ecosystem

This view implies above all, a paradigm shift from perceiving landscapes as nothing more 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. For studying landscapes in their totality as Gestalt systems, they have to be regarded as a **whole that is more than the sum of its parts.**

As a result, the information about the whole landscape is larger than the sum that can be derived in a mechanistic way from its parts. Therefore the state of the whole must be known to understand the collective parts. This means that from all the natural geophysical, bio-ecological, and cultural landscape components and all other human-made artifacts from its forests, grass- and shrublands, wetlands and rivers, agricultural fields, and from its residential and industrial areas, these patterns and processes contribute to the integral and truly realistic character of each local, regional, and global landscape.

From a hierarchical point of view, all these natural and cultural dimensions are intrinsically related to each other by the general state of the whole and its emergent qualities. The different landscape units and types are closely interlaced into a multilayered, stratified hierarchy of Janus-faced entities or "*holons*" senso Koestler (1968), being both parts of their higher-level supersystem and wholes with regard to their lower-level subsystems. Therefore, instead of a puzzle of separate particles forming a mosaic **in landscapes, we deal with a hierarchically structured interacting network at different multiple nested scales of our global "*Total Human Landscape*"** (THL). Together with increasing spatial, temporal and perceptional scales the complexity of patterns, processes and their resulting functions are increasing. Therefore, a better comprehension of the underlying ecological, historical, and cultural dynamics of representatives of THL is necessary. As will be shown below, this is true also for our prehistorian human influenced, modified, and converted THL.

This holistic landscape conception has to be complemented by a broader holistic view of the role of humans in nature as **integral parts of nature, forming a complex socio-ecological entity with their total environment.** This is the **Total Human Ecosystem** (THE), integrating humans and their total environment at the highest level of the global ecological hierarchy **above** the ecosystem level (Egler, 1964). Landscapes are **the concrete, space/time defined ordered wholes and Gestalt systems of our THE, along different functional, spatial, and perceptional dimensions** providing the spatial and functional matrix for all living organisms, their populations, communities, and ecosystems. Their spatial scales range from the smallest mappable landscape cell or ***ecotope*** to the ***ecosphere*** as the largest, global Total Human Landscape.

Whereas the natural landscape elements have evolved and are operating as part of the geosphere and biosphere, their cultural artifacts are a creation of the **noosphere** (from the Greek *noos* = mind). As described lucidly by the great systems thinker and planner, Erwin Jantsch (1980), the noosphere is an additional natural envelope of life in its totality that *Homo sapiens* have acquired throughout the evolution of his neocortex. It is "our mental space" and the domains of our perceptions, knowledge, feeling, volition, and consciousness enabling our self–awareness and cultural symbolization and their linguistic and artistic expression. We claim that the Epipaleolithic food gatherers and hunters at the last phase of their coevolution with their landscapes, in the final stages of the Pleistocene and the end of the (European) Glacier period more than 12,000 years ago, had already attained a high stage of noospheric cultural evolution. Later on, it enabled the development of additional noospheric realms of the info-socio- and psycho-spheres that emerged during the cultural evolution in the Holocene, through which modern man finally became a mighty geological agent with both constructive and destructive powers.

2.2 Autocatalysis and crosscatalysis, autopoiesis and self-organization and their role in evolution

Of great relevance for our discussion are the insights gained on the self-organization of living systems. The spontaneous emergence of new order, creating new structures and new forms of behavior within network patterns of living systems is made possible by their self-regulating feedback loops. Such systems on 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 (Eigen and Schuster, 1979), organisms, and ecosystems but also for THE landscapes as the spatial and functional matrix of interacting nonhuman and human living systems. This autopoietic process is made possible by **autocatalysis** by which one of the products of the reaction enters a cycle that helps to selfreproduce by creating its own synthesis. In cycles of **crosscatalysis** two or more subsystems are linked, so that they can support each other by catalyzing each other's synthesis and thereby mutually increasing their growth. Such positive feedback loops lead to **hypercycles** of mutually reinforcing processes, typically for systems, i.e., landscapes, which are far from equilibrium, together with the appearance of instabilities leading to new and higher forms of organization.

These nonequilibrium 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 previously stable systems and drive it subsequently to a new regime at a more complex state (Maturana and Varela, 1975; Prigogine and Stengers, 1984). As will be further explained below, in evolutionary processes these are expressed as ***bifurcations.***

Jantsch (1980) has laid the transdisciplinary foundations for a synthetic view of cosmic, geological, biological, ecological, and socio-cultural evolution leading to an all-embracing concept of coevolution and emphasizes our present "Macroshift" from the industrial to the post-industrial information cooperating as the creative player of an entire evolving universe. As a major paradigm shift from the Cartesian and Newtonian view of a mechanistic world it reaches far beyond the post-Darwinian and socio-biological interpretations of evolution. Laszlo (1987, 1994, 2001a,b) has adopted and further developed Jantsch's paradigms of these co-evolutionary patterns of change and transformation in the cosmos, organisms and in modern society, and its far-reaching consequences. This stems from the recognition that realms of evolution in the empirical world do not follow classical disciplinary boundaries although logically aligned with the unfortunate divisions of empirical science between the physical, biological, and social sciences. However, from the perspective of the synthetic evolution, these are not absolute and watertight divisions, but result from the above-mentioned theories based on investigations of systems, leading far from thermal and chemical equilibrium to the formation of dissipative structures.

In this "Grand Synthesis" (Laszlo, 1987, 1994), the evolutionary trajectories are not moving in a continuous and linear progression from the simpler to the more complex type of system, but "leap" by the sudden emergence of successive levels of higher organization. These discontinuous developments of sudden leaps from one kind of stable state occur as the above–mentioned **bifurcations**. In these, abrupt discontinuous changes in system behavior occur as a result of certain parameters crossing an apparent boundary of their domains of attraction in such **metastable systems.** As a result of such subtle “catastrophic” bifurcations, these systems may turn chaotic or disappear or lead to a new state of metastability on a higher level of organization. Their mutually reinforcing auto- and cross-catalytic feedback loops are triggered chiefly by technological innovations. On each level, the amount of cultural information that can be handled by the cycle is greater than that on the lower level, due to a greater diversity and richness of the components and structures. We have adopted this synthetic evolutionary perspective and view the long-term cultural history of human societies and their landscapes in the Mediterranean as proceeding by leaps through such crucial bifurcations at which the past trends broke down, allowing such dynamic systems to emerge on successively higher levels of organization on multiple hierarchical levels. In our case, they led from the primitive food-gathering hunting stage to our present, still chaotic transitional “Macroshift” bifurcation stage. However, in contrast to the human-landscape coevolution shaping the Pleistocene subnatural and seminatural landscapes, the Holocene agropastoral, urban industrial landscapes evolved as the result of human dominance. The introduction of fossil energy during the industrial revolution has caused a crucial bifurcation between the self-organizing autopoietic natural, seminatural, and traditional agropastoral **biosphere landscapes** and the human-created and driven urban-industrial **technosphere landscapes**. The biosphere landscapes are powered solely by solar energy and its conversion through photosynthetic assimilation of autotrophic plants into chemical energy and transmitted in the trophic food chain to heterotrophic herbivores. The rapidly expanding fossil energy powered technosphere landscapes endanger the future of biosphere landscape and their biological evolution and have led to the formation of our disorganized and unsustainable industrial Total Human landscape. Human society has the choice if our present macroshift bifurcation will lead to further biotic degradation and extinction or to a sustainable future for nature and humankind and further biological and cultural evolution (Laszlo, 1994; Naveh, 2003).

Contrary to the homeostatic equilibrium paradigm of the so-called “balance of nature”, our studies indicate that Mediterranean woodlands, shrublands and grasslands as seminatural and meta-stable landscapes continue to change among their tree, shrub, herb, and grass layers as long as the same perturbations continue with similar intensities and frequencies. The eminent geneticist Waddington (1975) coined the term **homeorhesis** (from the Greek meaning preserving the flow) for such dynamic flow equilibrium to denote the evolutionary stability of multifactorial systems or the preservation of the flow process of the evolutionary pathway of change through time. While undergoing such short- and long-term cyclic natural and human induced rotations of burning, grazing, browsing, cutting, coppicing, and cultivation superimposed on the seasonal and annual climatic fluctuations, they are apparently driven by positive feedback loops of cross-catalytic hypercycles. Their resulting defoliation pressures were incorporated in the landscape at different spatiotemporal scales. These **human perturbation-dependent** systems have acquired long-term adaptive resilience and evolutionary metastability, which is discussed further in Part II. Their thermodynamic behavior as dissipative structures has clearly pointed out 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 (Naveh, 1991, 1994b, 1998a,b; Naveh and Lieberman 1994).

2.3 New approaches to archeology and prehistoric human impacts

Of great significance to our discussion are recent developments in archeology undergoing a similar scientific revolution. According to Runnels (1995), it is shifting from monodisciplinary studies of single sites to inter- and even transdisciplinary studies of the natural and cultural history of whole landscapes and regions in cooperation with scientists from other, relevant disciplines such as geomorphology, biology, ecology, history, anthropology, and arts. These studies are making use of the most advanced methods of these sciences, and other sciences such as geophysics, using seismic refraction and ground penetrating radiation as well as remote sensing and other spatial explicit methods used by landscape ecologists.

An important result of these developments is the attempt to reconstruct the lives, economics, cultures, and beliefs of ancient societies not only on the basis of narrow utilitarian interpretations of the archeological findings of stone tools and other cultural artifacts. Thus, for instance, Ronen (2000) has shown in the example of such broader, transdisciplinary interpretations of pre-agricultural Aceramic Neolithic Cypriotic culture (about 6500 BC) that it could lead to a much better appreciation of the intellectual capacities and of the spiritual world of these people enabling them to utilize their natural resources in a sustainable way for long periods in a peaceful and technological simple way of life. Similar conclusions could be reached also in the case of the Natufians discussed below. Ronen and Adler (2001) have reached similar conclusions on the functions of the parameter walls of Jericho and the Khirokitia walls in Cyprus, regarding these not as part of military fortifications but as ideologically determined “magical defenses, separating at the very least, the built and the unbuilt areas”.

Until recently there was a general tendency to deny any significant human influence and to underestimate the importance of human habitation and food gathering and its impacts on their Pleistocene environment and its vegetation. Regarding these as insignificant, they were treated chiefly as hunters. Thus, for instance, Pons and Quezel (1985, p.35) in reviewing human impact in the Mediterranean claimed: “Early man was a hunter and gatherer and had relatively little influence on natural vegetation.” McNeill (1992) has accepted uncritically this view, maintaining that until the Neolithic revolution hunters and gatherers played almost no role because of their slender numbers. Although he recognized their early use of fire, he claimed that their activity scarcely affected vegetation complexes. But at the same time he maintained that such prehistoric fires started the “long history of anthropogenic erosion”. However, Rackham and Grove (2001) in their review of prehistoric and historic causes of erosion could not find any well-founded evidence that human activities were its major cause, as opposed to a much better correlation with climatic long- and short-term events.

We will present an alternative view of the ecological and evolutionary importance of paleolithic Mediterranean people as food collectors, hunters, and as vegetation manipulators, chiefly with the help of intentional fire. In this context, Leaky and Lewin (1979) stated in their description of early human evolution that it would be foolish to ignore the lessons that contemporary societies of the rapidly vanishing hunters and gatherers could teach us. On the basis of the importance of plants in their diets, economics, time spent on food collecting, and the tools used (mostly made of wood and therefore perishable), they concluded that it would be more accurate to refer to these people as well as to their Paleolithic ancestors, as gatherer-hunters (G-H) and not hunter-gatherers.

In a similar vein, Eisler (1986) critically re-examined the prevailing view regarding the dominating “man the hunter” as the ruler throughout prehistoric times. She offered an alternative of the equilibrium gender between men and women. She stressed the important role of woman in the economy of these early societies and as the religious image of “Mother God” and the symbol of the natural life cycle. This and the deep, spiritual links with nature are reflected also in the Paleolithic cave paintings in the Mediterranean, and as is shown below, also by the Natufians of Mount Carmel. In her opinion, the basis for these misconceptions is the stereotypic view of primitive man as a bloodthirsty militant. This distorted picture is indeed also very different from what we know today about these “primitive” pre-agricultural societies in Africa (Turnbull, 1961) and in New Guinea (Diamond, 2001). Based on his long personal experience, Diamond presents an impressive picture of the high-natural intelligence and environmental awareness of these New Guinean people and their intimate knowledge of plants and animals and their usefulness, which was apparently the result of a long-evolutionary adaptation process of living in intimate dependence on the natural world upon which their survival depended.

These are important insights, which help us in our attempts to reconstruct the cultural evolution of these pre-agricultural people and their still underestimated intellectual capacities. It should lead above all to a re-evaluation of their abilities as efficient "environmental managers" in the use of available natural resources and the important role of women in these activities. They could have even been influenced by their religious beliefs, like the North American Indians, as restraining cultural feedbacks for the overuse of their natural resources.

3. PAST AND PRESENT ENVIRONMENTAL CHARACTERISTICS

3.1 Mediterranean climate and biota

Five regions of the world - the Mediterranean basin, California, central Chile, the Cape of South Africa, and western and southern Australia - share a unique climatic regime of mild, wet winters and dry summers with 90% or more of the annual precipitation falling in the six cool months. These similarities are due to the symmetry of the atmospheric circulation, governed by the positioning and seasonal movement of the subtropical anticyclone on the equatorial side and the positioning of the cyclogenesis in the belt of mid-latitude westerlies on the poleward side. The present, strongly zonal, atmospheric gradient of the polar-to-equator temperature gradients, which is enhanced by the polar ice caps, renders the Earth's glacial history as pertinent to the discussion of the evolution of Mediterranean-type climates and their future (Deacon, 1983).

Thus, the presently observed rapid melting of the arctic ice caps and the rise in temperatures at the lower latitudes could also have far-reaching effects on global climate changes and on the disruption of these Mediterranean climate patterns, accompanied not only by drastic ecological landscape changes but also by social and economic upheavals (Naveh, 1995). As explained in more detail by Allen (2001) in a thorough description of these Mediterranean climates, the bi-seasonal summer drought and winter rainfall pattern already appeared 2-3 million years ago during the mid-late Pliocene chiefly as a result of global cooling during the establishment of permanent ice in the North Atlantic. However, this bi-seasonality has not been consistent and experienced major fluctuations in response to changes in Quaternary ice volume. This is especially true for the Pleistocene, during which our Mediterranean landscapes reached their final geomorphologic structure, converging with major steps of human biological and cultural evolution. It underwent severe glacial periods of colder and wetter conditions and drier, warmer, interglacial periods. The last Penniglacial 7,500-15,000 years ago was a period of considerable climatic and environmental changes in the Levant. On the basis of palynological findings, Weinstein-Evron (1993a) presented a schematic palynological cycling pattern of shifting humid, dry, and intermediate periods. Increased humidity seems always to precede cold conditions in the area. At the time of such humidity peaks, precipitation was higher than today and maquis and forests were probably more expansive in these landscapes. More recent pollen findings by Baruch and Bottema (1999) from Lake Hula in northern Israel show dramatic changes in the last 16,000 years from severe aridity to a highly humid climate. The later part of this period (ca. 14,500-11,000 B.P.) turned out to be the most humid period and the ensuing stage largely coinciding with the Younger Dryas, (ca. 10,500-5,500 B.P.) of renewed aridity to almost full glacial conditions. The early Holocene was marked by agradual return of humid conditions followed by prolonged stability. We should keep in mind that these pollen patterns can indicate only the general trends of climatic changes, but their resolution is too coarse for detecting the gradual, subtle vegetation changes from eventual human-induced modification of natural to subnatural and to seminatural agropastoral landscape during this crucial cultural and socio-economic transformation stage. By such pollen analysis maquis formations cannot be distinguished from forests with their different oak species and life forms as trees or shrubs caused by different grazing and fire pressures. Only when early agriculturalists carried out large-scale forest clearings and replaced the natural vegetation with cultivars on larger scales by plants whose pollen is wind-transported, such as olives, was this reflected by the occurrence of olive pollen derived from wild olives (Allen, 2001). In fact, according to Baruch and Bottema (1999), around 7,500 B.P. such anthropogenic effects on the vegetation become noticeable, principally marked by a conspicuous rise in the values for olive. These human impacts increased considerably during the second half of the Holocene. Similar phenomena have been noted in pollen diagrams from the Sea of Galilee. As statements on the presence or lack of anthropogenic vegetation changes in the Mediterranean during earlier periods are based solely on such palynological findings spanning hundreds of thousands of years from the Upper Pleistocene to the early Holocene, they may be very misleading. This does not mean, however, that even earlier, specific pollen findings cannot be interpreted as indications of human interferences. As will be shown below, early Mesolithic human activities around 100,000 years ago can be traced back in the Carmel caves from pollen of typical human follower species, taking advantage or even evolving in such human cleared and disturbed camp sites and their "kitchen" waste disposal.

All five Mediterranean climate regions are typical for their evergreen shrublands, dominated by species with evergreen tough and leathery sclerophyllous leaves. In a comprehensive ecological comparison of these regions, Di Castri (1981) showed that these species are generally replaced along environmental gradients of moisture and nutrient availability of other vegetation types. However, these gradients are also greatly influenced by human impacts on these landscapes and their vegetation. A recent overview of both natural and anthropogenic disturbance regimes in these so-called "Mediterranean-Type Ecosystems" has been provided by Rundel (1998).

Blondel and Aronson (1999), Allen (2001), and Grove and Rackham (2001) provided detailed descriptions of the Mediterranean biota. There are great differences in this respect in the different regions and countries. Because of the unique geographic location of the Mediterranean basin between Europe, Asia, and Africa it has served as a meeting point and melting ground for species of varying origins. As the southern most outpost of the eastern Mediterranean, Israel is the most pronounced example of a bridge and corridor for the different biogeographic elements of these regions.

Axelrod (1958) has shown that sclerophylly is an ancient character that long predates the evolution of summer-dry climates. He traced scleropyllous vegetation in North America-Eurasia back to Madro-Tertiary and Mediterranean – tertiary geoflora (the fossil flora with a common geological history), respectively, which had their origin in the southwestern portions of the continents in the late Cretaceous. The Mediterranean geoflora has been derived from Indo-Malesian, Paleo-African, and xerothermic Mesogen stock. Seasonal aridity already appeared sporadically in the Middle Eocene, but the true Mediterranean climate pattern was established only in the Pleistocene. The sclerophyll woody species were apparently best pre-adapted to climatic patterns of increasing drought and lower-winter temperatures that developed during the Pleniglacial in the Levant.

Tchernov (1988) maintained that at the end of the Pliocene and early Pleistocene, dissemination of biota into the southern Levant was only possible for a select number of species. At the onset of the Pleistocene the southern Levant was already divided into several morphotectonic domains that were primarily responsible for landscape formation and the structuring of their fauna and flora into a well-established biogeographic framework. However, during the rest of the Quarternary, tectonic geographic and climatic events continued to play an important role in reshaping these landscapes. These factors resulted in changes of dispersal and abundance of plant and animal groups, sometimes affecting their rate of biotic turnover and extinction. The main route of biotic and hominid dispersal, from Africa to the rest of the world, took place through Israel, as the southern Levantine corridor. The shift toward aridity in the Quarternary became a major causal factor for the extinction of many Afrotropical and Palearctic elements and for the increased separation between tropical Africa and Eurasia. The above-mentioned impact of glacial episodes and the proximity of large desert domains also played a major role in the distribution of Levantine plants, animals, and humans (Horowitz, 1992). According to Pignatti (1978), large numbers of chiefly herbaceous and annual plant taxa, which evolved during the Pleistocene in the Mediterranean basin, were accompanied by further speciation of woody plants and endemism. Presently, in all of these regions, but especially in the Mediterranean basin, with the exception of the rapidly vanishing coastal dunes, wetlands, and marshes the uncultivatable uplands have become the last refuges of nature, which means plants and animals are found spontaneously occurring and reproducing. Wherever these uplands have not yet been converted into dense pine or eucalyptus forests or depleted into scrub and rock deserts, they are distinguished by their great ecological heterogeneity and biological diversity. Although covering only a tiny 1.2% of the Earth's surface, their contribution to species diversity of vascular plants far exceeds their relatively small area of coverage. The largest number of these species can be found in the Mediterranean basin (25,000), making up 20% of the world's total (Cowling et al., 1996). Therefore, it has been recognized as one of the 18 most important biodiversity "hot spots". On the basis of species/area ratio, the Mediterranean territory of Israel is, after Cyprus, by far the richest containing more than 1500 species and a ratio of 0.15 – as compared to 0.01 in Turkey, 0.04 in Greece, and even less in all other Mediterranean landscapes (Naveh and Kutiel, 1990). The Mediterranean flora is especially rich in herbaceous plants including many annuals and exceptional colorful flowering compositae and geophytes with ornamental values. Among these are many rare and endemic plants. Many grasses and legumes are outstanding pasture plants and are cultivated widely in improved pastures, especially in Australia. Among the woody plants, and especially in the Labiatae family, there are many species with great value for pharmaceutical, cosmetic, spice, balsam, and other uses with considerable economic potentials. These plants are now grown, collected, and utilized with increasing intensity for commercial production. The Mediterranean zone of northern Israel is the center of distribution in the Near East "Fertile Crescent" of the wild tetraploid emmer wheat *Triticum dicoccoides*, the progenitor of most tetraploid and hexaploid cultivated wheat, which will play an important role in further wheat improvement. Nevo and his coworkers at the Institute of Evolution of the University of Haifa have studied the rich genetic resources of cultivated wheat since 1971. It served these scientists at the same time as a major model organism for evolution (Nevo, 2001a; Nevo et al., 2003). Its importance for the coevolutionary process of the emergence of agriculture will be discussed below.

A comparison of the floristic and structural diversity and species richness of shrublands and woodlands of northern Israel with those of southern France near Montpellier revealed that regardless of the scale of observation, alpha species richness diversity was higher in Israel across the range of all vegetation structures and land-use histories. It was highest in the semi-arid ecotones of the Mediterranean zone, on Mount Gilboa of Israel in an open shrub community moderately grazed, but chiefly by gazelles. These were dominated by Pistacia lentiscus with many sub-shrubs, reaching 179 species /1000m^2 in comparison with only 79 species in a Quercus coccifera community in France. The same was also true in a comparison in “ecological equivalent” study plots (Naveh, 1969) between Mediterranean-type woodland and oak savanna communities on Mount Carmel and in the Carmel Valley in Central California. The communities of Israel were richer in life forms and had more climbers, geophytes, and woodland legumes. In moderately grazed woodlands in Israel of 1000m^2 we counted 137 species and of these 110 – were mainly annual-herbs, as compared with only 47 species with 41 herbs in California. In both countries, closed shrublands were much poorer than those of Israel and had only 35 species with 17 herbs in Israel and even less in California (Naveh and Whittaker, 1979).

A further comparison between these Mediterranean plant communities with those in central Chile, southwest Australia, and the Cape region in South Africa showed the greater richness in all growth-form categories and higher-total diversity and lower-concentration dominance in Chile, as compared to California. We related the greater richness in woody plants of the Chilean vegetation to a long-term evolutionary history, but the greater richness in herbs - like in Israel - to the longer history of more severe human disturbances by Spanish colonizers, opening the canopies of the Chilean shrub communities about 400 years ago and only 200 years ago in California. However we argued further that because of their much older origin, the Australian and South African Gondwanan shrub communities diverge from the European, Chilean and California ones: They lack in annual species but are extremely rich in woody species, and, therefore, no similar conclusion can be drawn from the length of human habitation and its effect on their structure and diversity (Naveh and Whittaker, 1979).

3.2 The natural environment of Mount Carmel

The chief study site of Mt. Carmel is an isolated mountain ridge, rising from the northern Mediterranean Sea shore of Israel to a height of 450-500 m. It represents a typical example of the rich regional seminatural and rural, cultural landscapes of the eastern Mediterranean and southern Levant, whose great natural and cultural values are threatened presently by the mutually amplifying combination of urban-industrial, agricultural, and recreational pressures.

Fortunately, the unique biological, ecological, geological, archeological and scenic features of Mt. Carmel have been recognized over time by foresighted regional planners like Joseph Bruzkus from the Ministry of the Interior with full support by the Haifa Municipalities and reinforced by public pressure led by the Israel Society for the Protection of Nature. From a total area of 232 km^2, 84 km^2 were declared as the Carmel National Park (CNP) in 1970, incorporating nature reserves of 31 km^2 with about 55 km^2 of densely planted mono-species forests of *Pinus halepensis*.

Used each year by more than two million visitors, the nature reserve is the largest biologically, and culturally the richest, most attractive open landscape, open-door recreational area in the densely populated coastal zone of Israel. The Carmel National Park and its surroundings fulfill important ecological, social, psychotherapeutic, educational and scientific functions. Let us hope that the Israel Nature and Park Authorities will obtain sufficient financial support from the Israel government for continuing to ensure these vital functions for the sake of present and future generations.

Mt. Carmel has a typically mild Mediterranean climate with winter and spring rains ranging from 500-600 mm average annual rainfall in the lower parts to 700-900 mm in the higher parts. According to the UNESCO-FAO (1962) bioclimatic classification, these are the typical drier, warmer, “xerothermic and wetter and slightly cooler” accentuated thermo-Mediterranean bioclimates with a large number of 125-200 pluviothermic dry days in which both the natural and rain-fed agricultural vegetation is highly fire-prone. Therefore, they could also be called **Mediterranean fire bioclimates** (Naveh, 1973). Their great inter- and intraseasonal variability has further increased in the last 10-15 years, most probably because of global climate changes, which has apparently disrupted the typical Mediterranean rainfall and temperature regimes (Naveh, 1995).

Mt. Carmel is distinguished by its great stratigraphic, geomorphologic, and topographic heterogeneity resulting from this dynamic tectonic history and its unique paleogeographic location at the edge of a shallow platform. The dominating rocks consist of dolomites and crystalline limestones, which contributed to the karstic nature and the very scenic appearance of some of these rock formations, especially those facing the Mediterranean. Other rocks are chalks, marls, as well as volcanic tuff and sandstones along the coastal line. The mountain areas are covered chiefly by shallow terra rossa, light and brown rendzina, brown Mediterranean forest soils, and deeper colluvial soils. The soils of the coastal area primarily include deep alluvial soils (Bein and Sass, 1980; Nir 1980; Singer and Ravikovitch, 1980).

Like other mountain landscapes in the Mediterranean, Mt. Carmel is a relatively young geological system, which gained its present geomorphologic form by violent uplift in the Late Tertiary and early Quaternary period as an isolated mountain belt in which Upper Cretaceous (mostly Cenomanian-Turonian) rocks are exposed. Its final shaping was the result of tectonic and volcanic activities during the Pleistocene. These caused intense mountain rising and erosion, sea ingressions and regressions, followed by increasing diversification of local site conditions. Its western boundary, which in places follows ancient reef trends, has been shaped through coastal abrasion of the Mediterranean Sea during the Pleistocene and its changing sea levels. Horowitz (1979) has described these dramatic morphotectonic evolutionary alternations. They created many new habitats such as canyons and gorges with steep slopes and bare rock surfaces, contrasting north-south and east-west exposures in the Carmel uplands and alluvial fans, vernal pools, saline zones playas, bogs, swamps, marshes as well as sand-covered hills and flat in the coastal lowlands. These further increased the edaphic and topographic heterogeneity and microsite diversity and opened many opportunities for plant and animal colonization and speciation. The volcanic activities caused many recurring large and hot wildfires. However, their far-ranging evolutionary and ecological landscape impacts were completely overlooked in these studies.

The most previous thorough palynological study on the Carmel coast near Dor has been carried out to a depth of 10.5 meters reaching the radiocarbon date of 23,400 Y.B.P. at the bottom of a marsh, which was formed during that period (Kadosh, 2002). However, in these anaerobic conditions, only in the upper layer of the early Neolithic at the beginning of the Holocene (between 9,000 to 8,200 Y.B.P.) such palynological pollen data could be obtained. This points to typical Mediterranean vegetation, dominated by *Quercus calliprinos*, with many herbaceous plants, apparently from a more humid and cooler climate than today. Notwithstanding these climatic fluctuations, we also have much earlier evidence from other palynological studies that the Carmel flora - like all other floras of the south Levant - has been mainly of the Mediterranean type from the Pleistocene (Weinstein-Evron, 1991, 1993a,b, 1998). Therefore, we can assume that the major coevolutionary process described below took place in a Mediterranean environment and climate, at least from the botanical point of view.

The bio-climatic variability as well as the unique geographical position of Mt. Carmel near the Mediterranean Sea and its great geomorphologic, lithological, and edaphic landscape heterogeneity has favored the evolution of a rich fauna and flora. The latter is presently comprised of close to 1500 plant species, mostly annual and perennial herbs with several endemic and rare species as well as a great number of ornamental flowering geophytes. For many of the Eu-Mediterranean species, Mt. Carmel is the southernmost limit of their distribution. The latter include *Pinus halepensis,* the only natural occurring conifer tree in Israel. The CNP carries its last larger forest remnants, with a dense woody understory, and a well-developed, multilayered maquis, dominated by *Quercus calliprinos.* The lower belts are covered by more open, park-like woodlands and shrublands dominated by *Ceratonia siliqua, Pistacia lentiscus*, *Sarcopoterium spinosum,* or *Quercus ithaburensis* with a rich herbaceous understory.

The great macro- and microsite heterogeneity of Mt. Carmel induced the great floristic diversity both on the interspecies level and the intraspecific level. Examples of ecotypic variations have been found on different sites in two of the most abundant woody and herbaceous plants, namely *Pistacia lentiscus* (Swarzboim, 1978) and *Piptatherum miliaceum* (Naveh, 1959). As will be discussed below, it may be also of great evolutionary significance that these species are distinguished by their great regeneration capacities after fire.

The present vegetation of Mt. Carmel consists chiefly of complex mosaics of degrading and regenerating plant communities. Depending on site conditions and past and present land-use pressures, this patchy vegetation ranges from rich, productive open grasslands and woodlands to severely depleted dwarf-shrub communities (batha or phrygana) and denuded rock deserts; from rich multilayered semi-open shrublands and forests to one-to-two-layered, closed, tall shrublands (maquis or mattoral). The latter is composed chiefly by sclerophyllous phanerophytes and dominated in Israel by *Quercus calliprinos.*

Most of these sclerophyll trees and shrubs are distinguished by dual root systems that can spread horizontally and penetrate deeply into rock cracks, vigorously resprouting from their roots after fire, grazing, or cutting. They respond favorably to pruning and coppicing on one stem. If resprouting from suckers is prevented they soon attain the stature of small trees. In this way closed, one-layered, very fire-prone, and unproductive shrub thickets can be converted into rich, multilayered, park-like groves and woodlands. This apparently, was the way sacred oak groves, mistakenly regarded as remnants of “climax” oak communities, have been created.

In a series of extensive multidisciplinary studies carried out since 1991 at Lower Nahal Oren on adjacent slopes with opposite south and north exposures, Nevo and his coworkers investigated the striking differences in their vegetation cover as well as in the biogeographic origin of the flora and fauna. Up until now, they have identified 2000 species including 320 vascular plants displaying qualitative or quantitative divergences between and within slopes. These findings were more recently corroborated in another study in slightly more humid conditions in the western Upper Galilee.

All these studies, ranging from the genome up to the landscape level provide convincing proof that environmental stress - in this case the difference in solar radiation and humidity - act as strong evolutionary forces for natural selection along regional climatic, topoclimatic and microclimatic gradients. Field microscale studies on the relations between molecular evolution and environmental stress on annual grasses abundant on Mt. Carmel, revealed that edaphic (terra rossa vs. basalt soil; rock vs. deep soil) and microclimatic (sun vs. shade; and high vs. low solar radiation) stresses in *Hordeum spontaneum* (wild barley), *Triticum dicoccoides* (wild emmer wheat), and *Aegilops peregrina* point inferentially to natural selection as a major differentiating factor of qualitative and quantitative patterns of genetic diversity at single loci, but primarily at multilocus structures and genome organizations (Finkel et al., 2001; Nevo, 2001b). We should, therefore, not reject the hypothesis that the long-lasting defoliation stress factors induced by foraging wildlife and humans acted as strong natural selection pressures, even if we are not yet in the position to reveal their gene-ecological evolutionary mechanism.

4. THE EVOLUTION OF THE MEDITERRANEAN LANDSCAPE OF MT. CARMEL IN THE PLEISTOCENE AND EARLY HOLOCENE

4.1 Major phases of land use history in Mediterranean landscapes of Israel

Naveh and Dan (1973) and Naveh and Kutiel (1990) distinguished three major periods of human-induced changes in the landscapes and vegetation of Israel:

1. A very long period during the Pleistocene, which marked the major phases of the coevolution of Mediterranean peoples with their landscapes. During this period, the natural landscape was first transformed into a subnatural one, changing the floristic composition, but largely retained the natural vegetation structure and formation. It is the second phase, during which this coevolution reached its peak and intensive vegetation management transformed most of the natural and subnatural landscape into seminatural vegetation that altering their structures took place. In this period the cornerstones were laid for the metastable homeorhetic flow equilibrium on which the vegetation dynamics of these seminatural landscapes are based until present times.
2. A long prehistoric and historic agricultural period in the Holocene, during which the agropastoral cultural landscape was shaped, reached its peak and then gradually declined. Seminatural vegetation

formations were maintained in a metastable stage of homeorhetic flow equilibrium.

3. A recent, short, modern “neotechnological” period in the 20th century of increasing heavy human pressures on these solar energy-powered seminatural biosphere landscapes by fossil-energy powered agro-industrial, rural, and urban industrial technosphere landscapes caused the biological and cultural deterioration of the Mediterranean landscape and the formation of the disorganized Total Industrial Landscape.

In this part of our essay, I will deal chiefly with the Pleistocene and the earlier Holocene periods, marking the major coevolutionary human-landscape stages. For this purpose, I will further broaden the claim made by Di Castri (1981) that thanks to the continuing interaction between natural and anthropogenic features from the Middle Pleistocene onward, human beings coevolved with Mediterranean ecosystems. Coevolutionary features are present in a number of ecological and cultural characteristics in this region. For our coevolutionary theory, I apply the definition of Stebbins (1982) who regarded coevolution as a simultaneous evolution of two genetically independent but ecologically interdependent lines via both biological and cultural templates.

From the Middle Pleistocene onward, the geological and biological landscape evolution coincided with major phases of the biological and cultural evolution of humans. During this long period of more than a million years, the Lower Paleolithic *Homo erectus* was replaced by more advanced food gatherers and hunters such as Middle Paleolithic Neanderthaloids and the first *Homo sapiens* around 100,000 years ago, and subsequently by the intensive food collecting Epipaleolithic *Homo sapiens sapiens* and the food-producing Neolithic *Homo sapiens sapiens* in the early stages of the Holocene, around 12,000 to 10,000 years ago.

We regard these closely coupled evolutionary processes and their mutually beneficial feedback loops of auto- and cross-catalytic networks and their hypercycles as the coevolution of Mediterranean peoples, their landscapes, and vegetation with both natural and human-set fires playing an important role. Naveh and Vernet (1991) described this coevolution in the context of the palaeohistory of the Mediterranean biota. In the caves of Mt. Carmel and especially in those of Nahal Hame'arot (“The River of the Caves”) some of its crucial stages have been documented by archeological findings. The significance of this coevolutionary process has been described in detail by Naveh (1984) and will be further updated in this essay.

4.2 Early phases of coevolution from the Middle Pleistocene onwards

According to Axelrod (1958, 1989), the evolution of the Mediterranean in general, including Mt. Carmel, has much in common with California. In both cases, fire and drought played apparently important evolutionary roles. Many wide-ranging wildfires caused by volcanic eruptions as well as by lightening have raged presumably throughout the Pleistocene and on Mt. Carmel also.

Presently, lightening out of a clear sky may occur in rare cases on several days in April-June causing wildfires. However in ancient times, such a fire on a dry day, if not put out immediately, could catch the undisturbed, dense, and highly inflammable woody, herbaceous vegetation and spread rapidly over vast areas. Such fires on wildlands and pastures were mentioned in the Bible in connection with lightening as the “fire of God” and “the heat of summer drought” in the Book of Job 9 (1:6). They also gained special symbolic importance for Mt. Carmel where the prophet Elijah fought the Baal prophets and “the fire of the Lord fell and consumed the burnt sacrifices, and the wood, and the stones, and the dust and licked up the water that was in the trench” (Kings 18, 38).

Such hot fires have probably destroyed most of the woody aboveground vegetation from time to time. Therefore, as explained in more detail elsewhere (Naveh, 1974), only those plants and animals with efficient adaptive resilience could survive such recurring fire stresses as well as increasing aridity. In California, Anderson (1956) showed that even at present times, fire-induced shrub-openings provide ideal opportunities for further speciation, hybridization, and genotype recombination of such woody fire-followers (or “pyrophytes”).

The Levant apparently remains the only potential corridor for human migrations out of Africa. These were, as a rule, associated with biotic dispersal events, mainly large mammals. Tchernov et al. (1994) summarized recent findings and the Quarternary chronosequence and faunal remains of the earliest sites that mark the dispersal routes of *Homo erectus* into Eurasia in the Early Acheulian Bone Bearing Beds in northern Israel from Ubeidiya, in central Jordan Valley, near Lake Kinnereth, Gesher Benot Yaakov, south of the Hula Valley on both sides of the Jordan River, and at the Evron Quarry, on the coastal plains of the western Galilee, north of Haifa.

The Ubeidiya formation is among the oldest known stone industries, representing occurrences of early *Homo* outside Africa and the most intensively explored Lower Paleolithic site in Israel and the Levant. Its lithic assembly showing close affinity with Olduvai Upper Bed II dated recently 1.4 myr, in lacustrine and lava flows fluviatile deposits, which accumulated inside central Jordan Valley after the major tectonic activity, forming the

Jordan Rift Valley. Its formation, therefore, most probably marks one of the earliest stations on the route of human dispersal from Africa. The rich mammalian community consists of 45 genera originating from different biogeographically provinces from Africa and Eurasia, exhibiting the transition from early Lower Pleistocene to Middle-Upper Pleistocene fauna. According to palynological evidence for lacustrine sediment (Horowitz, 1979), its paleoenvironment included a hilly area covered with mixed Mediterranean forest with preponderance of sclerophyll phanerophytes such as *Quercus* and *Pistacia,* with indications of a climate that was more humid and cooler than the present semi-arid hot climate prevailing in the Jordan Valley.

The second site of Acheulian occupancy, Gesher Benot Yaakov, is of special significance for our discussion. Here, Stekelis (1960) found burned fibia fractures and within the bifacially worked artifacts, cleavers and hand axes made of basalt, dated younger than 0.800 myr. This is our first archeological evidence of fire not only in Israel, but according to Clark (1960) also of its use by *Homo erectus* in general. The third site of Early Paleolithic activity is at the Evron quarry with Acheulian deposits of flint artifacts and faunal artifacts dated older than 0.800 myr.

The mammalian assemblages, presented by Tchernov et al. (1994) of all these Lower Paleolithic sites, clearly show that already at that time the vegetation was exposed to foraging from a great diversity of ancient herbivores, ranging from elephants and rhinos to camels, gazelles, and gerbille rodents. However, we should not neglect the effect of human habitation and foraging on the surroundings and its vegetation and soil near their camp site and fire places, interacting with fire, grazing, and browsing for game and hunting.

Of special relevance in this respect are the remarks by Carl Sauer (1956, p.53), the eminent regional and cultural geographer, who can be regarded as the first American landscape ecologist (although he was not at all aware of such a term!). In his opening lecture of the now classical Chicago Symposium on “Man's Role in Changing the Face of the Earth” he stated: “The appearance or disappearance, increase or decrease of particular plants and animals may not spell out obligatory climatic change as has been so freely inferred… The intervention of man and animals has also occurred to disturb the balance… Dear thrive on browse; they increase wherever palatable twigs become abundant in brushlands and with young tree growth; ecological factors of disturbance other than climate may determine the food available to them and the numbers found in archeological remains”.

The close interaction between the creation and maintenance of anthropogenic environments around human habitations, such as those of the Paleolithic Carmel G-H with their cultural traits, has been emphasized also by Rindos (1984) in his coevolutionary treatment of agriculture. He defined coevolution as an evolutionary process in which the establishment of a symbiotic relationship between organisms, increasing the fitness of all involved, brings about changes in the traits of the organisms.

Considering these interrelations with plants as the first step of “incidental domestication”, Rindos (1984, p.137) stated: “the habitual destruction of preservation of species will have major effects on the floristic structure of the region, and eventually on the directions open in plant evolution. Such habitual activities, passed as a cultural trait, are inseparable from human language”. Such interactions included destruction and preservation of plant species, opening of gaps in the closed vegetation canopy for food and fuel, the clearing of land for habitation and the trampling of paths, the digging for bulbs and burrowing animals, and the disposing of human kitchen waste. All these intentional and unintentional interferences opened new regeneration niches senso Grubb (1977) creating favorable conditions for herbaceous colonizers

The interferences of these widely scattered and scarce populations with the vegetation canopy, its litter, humus, and upper soil layer was only very slight and very patchy. However, these initial anthropogenic landscape modifications together with accidental forest gaps, opened by wildfires or by other catastrophic events, and later on fires intentionally set by humans, could have been further enhanced by positive feedback loops with fire, foraging and hunting, and their cross-catalytic network relations. Therefore, on the long range they could have carried far-reaching implications on plant evolution and vegetation dynamics and on the landscape as a whole. The richness of the Carmel vegetation in usable plants both for foraging humans and herbivores is clearly indicated in Table 1, showing all vascular species growing near one of the important archeological sites of Mt. Carmel.

Bar-Josef (1984) has already pointed out that tectonics and erosion have obliterated most of the direct archeological evidence in the Pleistocene. No ash deposits and sparse floral remains have been detected in open *in-situ* habitations. Even recent sophisticated flooding methods have not provided large samples of vegetal relics in shallow and eroded Mediterranean upland soils, especially terra rossa in which preservation is very poor. In the specific climatic and edaphic conditions of Mediterranean uplands most of the ashes of forest and brush fires are washed away by the first heavy rains, and remnants become intimately mixed with the thin upper layer of humus-rich terra rossa or rendzina soils (Naveh, 1973). We can, therefore, also hardly expect to find archeological evidence of such fires, especially since the Carmel slopes underwent severe geological erosion and the above described morphogenetic upheavals.

Table 1. Exploitable plant species of the surroundings of Nahal Sefunim determination for human consumption according to Dafni (1984, odified after Naveh, 1984 by Weinstein-Evron, 1998).

WOODY PLANTS					
Trees		**Shrubs**		**Dwarf shrubs**	
Arbutus andrachne	F W	*Calicotome villosa*	Fl Br W	*Cistus salviifolius*	L
Ceratonia siliqua	F! P! Br W	*Genista fasselata*	W	*Cistus creticus*	L
Cercis siliquastrum	Fl F Br W	*Pistacia lentiscus*	Br W	*Coridothymus capitatus*	L
Crataegus aronia	F Br W	*Rhamnus alaternus*	Br W	*Majorana syriaca*	L
Laurus nobilis	L Br W	*Rhamnus palaestina*	F Br W	*Melissa officinalis*	L
Olea europaea	F! Br W!	*Ruscus aculeatus*	L	*Micromeria fruticosa*	L
Phyllirea latifolia	Br W!	*Asparagus aphyllus*	Sh	*Salvia fruticosa*	L
Pinus halepensis	W	*Smilax aspera*	Sh	*Sarcopoterium spinosum*	Br W
Pistacia palaestina	F Br! W	*Tamus communis*	Sh	*Satureja thymbra*	L
Styrax officinalis	W			*Teucrium capitatum*	L
Quercus calliprinos	F Br! W				
HERBACEOUS					
PLANTS		**Legumes**		**Miscellaneaous herbs**	
Geophytes	L	*Anthyllis tetraphylla*	P	*Alcea acaulis*	L S
Arisarum vulgare	L	*Coronilla cretica*	P	*Alcea setosa*	L S
Arum dioscioridis	B	*Hippocrepis unisiliquosa*	P	*Anagallis arvensis*	L
Asphodelus ramosus	B	*Hymenocarpos circinnatus*	S P	*Caspella bursa-pastoris*	L
Crocus hyemalis	L Fl	*Lathyrus blepharicarpus*	S P	*Convolvulus caelesyriacus*	P
Cyclamen persicum	B	*Lotus peregrinus*	P	*Daucus carota*	R
Ophrys umbilicata	B	*Medicago orbicularis*	P!	*Erodium gruinum*	P
Ophrys bornmuelleri	B	*Medicago scutellata*	P!	*Erodium moschatum*	P
Ophrys israelitica	B	*Medicago polymorpha*	P!	*Foeniculum vulgare*	L
Ophrys galilaea	B	*Onobrychis squarrosa*	P	*Geranium molle*	P
Ophrys transhyrcana	B	*Pisum elatius*	S L P	*Geranium purpureum*	P
Orchis caspia	B	*Scorpiurus muricatus*	P!	*Geranium rotundifolium*	P
Orchis galilaea	B	*Tetragonolobus paleastinus*	P!	*Isatis lusitanica*	L
Orchis tridentata	B	*Trifolium campestre*	P!	*Kicksia spuria*	P
Serapias levantina	B	*Trifolium clusii*	P	*Mandragora autumnalis*	F
Tulipa agenensis		*Trifolium clypeatum*	P!	*Nigella arvensis*	S
		Trifolium stellatum	P	*Papaver carmeli*	S
Grasses	S P	*Vicia hybrida*	S P!	*Plantago cretica*	L
Aegilops ovata	P			*Plantago afra*	L
Brachypodium	P!	**Asteraceae**		*Salvia hierosolymitana*	L
distachyon	P!	*Calendula arvensis*	L P	*Salvia pinnata*	L
Andropogon distachyus	P	*Carduus argentatus*	L	*Sanguisorba minor*	L P
Avena sterilis	P	*Carlina involucrata*	L	*Sinapsis arvensis*	L
Bromus alopecurus	P	*Catananche lutea*	P		
Bromus syriacus	P!	*Cichorium pumilum*	L S P		
Catapodium rigidum	S B P!	*Gundelia tournefortii*	C		
Dactylis glomerata	S P!	*Hedypnois cretica*	P		
Hordeum bulbosum	P	*Inula viscosa*	L C		
Hordeum spontaneum	P	*Notobasis syriaca*	P		
Hyparrhenia hirta	P	*Rhagadiolus stellatus*	P		
Lopochloa phleoides	P!	*Scorzonera papposa*	B P		
Phleum subulatum	P!	*Senecio vernalis*	P		

Piptatherum miliaceaum	P	*Tolpis virgata*	P		
Piptatherum blancheanum		*Thrincia tuberosa*	P		
Stipa bromoides					

F- fruits, S-seeds, B- bulbs, corms, etc., Fl - flowers, L- leaves, Sh- shoots, R- roots, C- capitulum. P- pasture for livestock and browsers (Br). W-wood. (!- high value).

Fortunately, Mt. Carmel is endowed by karstic caves and much of our contentions on this coevolution are supported chiefly by the archeological findings and sequences from the Paleolithic layers of Quaternary pollen spectra in the Tabun cave (Horowitz 1979) and those from the El-Wad cave (Weinstein-Evron, 1996). These and the Jamal cave are neighboring karstic caves, located about 20 km south of Haifa, on the slopes of the south bank of Nahal Me'arot at its outlet to the coastal plain. They have been formed by dissolution of the Cenomanian reef core in the early stages or the Middle Pleistocene during the Mindel and Riss glacial periods in Europe. Thanks to the findings in these caves the coevolutionary process can be traced back here to their Lower Paleolithic layers even if most traces of hearths have been erased by erosion and by changes in sea level followed by sedimentation.

Garrod and Bate (1937) were the first to describe the long and rich archeological sequence in Tabun, extending from the Lower Paleolithic layers to the Middle Paleolithic. In this cave they found direct evidence of human habitation in a nearly complete skeleton of a woman in the younger Mousterian layers (70,000-90,000 years ago) and identified as belonging to the Neanderthaloids of the Middle Pleistocene.

Of special importance our coevolutionary hypothesis and Rindo's are the non-arboreal pollen samples collected by Horowitz (1979) from the lowest Beds F of the Tabun cave. These differed greatly in composition from all the others, but could not be interpreted by possible climatic changes. This could have been, therefore, the first palynological indication of such paleolithic modifications of the natural pristine landscape ecotope into a subnatural one, and, as such, the first coevolutionary step towards the creation of the Lower Paleolithic "cultural" landscape. Many of these herbaceous plants and fire followers evolved during the Pleistocene as opportunistic ruderals, which could best take advantage of the improved light, fertility, and moisture regimes (Dimbleby, 1985). This could have been the case also with some of the plants found in these beds: In one bed, *Scabiosa prolifera* made up 50 percent of the pollen; in another, Compositae were dominant and in the third, Compositae and Graminae were dominant. Similar assemblages of these plants can be found today in close proximity to the Tabun cave and as further discussed below, in other nutrient-rich, ruderalic sites, benefiting also from recent fire events. Further evidence of pollen samples of such ruderalic plants has been provided by Weinstein-Evron (1996) from the epipaleolithic Early Natufian layers to which we will refer below. Most recently Tatskin et al. (1995) investigated wind-blown sedimentary fill of lithic assemblages in the Tabun and Jamal caves. They identified sedimentological and geochemical processes in the formation of sediments of complex sequences from the Lower Paleolithic Acheullean-Yabrudian culture assemblages, exhibiting numerous post-depositional biogeochemical changes, which occurred over a long time span. Some of these can be related to anthropogenic activity, but others could have occurred later, following ground water intrusion into the cave system. With the help of micro-morphological methods they could recognize anthropological sediments of charred organic material, incorporated into microaggregates, scattered pieces of charcoal 0.5-0.9 mm across. In the sediment of layer G of the Tabun cave they detected indications of anthropogenic burning by ferruginized chips of bones. These findings indicate human occupation and the use of fire from the Middle Pleistocene onward in Israel. Ikeya and Poulianos (1970) claimed that the first human "fire cultures" of hearths can be traced even farther back to about one million years in the lowest levels of the Petralona karstic limestone cave in northern Greece, resembling in many aspects our Carmel caves and their surrounding landscape.

We can further assume that more than any other fire feature, as the first extrasomatal energy source, affected not only their environment and shaped their landscapes, but also their life, behavior, and culture. This has already been claimed by Sauer (1956, p.54-55) in the above-mentioned lecture, in which he devoted much attention to fire. He stated:

> "Speech, tools and fire are tripod of culture and have been so, we think, from the beginning… About the fireplace, social life took form, and the exchange of idea was fostered. The availability of fuel has been one of the main factors determining the location of clustered habitation".

He mentioned the various sources from woody plants available as fuel and the benefits for human and wildlife consumption from the lush protein rich post fire resprouting woody vegetation and the increase of seeds.

> "On burned-over camp sites fire cleared away small and young growth, stimulated annual plants, aided in collecting and became elaborated in time into the fire drive, a formally organized procedure among the cultures of the Upper Paleolithic *"grande chasse"* and of their New World counterpart… Minor element in a natural flora, originally mainly confined to accidentally disturbed and exposed situations, such as windfalls and eroding slopes, have opened to them by recurring burning the chance to spread and multiply. In most cases the shift is from mesophytic to less exacting, more xeric, forms to those that do not acquire ample soil moisture and can tolerate at all times full exposure to sun… In areas controlled by customary burning, a near-ecological

> equilibrium may have attained, and a biotic recombination maintained by similarly repeated human intervention. This is not destructive exploitation".

Sauer (1961) also pointed out to volcanism in the eastern Mediterranean and the rift valley as the first source of such fires. These contentions by Sauer have been verified by Perles (1977) in her comprehensive review of the prehistoric use of fire, claiming that "Mankind could have involved into *Homo habilis* without fire but it would never have become *Homo sapiens* without fire." This important statement can now be further corroborated by even more substantial proof from both archeological findings on Mt. Carmel and elsewhere. These will be interpreted in light of the insights we gained from our fire ecology studies and the theoretical considerations on synthetic evolution and self-organization.

4.3 Major phases of coevolution in the Upper Pleistocene

4.3.1 The Middle and Upper Paleolithic people and the evolution of the fire-induced subnatural landscapes

According to Bar-Josef (1984) the above–described lithic Acheulian assemblages still show African similarities or even origin. It was only during the Early Upper Pleistocene that the special character of early Mediterranean and Levant Stone cultures emerged, exhibiting special adaptation to these environments. This period also marked the beginning of major coevolution during the gradual intensification of human activities and more sophisticated use of fire by Mousterians and their more sophisticated stone tool and hunting techniques.

The gradual intensification of human interferences was accompanied most probably by a more efficient use of fire by Mousterian gatherers-hunters. According to Perles (1977), mastering fire was adapted about 100000 years ago by these Neanderthaloids who produced lamps to light their caves and torches to carry fire. They could open dense forest and bush thickets to facilitate hunting and food collecting and increase edible food by encouraging the lush regeneration or trees and shrubs, invading grasses, bulbs, and tuberous plants.

That these people had reached a high intellectual level is inferred by their mortuary practices. As reported by Solecki (1977) at the Shanidar cave in the Kurdish mountains, seeds of flowering plants, which grew outside the cave, were found in soil samples taken from around the burials for 'Neanderthaloid IV'. The findings of such plant species, known for their medical and ornamental values can serve as further proof of the modification of the natural vegetation and by paleolithic gatherers and their role in spreading herbaceous plants.

Evidence for the use of fire by Mediterranean Mousterian cultures has been provided also at the Kasitstra caves near Lake Ionina in Greece (Higgs et al., 1967). From this period Vernet (1973) reported findings of charcoal specimens of sclerophylls and phanerophytes such as *Phyllirea* and *Quercus* in southeastern France. From this period onward, the Tabun cave bears provided clear evidence of human use of fire by reddened earth and mixed ashes from hearths. According to Jelinek (1981), the upper Mousterian layers indicate even repeated burning of the whole cave surface, reminiscent of the practices of Australian aborigines and Bushmen for clearing their caves by fire. Ronen (personal communication) speculated that this could have been caused also by accumulation of wind-blown fine ash deposits, originating from the woody vegetation canopy surrounding the cave. It seems, therefore, reasonable to assume that from the early phases of the Late Acheulian and Middle Paleolithic cultures onward, fire became a major driving force in the mutual-causal feedback relations between these Mediterranean ancient people and their environment.

At the same time, we now have a much firmer basis corroborating the claims by Sauer of the cultural importance of human-set fires for food collection and hunting. After observing the beneficial effect of wildfires they could have realized that it could serve not only as the major energy source for heating and cooking but also for opening dense forests and brush thickets. As a result, intentional set spotty fires could have also been used to create more accessible and richer ecotones for food collecting and hunting and to increase edible food by encouraging the lush regeneration of woody plants and invading herbaceous plants. That this has been most probably the case can be inferred from the results of the fire ecology studies in the western Galilee (Naveh, 1960, 1973, 1974) and in the Carmel region (Naveh, 1999), which will be further reported in subchapter VIII.

In addition to other more or less catastrophic natural perturbations, increasing drought and fire caused by volcanic activities and by lightening acted as a strong selection force. As explained in detail by Naveh (1975), those woody and herbaceous genotypes, which developed the most efficient physiological and morphological evolutionary strategies for active and passive vegetative and reproductive regeneration mechanisms, had the best chances to overcome natural and human-induced fire stresses.

The unique combination of natural raging wildfires and human-set fires became, therefore, major landscape shaping factors, converting them gradually from natural, pristine ones to subnatural and seminatural “cultural” landscapes. As will be shown below, this process was further intensified from the Neolithic agricultural revolution onward, in which many of these seminatural biosphere landscapes were converted into agropastoral landscapes. This occurred most probably during the drier, warmer interpluvials in which the Mediterranean climate patterns became established. It created favorable conditions for the germination of light demanding woody plants, such as *Pinus halepensis* and most chamaephytes as well as for the above-mentioned herbaceous plants facilitating their spread over vast areas.

4.3.2 The epipaleolithic Natufians and the evolution of the seminatural landscape of their Total Human Landscape

During the last Pluvial (10-15,000 years ago), the fire-induced landscape modification reached its peak due to prospering and culturally advanced Epipaleolithic economies, such as the Natufians of Mt. Carmel. This period has been described by Braidwood (1967) as the final transitional stage from the more primitive economy of food gathering into the more advanced, better equipped, better organized, more purposeful, and specialized food collecting. As such, a crucial cultural and socio-economic threshold, especially in the later part of the Natufian epipaleolithic culture, has come to be in the last 30 years, one of the major foci of Levantine prehistoric research, with Mt. Carmel as one of its most important centers.

Bar-Josef (1983, 1998) has summarized and discussed comprehensively the major archeological findings and their meaning for the life, culture and economy of the Natufians. Weinstein-Evron (1998) has provided a very thorough account of all the archeological and geophysical studies carried out in the El-Wad cave, in relation to the Early Natufians from the first excavations by Garrod (1929) until her own recent palynological research and her conclusions on their use of the site and environment.

This was apparently the oldest occurrence of Early Natufians in northern Israel, and elsewhere. They occupied this cave and its terrace according to radiocarbon dated charcoal samples from around 12,940 B.P. until around 10,680 BP. This period coincides largely with the European Late Glacial and in spite of the climatic fluctuations between an earlier colder and drier period, followed by more humid conditions and by a colder interval during the young Dryas (ca 1,100-10,000), followed again by a milder climate the typical Mediterranean geographical pattern and the winter rainfall in the Late Pleistocene in the southern Levant was well established. As will be shown below, this has been corroborated for Mt. Carmel and its surroundings also by the palynological studies of Weinstein-Evron and her coworkers.

Bar-Josef (1983, 1998) has presented an impressive picture of the Natufians sophisticated technologies and subsistence strategies for a rather intensive, broad-spectrum utilization of the fauna and flora occurring in typical Mediterranean landscape mosaics in the ecotones of the mountain foothill, coastal plains and river valleys. Living in small, mobile bands and as semi-sedentary groups in hamlets, they became an example of the archeological expression of intensive gathering, hunting and fishing, along with a number of agricultural pre-adaptations, reflected in certain utensils and installations. “The social evolution that occurred in parts of these 'Proto-Mediterranean' populations seems to be an autochthonic change, resulting in differentiation between the human occupations of the Mediterranean and the Irano-Turanian zones and those of the higher mountain and deserts. This differentiation is reinforced in the following millennia and appears to be one of the basic cultural components of the Levant” (Bar-Josef, 1983; 28). Such Proto-Mediterranean populations showed some similarities to Mousterian ancestors, as well as to the scarce remains from the Upper Paleolithic and earlier Epipaleolithic remains. The Natufians were short to medium in stature and their mean age of death was about 30 years, and maximum life span may have been around 50 years. Bar Josef (1983) suggested, that the Natufians lived - like hunter-gatherers of today - **under** the carrying capacity of their environment. If we estimate their population around 500 people along the Carmel coast and its western slopes and wadis, they may have reached densities of about 4 persons/km^2. According to Baumhoff (1963), these are the densities of the coastal California Indians, to which we will refer further below.

Up to now, no other findings outside the Levant have yet posed any indications of a paleolithic entity resembling the Natufians, and probably no other cultural remains from this period have uncovered such a wealth of information providing the basis for a better construction of pre-agricultural living and socio-economic systems. Weinstein-Evron (1998) described in detail all archeological findings in El-Wad cave and the adjacent terrace connected with the organization of their living place. They even constructed houses and thus developed a complex and rich communal, cultural and spiritual life. The layout of this Natufian settlement included a cemetery and a special dumping ground for waste, indicating the high level of social organization achieved already by these early Natufians (Fig. 1).

In this cave they found a rich assemblage of lithics, ground stone and bone implements and numerous human burials, and what Weinstein-Evron and Belfer-Cohen (1993) called “a burst of artistic creativity of artistic objects and decorative items”, such as figurines, beads and pendants, as well as decorated sickle hafts. All these findings point also to the advanced hunting, food collecting and preparing technologies, such as the use of archery for hunting and of flint sickles to cut wild grasses and mortars and pestles in the preparation of staple food from roasted cereals and acorns. This roasting of cereals preceded that of the later Neolithic cultures. Their bone industry is far richer in quantity and contains more elaborate, varied morphologies than does any other earlier or later Levantine archeological entity. Many objects bear specific decoration such as the carved shafts from el-Wad and the Kebara caves with young ruminants at the edge.

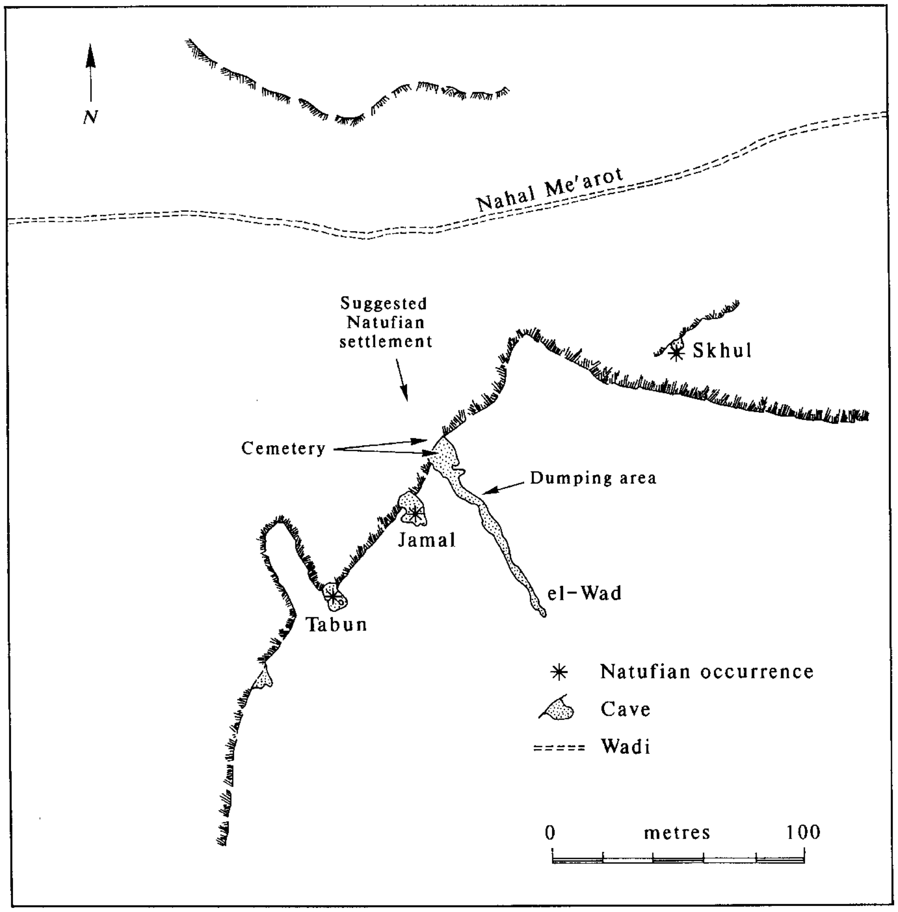

Figure 1. A suggested layout for the Natufian site at El-Wad (Weinstein-Evron, 1998)

Marine shells for jewelry were collected from the shore of the Mediterranean Sea, or more rarely, were brought from the Red Sea. Of special significance for their close symbiotic relations with nature is a horn core with a man's head at one end and a bovid's head at the other end. Red ochre fragments composed of hematite were also found on pestles in this cave, which were used for grinding of both yellow goethite and red hematite rocks. These pigments could have been produced by grinding natural hematite iron oxide extracted from the veins of rock outcrops or alluvium clays or by heating the more common goethite. Such red colors also appear on burned iron oxide, containing limestone and dolomites of volcanic outcrops of Mt. Carmel after hot brush burning with which the Natufians were most probably well acquainted.

The frequency of such volcanic outcrops on Mt. Carmel, shown in Fig. 2, can serve as a good indication for the occurrence of many hot wildfires during volcanic outbreaks in the Pleistocene in addition to those wildfires caused most probably by lightening.

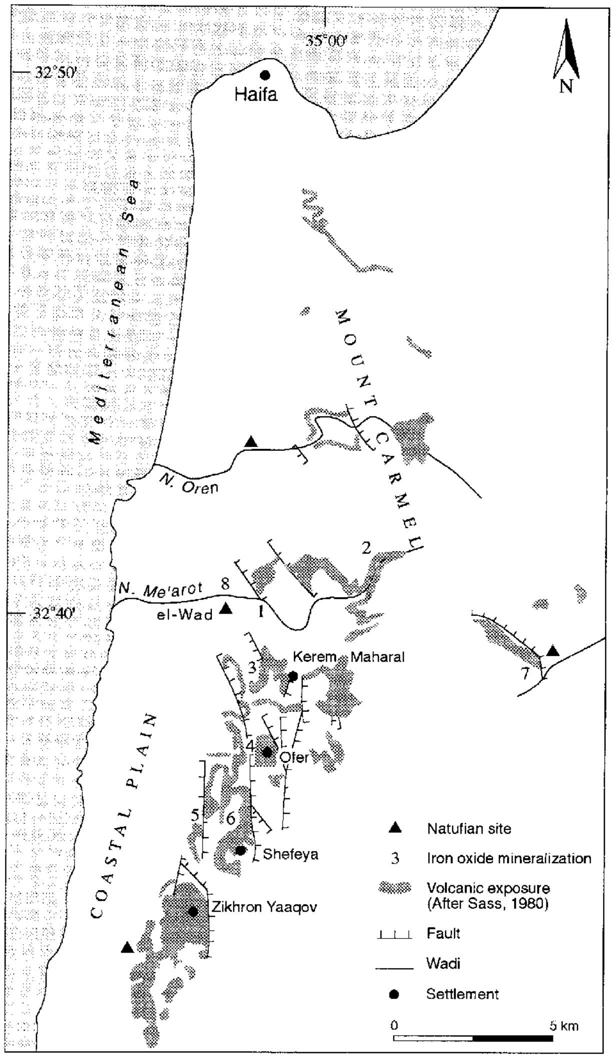

Figure 2. Location map of the volcanic outcrops and iron mineralization sites with Natufian sites of Mt. Carmel (Weinstein-Evron, 1998)

Of great significance for our contentions on the impacts of these Natufians on the vegetation are the palynological findings from el-Wad. As shown in Table 2, these pollen examples are dominated by ruderalic, insect-pollinated and many clusters of pollen, indicating human habitation and activity.

Table 2. The Natufian pollen spectra from El-Wad (Weinstein-Evron, 1998)

Pollen Type	**Sample I40c/125**	**Sample I42b/129**	**Sample** I40a/143
Quercus	10.5	12.8	7.1
Pinus	10.5	12.6	5.5
Olea europaea	-	0.8	2.2
Pistacia	3.5	1.4	4.4
Acer	1.0	-	0.3
Arbutus	0.6	-	1.4
Crataegus	12.1	1.2	10.4
Rhamnus	-	0.6	-
Ceratonia siliqua	7.3	0.4	8.2
Styrax	0.6	-	-
Myrtus	13.7	3.3	8.2
Total AP	**59.8**	**33.1**	**47.7**
Gramineae	3.5	13.0	4.6
Compositae	4.8	3.1	8.7
Centaurea	-	-	0.5
Chenopodiaceae	1.0	0.2	1.1
Umbelliferae	2.9	5.1	8.5
Plantago	0.3	0.4	-
Ephedra	-	0.4	0.3
Malvaceae	-	4.3	-
Polygonaceae	3.5	2.5	4.1
Cruciferae	-	1.4	0.3
Dipsacaceae	0.6	14.0	4.9
Liliaceae	1.0	-	-
Asphodelus microcarpus	-	2.9	-
Papilionaceae	8.9	5.1	7.9
Labiatae	7.1	6.0	5.5
Cucurbitaceae	-	1.0	-
Sarcopoterium spinosum	0.3	1.6	0.3
Caryophyllaceae	-	-	0.3
Rubiaceae	-	-	0.5
Euphorbiaceae	2.6	2.3	1.9
Convolvulaceae	1.0	0.6	0.3
Cistaceae	0.3	2.7	1.4
Primulaceae	1.0	-	-
Ranunculaceae	1.3	-	0.8
Rutaceae	0.3	-	-
Capparis	-	-	0.5
Total Counted	**314**	**486**	**366**
Clusters (No)	**1**	**-**	**76**
Tamarix	-	-	9
Olea europaea	-	-	14
Hydrophilous (No)	**-**	**1**	**1**
Sparganium			
Cyperaceae			

In this cave, the presence of Mediterranean sclerophylls was also indicated by the earlier findings of Bankroft (1937) of a few pieces of wood charcoal of *Quercus* sp. and *Olea europea* in Upper Paleolithic layers of the El-Wad cave. More recently, Lev-Yadun and Weinstein-Evron (1994) identified 32 pieces, 5-10 cm long of Early Natufian Epipaleolithic wood charcoal of *Quercus calliprinos, Q. ithaburensis, Myrtus communis Cupressus sempervirens*, *Salix* sp., and *Tamarix* sp.

According to Weinstein-Evron (1998), these findings provide further proof that the Natufians in the Carmel region lived in a typical Mediterranean landscape, representing 3 major habitats: (1) forests and maquis, (2) marshes and other wet land habitats and (3) in disturbed ecotopes, probably in the immediate surroundings, represented by ruderals such as Dipsaceae and Malvaceae. The investigator speculated that the mountains near the cave were densely covered by *Q. calliprinos* dominated maquis, and as exists today, the drier slopes by more open woodland formations of Ceratonia siliqua-Pistacia lentiscus and of the Tabor oak *Q. ithaburensis*. Pods of the carob trees *Ceratonia siliqua* and acorns of the Tabor oak were used as staple food, even until the turn of the last century, whereas *Q. calliprinos* may have been preferred as fuel and for building purposes and the myrtle Myrtus communis may have been used for its therapeutic and aromatic characteristics or even as a ritual plant.

Overrepresentation of gazelles (*Gazella gazelle*) among the faunal assemblages is generally seen as an indication of the exploitation of local game fauna from the more open, savanna woodlands and grassy sites in the coastal plains, but in our opinion also from recently burned wooded landscapes, *Dama mesopotamica*, *Capreolus capreolus,* and *Cervus elaphus* were probably hunted in the more densely wooded maquis and forests of Mt. Carmel and the coastal plain. In fact, Weinstein-Evron (1998) mentioned that *Microtus guentheri* and *Spalax ehrenbergi* were among the rodents found, suggesting the existence of stands of grasslands around the site, "resulting from human activity in the immediate vicinity of El-Wad".

The high incidence of young gazelles in several Natufian sites on Mt. Carmel may be interpreted as an attempt at a kind of "incipient domestication" although the gazelles' behavior seems not to be suitable for this. However, with the help of repeated burning, they could have created grassy pasture enclosures, surrounded by shrubland or forest to attract gazelles but possibly also to "semi-tame" their kids. Bar-Josef (1983) even speculated whether the sickles were used to cut grass for feeding gazelles.

Tchernov (1975) interpreted the appearance of typical desert rock dweller rodents such as *Acomys russatus*, *A. cahirinis,* and *Gerbillus dasyuru* as indicators of a principal climatic trend of desiccation during the Late Pleistocene. On the other hand Bottema and van Zeist (1981) suggested that the desiccation from this period onward may not necessarily have been climatically determined, but caused by the increasing human interference with the natural vegetation. The term "desiccations" should be, therefore, only interpreted as a reduction in the woody cover at the expense of the increase of a more open, herbaceous vegetation cover. This also could be a much more plausible explanation for this rodent invasion into the newly created more open and rocky sites, resulting from the increasing burning activities which most probably also encouraged the invasion and colonization of the rock outcrops of the more xeric *Quercus ithaburensis* woodlands by herbaceous plants or their more drought tolerant genotypes – such as those of *Hordeum spontaneum* (Nevo et al., 1986). These assumptions are fully supported by the contentions of the prominent Italian botanist and ecologist, Pignatti (1983) on the important human role not only in the stimulation of the evolution of the flora, but also in the evolution of new habitats in the first seminatural cultural landscapes created in the Mediterranean basin.

In his paleo-ecological interpretations of faunal remains from Mt. Carmel, Tchernov (1984) described these landscapes as "a kind of constant balance between open country and woodland". It is very possible that on the rocky and less fertile terra rossa and light rendzina soils, they were most probably dominated by sclerophyll trees and shrubs with a fire-induced and rapidly spreading light demanding herbaceous understory, maintained by rotational burning. These grasses became dominant in the fertile brown rendzina soils, and others such as *Pragmites* and *Festuca* were dominant in the wetlands. The denser and more productive stands could have been the most preferable habitats for the cutting of grasses and collecting their seeds. The latter could have been accomplished also by collecting their scorched seed dispersal units directly from the ground after burning their dry stands. According to Harlan (1967), these primitive glumed cereals needed to be parched before they could be thrashed and winnowed.

In conclusion, through intensive, vegetation management the Natufians created the first proto-agricultural seminatural Total Human Landscape. This was the most efficient way for channeling high-quality chemical energy of the natural, spontaneous-occurring wild plants and herbivores into human food production on a sustainable basis.

4.3.3 A comparison of the Natufians with Californian Pre-European Indians

One of the major disadvantages in comparing prehistoric G-H with contemporary ones is that the latter cannot be considered true pre- or proto-agriculturalists in their evolutionary development. These are only non-agriculturalists out of constrains, living in marginal environments for farming, such as arid lands or dense tropical forests. Being in contact, one way or another, with modern societies, they are not only exposed to infectious diseases, but they are also culturally “contaminated” by their tools, weapons, and information. This was not the case with the Californian Indians before their closer contacts with the Spanish missioners before 1769. Although living many thousands of years later in time, we can assume that they had reached about the same cultural evolutionary stage as that of the highly developed, sophisticated, pre-agricultural, subsistence economy - the Natufians. Like the Natufians, the Californian Indians had lived in close symbiotic relations with nature making efficient use of resources without destroying them.

Diamond (2001) maintained that the reasons why agriculture (and all following cultural and socio-economic developments) evolved in the Fertile Crescent – including the Levant and Israel some 10,000 years ago - was not because of any inherent intellectual superiority of the inhabitants over the Indians, living in comparable climatic conditions in California. This was chiefly the advantage of a larger biotic diversity and especially of a much higher diversity of wild plants – especially larger seeds of grasses (as well as legumes!) and suitable animal species for domestication.

Thanks to the extensive studies by archeologists, anthropologists, and ethnologists for many years under the leadership of Alfred Kroeber from the University of Berkeley, a plethora of information has become available on the life of these pre-European Indians lending strong support to our contentions. Much of this has been summarized by Heizer and Elsasser (1980) in a very readable and well-illustrated way.

The oldest evidence of human presence in California dates back 9-10,000 years and through time, until the arrival of the first Whites in the sixteenths century, a dense network of more than a hundred Indian tribes and tribuletes spread over the whole state. For our comparison, of greatest interest are those tribes living in ecologically comparable conditions to the Natufians in the ecotones between the coast, the foothills, and the coastal mountain. Such ecological equivalent landscapes stretch from the Carmel to the Santa Barbara regions. These were occupied chiefly by the Esselen, the Salinan, and farther south by the Chumash. As fishermen, gatherers, and hunters those closest to the coast and the coastal foothills and mountains enjoyed the richest and greatest variety of food. Their diet included salmon and many other fishes and sea food, many edible parts of plants with acorns of the seven oak species occurring in Central California, serving as a major staple food and stored in granaries even for two years. They sometimes mixed the acorn meat with edible grass seeds of wild ryes (*Elymus* spp.), and other grasses. In the vicinities of the Franciscan missions they also used wild oats (*Avena fatua*) which was accidentally introduced with wheat seeds from Europe and rapidly invaded the grassland, thanks to its pre-adaptation to similar conditions. Among the game species deer, elk, antelopes, and rabbits as well as waterfowl were also abundant. In this way, a highly versatile and healthy year-round diet was ensured. This helped them to overcome drought periods and famine better than populations of the drier inlands valleys and the South, and enabled them to reach the highest population densities of any North American Indians (Baumhoff, 1963). As reported by Heizer and Elsasser (1980), many more plants were used for medical or other purposes. Their material wealth was reflected in the elaborate round houses with wooden framing of their well-organized villages with several hundred inhabitants, in their spectacular religious cult ceremonies, and the great efforts and skill invested in the ornamentation of their tools and especially their baskets.

According to Heizer and Elsasser (1980), the Californian Indians acted as important agents for the dispersal of certain grasses, berry-producing trees, and shrubs. So far as is known from the archeological record, they never over hunted any animal to the point of extinction, and they did not seem to have affected the overall distribution of game animals and birds. As highly accomplished practical botanists and zoologists, they were also knowledgeable in understanding nature in such a manner as to use it without destroying it – that means in a most sustainable manner. Therefore, as land managers these Indians were in some ways far ahead of us today. Heizer and Elasser (1980) described their elaborate ways of making fire by various types of fire “drills” and many other uses of fire. These included the cutting down of trees, the leaching out of the tannin of acorns with hot water, and the catching of grasshoppers by firing a circular area and then roasting them in a kind of earth oven with hot rocks.

However, most relevant for our comparison is their sophisticated use of intentionally set fires, as described by these authors and in more detail also by Lewis (1973). In order to improve visibility for hunting, the grazing conditions for deer, and to increase the yields of wild grasses, fruits and berries harvest, and to uncover acorns and nuts, they set cooler fires in shorter cycles and on smaller patches than the natural wildfires. Thus, they created heterogeneous mosaics of open forests and woodlands in different regeneration stages, dominated, to a great extent as in the Mediterranean, by sclerophyll phanerophytes with a rich herbaceous understory. It resulted in the establishment of what Lewis described as “a dynamic balance of natural forces”. This is comparable to the fire-induced homeorhetic flow equilibrium of the seminatural Epipaleolithic landscapes.

Lewis (1985) carried out extensive anthropological and ecological research on the “pyrotechnics” by native North Americans and Aborigines in North Australia, who still use fire to increase their plant and animal food resources. He concluded that the general aim of such intentional use of fire in some areas, but excluding it from others is to enhance and maintain an overall fire mosaic. This means a complex, more productive, and stable environment than what would have been derived from natural fires in terms of seasonality, frequency, and intensity.

He rightly emphasized that habitat burning was but one component in the total system of foraging adaptation. According to Bean and Lawton (1973), these "semi-agricultural Indians of the central California coast reached a very 'efficient' interlocking of energy extraction processes". They suggested that Lewis' findings could provide new perspectives and ideas for other cultural evolutionists and ecologists showing how high levels of cultural integration and adaptation could have been reached by hunting, fishing, and food gathering communities in intensive proto- and semi-agricultural utilization of their natural resources. This may also be true for the advanced Epipaleolithic Natufians.

Heizer and Elsasser (1980, 220) concluded that we could see in these Indians the "true ecological man who was truly a part of the land and the water and the mountains and the valleys in which they lived. The environmentalists and conservationists of today feel a kinship with the Indians in their respect for nature, a feeling which at times rises to that of the sanctity of the natural world."

4.3.4 Some lessons from this ecological and functional analogy

This comparison lends strong support for the need in replacing the misconception on the passive environmental role of the paleolithic pre-agricultural foragers with the recognition of their active role and its far-reaching implications. The Coastal Californian Indians could also give us some cultural clues on how the pre-agricultural Natufians could reach such a peak in their coevolution with their landscapes. There is now ample archeological evidence that the Natufians developed a complex and rich communal, cultural, and spiritual life, based on an advanced, intensive, broad-spectrum, metastable, proto-agricultural food collecting-hunting-fishing economy. This resembles in many ways that of the Californian Coastal Indians at the time of their first close contacts with Europeans. Presumably, in the gradual conversion of the Carmel slopes and the open coastal plains and hills into a mosaic of seminatural ecotopes, driven by auto- and cross-catalytic feedback loops, both natural and intentionally set fire, operated also as what Renfrew (1979) defined as a "multiplier effect". It induced these mutually beneficial couplings of the Natufians with their landscapes through the conversion of denser forests and maquis into more open, diversified and fine-grained vegetation patterns, richer in herbaceous fire followers. A similar process of landscape conversion has apparently taken place along the Central Coast of California. In both cases their close symbiotic relations with nature ensured their sustainable landscape management during which fire was incorporated as a larger-scale cultural –

that means anthropogenic - perturbation factor, closely coupled with humans and wild animals foraging. In both cases, thanks to longer- as well as shorter-term rotationally shifting defoliation pressures, a homeorhetic flow equilibrium between the woody and herbaceous vegetation layers and their postfire regeneration stages could have been maintained.

4.4 The final phase of coevolution during the Early Neolithic period

Thanks to the extensive studies in Israel by such outstanding geneticists, evolutionists, and paleoecologists as Zohary, Nevo, Kislev, and their assistants a very sound scientific foundation has been provided for the actual evolutionary process of domestication in Israel and the Fertile Crescent. However, the actual causes for this transition from intensive food collection to food production are still a matter of great controversy.

Rejecting exclusively deterministic climatic or demographic explanations, Rindos (1984) has described this as the final evolutionary stage of “specialized domestication of plants and animals” by reciprocal adaptation and coevolution. Broadening the ecological and cultural scales of these symbiotic relationships we can regard them as the culmination of the self-organizing process operating in such human–landscape coevolution. In this process, new evolutionary patterns of greater efficiency in solar energy channeling from selected plants on restricted areas of these biosphere landscapes into human food production and livelihood was favored and, therefore, succeeded in gradually replacing the former patterns of gathering-hunting. This does not exclude the possibility that dramatic ecological changes such as turbulent climate changes and the extinction of big herbivores, together with increasing demographic pressures, could have caused acute crisis situations. Some or all of these factors have apparently induced the breakdown of the economic and cultural patterns, forcing the adaptation of new technologies and new ways of life, for which the above described inventions were most suitable.

Diamond (2001, p.111) has rightly pointed out that the prerequisites for planting cereals as crops were technological innovations and their adoption by the Epipaleolithic Natufians for the exploitation of wild cereals. These included “sickles of flint blades cemented unto wooden or bone handles, for harvesting wild grains; baskets in which to carry the grains home from the hillsides, where they grew; mortars and pestles, so that they could be stored without sprouting; and underground storage pits, some of them plastered to make them waterproof”. But it was also preconditioned by the greater abundance of these cereals, for which the earlier technological innovation of controlled-burning, together with rational and judicious vegetation management was at least partly responsible. This, in turn, was the result of the close cognitive and spiritual bonds of the Natufians with their natural surroundings. In this subchapter we will show that fire played a more important role in this Neolithic revolution.

Lewis (1972) has claimed that fire has played an important role in a comprehensive review essay. He also believed that in these earliest phases of the broad spectrum revolution in the oak-pistachio area, the intensification and seasonal extension of man-made fires, coupled with increasing grazing (of either wild or domesticated animals), could have provided the necessary 'shock stimulus' leading to the emergence of agriculture. On the basis of the findings in the Shanidar cave in northern Iraq at the ecotones between the Mediterranean oak-pistachio woodland belt and the semi-arid Assyrian steppe Lewis (1972) speculated that the sudden appearance of numerous larger-seeded Ceralia type grasses at the Proto-Neolithic period, together with pollen grains, which appear to be clearly domesticated, have been caused by increasing human activities and was directly correlated to the reduction of trees and to the findings of extensive, multicolored dry and dusty ash beds in these caves. As mentioned above, according to Ronen such ash deposit findings by Jelinek (1981) in the Tabun cave of Mt. Carmel could have been caused also by accumulation of wind-blown fine ash deposits, originating from the woody vegetation canopy surrounding the cave. Lewis (1972, p.209) reported that “in burns of grasslands and brushlands great amounts of fine ash become airborne which, in the less disturbed air of a cave, would have settled like ordinary house dust”.

Kislev (1984, pp.62-63) described this early stage of the emergence of cereal agriculture as “the agrotechnical revolution”, initiated by the Natufians with their intensive collection and consumption of seeds including wild diploid tetraploid wheat and barley. He considered the invention of the sickle as a major component of this agrotechnical revolution. It was twice as efficient as manual reaping and allowed the grain to ripen out fully before gathering without a loss of yield. He assumed that in the next stage of the “domestication revolution”, the invention of fields by Neolithic people was inspired by the observation of indigenous natural grasslands of annuals, such as wild emmer and barley occurring on open forest belts of deciduous oaks. He further speculated that they may have burned off unwanted grasses and used the cleared space for sowing grain” and then, later on they also cleared dense woods of evergreen sclerophyll low trees and shrubs. This transformation of the landscape from evergreen vegetation to fields with annual winter grasses started in the prepottery Neolithic from 8500-7600 B.C. We have already explained that this transformation was made possible by the use of repeated fires, inducing the post fire grass flush.

However, our fire ecology studies have shown that burning such wild grass stands does not prevent their germination in the following rain season and may even stimulate it (Naveh, 1973), preventing the germination and development of sown grasses; a very different situation is created by the burning of denser tree and shrub stands. The striking effect of their ash seed beds on the increase in grain yield, as a result of the rise in soil fertility (reported below in more detail), could have acted as a major cultural trigger and multiplier effect for initiating the cultivation of these cereals in the early Holocene on Mt. Carmel and elsewhere. As indicated by the demonstrations of Iversen (1971), flint axes could be used for the felling of well-developed oaks and other tall trees in favorable sites, burning them and exploiting their ash seedbeds for the cultivation of these cereals. That this could have been also the case on the deeper and more fertile soils of the broader riverbeds, wadis, and terraces on Mt. Carmel is implied by the findings of the great assemblages of such flint axes in the Sefunim cave by Ronen (1984). Such slash-burn rotations have been repeated several thousand years later by the Neolithic farmers in Europe (Narr, 1956). Archeological evidence for such Neolithic land clearing is indicated also by paleobotanical findings in west Mediterranean *Quercus pubescens* forests by Pons and Quezel (1985). They showed that in southern France, in the Rhone Valley, early slash-and-burn agriculture is suggested by charcoal dated 7350 B.C. There was a simultaneous decrease in the percentage of deciduous oak pollen, and a higher percentage of Labiatae and Leguminosae, *Plantago*, Compositae and other species considered to be weeds of cereal cultivation. Cereal pollen appeared at the same time.

According to Van Andel and Runnels (1995), the first European farmers established themselves in the empty plains of the Thessaly some 9000 years ago. The may have flourished there thanks to the natural irrigation of river and lake flood plains, providing favorable soil conditions for cultivation. After more than a thousand years, they spread to the Balkans and beyond and this may lead to a modified version of the “wave-of-advance model” of the diffusion of agriculture from the Fertile Crescent and the Levant, presumably driven by demographic pressures only.

There is little botanical evidence for major exploitation of the terrace foothills in Greece before the Bronze Age. However, any clearing of the willow and alder cover of these flood plains would have been poorly reflected in the pollen record (Van Andel and Runnels, 1995). Therefore, even if there is no evidence of human occupation from Mesolithic times like on Mt. Carmel and in Israel and in other locations of the Levant; we should not exclude the possibility that also here, such a slash-burn system was introduced as the first step towards crop cultivation together with the first wave of agricultural diffusion.

One possibility is that such cleared and burned forest fields, wherever established, served as “experimental” sites for many species and that those most suitable were further domesticated, while others became facultative weeds, adopting their present dual position as part of both seminatural and agricultural vegetation. Such newly open niches could have favored the emergence of obligatory weeds as an evolutionary “side product” of cultivation and domestication. All these plants together with the post-harvest remnants of the cereals and pulses served as the most valuable pasture plants for the grazing livestock whose domestication was also initiated at the Early Pottery Neolithic. The faunal remains of Mt. Carmel from this period at the Sefunim cave already contained domesticated goats (Ronen, 1984). Goats were apparently much easier to domesticate than gazelles. They are most efficient ungulates for converting the primary production of woody and highly lignified plants, together with the fire-stimulated herbaceous vegetation of the rocky Carmel uplands into animal products.

Figure 3 can give us a clue of the great agro-pastoral potentials of the el-Wad surroundings: In addition to the cultivated fields and the uplands, which could be utilized chiefly in the rain season, also the swamp and marshlands and their fire-stimulated summer-green perennial grasses and legumes could provide highly nutritious fodder. This increase in food production potentials may explain a general increase in population densities by more than five times, as estimated by Hassan (1981) after the completion of domestication around 7,000 BC.

The reduction of the earlier Neolithic mixed, broad-spectrum food collection and production economies into specialist agro-pastoral economies is indicated by late Neolithic and Chalcolithic settlement concentrations, adjacent to their field and lowland pastures on Mt. Carmel (Naveh, 1984).

In conclusion, during the final stages of the coevolution leading to the domestication of agricultural plants and animals, flint axes and prescribed burning have most probably played an important role in the conversion of the natural and seminatural forest and woodland ecotopes into cultivated and grazed agro-ecotopes. It was the beginning of a major step in the evolution of the cultural landscape of Mt. Carmel. However, by the creation of their agro-pastoral Total Human Ecosystem, the early Holocene farmer and livestock breeder moved from the Paleolithic coevolutionary reciprocal relationship with the Carmel landscape towards a more one-sided exploitation and domination of the newly created Agropastoral Human Landscape. He became the chief controlling agent, whose land use practices changed all depending ecosystem variables of vegetation and soil of the state factor equation senso Jenny (1961).

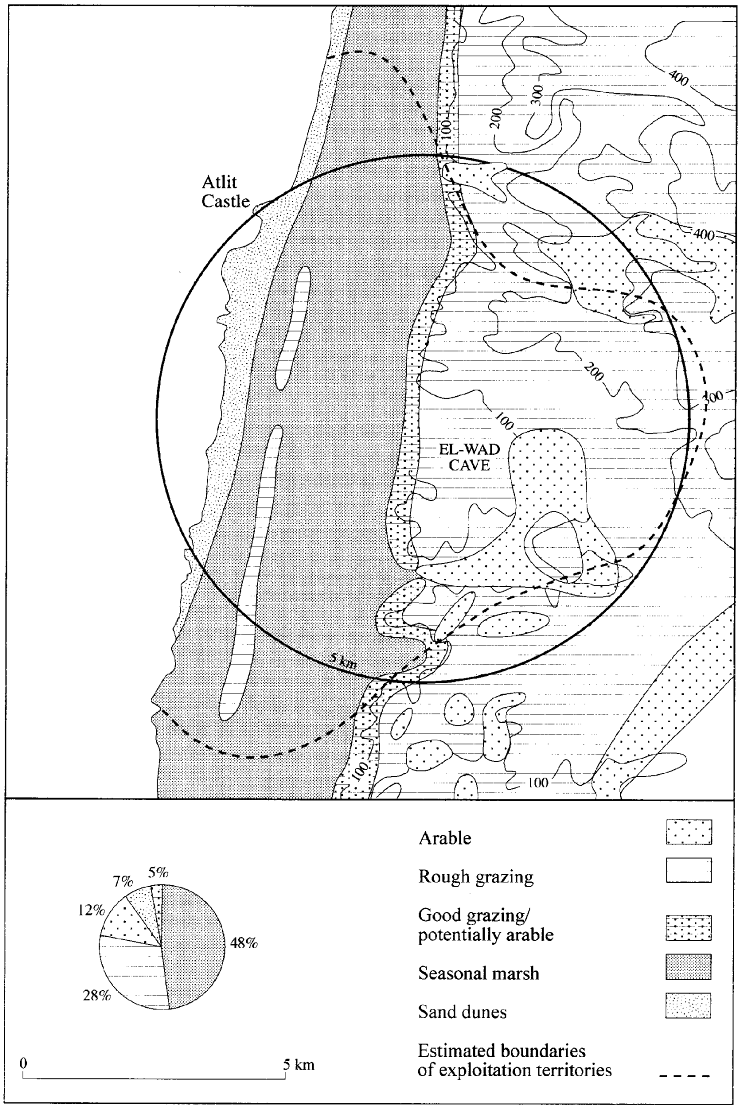

Figure 3. Territorial analysis of El-Wad, within a radius of 5 km (Weinstein-Evron, 1998)

5. THE AGROPASTORAL TOTAL HUMAN LANDSCAPE OF THE HOLOCENE

In his insightful account of the Neolithic revolution, the German landscape historian Sieferle (1997) rightly emphasized that this was not simply a transformation of a long-lasting stable situation of a pristine natural landscape into a cultural landscape. It disrupted a dynamic process of the gradual formation of seminatural landscapes, described here as a coevolutionary process. Therefore, all conservation and restoration theories and practices aimed at the return of such natural landscapes and its assumed climax vegetation are futile. We can only attempt to conserve and restore the most valuable parts of the cultural agro-pastoral landscapes, which evolved and remained as a side-product of the agricultural economy and life style until the early last century.

According to Sieferle (1996) the Neolithic revolution did not lead to an improvement of the living conditions. On the contrary, farmers had to spend much more time and energy, tilling their fields and caring for and feeding and/or herding their livestock. The nutrient value of the food became much lower and less healthy after it was reduced from the great choice of wild plants and animals into a few crops and into a few energetically expensive animal products. It led from the utilization of extensive areas of natural biomass production to its monopolization on a restricted area of cultivated land in which the crops were exposed to the hazards of great annual and seasonal climatic fluctuations and to the competition by weeds and the attacks by diseases and pests. It was, therefore, a much less stable ecological system in which the coevolution of the passive food collector and hunter (from the point of view of solar energy conversion into biomass production) with his landscapes was replaced by a much more ‘active’ participation in the food production process of energy conversion, requiring constant care for his crops and livestock. Although he dominated these reciprocal relations, this meant that more chemical and mechanical energy had to be invested and gained from the annual biomass produced than could be converted into human food and other products. The fluctuating annual crop harvested had replaced now long-term, sustainable productivity of the autopoietic production and regeneration capacities of the wild plant and animals of seminatural biosphere landscapes. It became therefore a much more fragile energetic system than that of the Epipaleolithic G-H who lived in a surplus of food, with the probable exception of catastrophic geological and climatic events. However, this was apparently not the case during the Natufian peak of coevolution, especially since he learned to raise the efficiency of energy extraction by the use of fire and vegetation management, like his Coastal Indian cultural and ecological counterpart.

Nevertheless, because of the much more intensive land use, the rapidly expanding Mediterranean agropastoralist populations “defeated” the G-H finally at the end of the Neolithic period. The conversion of the lowlands into agricultural fields almost completely destroyed the natural vegetation. It led chiefly in the less stable soils and in hilly topography to severe erosion. Its traces can still be witnessed in the erosive exposure of calcified paleosols in the central coastal plains of Israel (Dan and Yaalon, 1971).

The final formation of the agropastoral upland and lowland landscapes was initiated several millennia later in the Early Bronze Age, after the domestication of fruit trees. This was achieved by shifting from sexual production of pre-adapted wild populations into vegetative propagation of clones (Zohary and Spiegel-Roy, 1973). It reached its peak only during the Israelite period of the Iron Age from 2100 B.C. onward, with the help of iron tools enabling the uprooting of shrubs and trees and the clearing and terracing of upland fields. Wherever the slopes were too steep or too rocky for arable agriculture, favorable microsites between rock outcroppings were planted with fruit trees such as olives, figs, pomegranates, and vine grapes.

The natural vegetation was apparently left for soil protection along terrace walls and on steeper slopes between the terraces. As described vividly by Feliks (1968) on the basis of biblical sources, planted trees were protected from grazing animals by stone fences, covered with thorny brushes and thistles. All other nonarable uplands served as pastures for goats and other livestock as well as for the wildlife. Wild plants were collected for use as herb spices, medical plants, and sources for fuel and for the construction of tools (including wooden ploughs). Since they were first documented in the Bible, the Talmud and classical literature, these “polyculture” patterns of multiple upland resource utilization lasted with varying intensities on Mt. Carmel and elsewhere throughout the whole history until the middle of the last century. Combined with irrigation, water conservation, crop rotation, manuring, and stubble burning they reached their highest level of agro-and hydro-technological sophistication during Roman times. Such intensive multiple upland use can be regarded as one of the few instances in which agriculture improved the initial ecosystem factors of topography, soil parent material, and moisture regime on a long-term basis, albeit at the expense of the natural flora and fauna.

This total agropastoral landscape transformation was closely connected with the rise of the first proto-urban “technosphere” civilizations and their human-made artifacts. These left many archeological imprints on the Carmel landscape as tells and ruins, chiefly along the coast and in broad riverbeds (Kloner and Olami, 1980).

That this system was not only ecologically, but also economically viable and profitable, can be judged by the fact that in the first century, according to Flavius Josephus, the rocky mountains of the Galilee alone maintained a dense population of 2.5 million people, chiefly farmers, enjoying high incomes from the export of olive oil and wine. The demands of expanding and wealthy populations for timber, fuel, and charcoal lead to extensive forest clearing.

On the basis of many records of fire in both biblical and classical sources (Naveh, 1973, 1974; Liacos, 1974), we can safely assume that natural fires caused by lightening as well as human-set fires continued to be an integral part of the Carmel environment, and also of all other Mediterranean uplands by periodic maquis and shrubland burning to increase herbaceous fodder and to prevent the re-encroachment of dense woods, benefiting at the same time from the lush, woody, post fire regeneration.

We have no information on the timing and intensities of these fires, but is seems very likely, that the natural wildfires, which raged during geological times, were of much higher intensity, more extensive and destructive, especially those connected with volcanic activity. Lightening fires in the cooler and wetter seasons could have been spottier, also causing fires with lower intensity, which therefore had cooler fire temperatures and less far-reaching impacts. The dense woody canopy was opened, at least partly, by the fire-induced vegetation manipulation of the Pleistocene G-H and now may be even more opened by the agropastoralist throughout historical times. For the pastoralists, the desirable fire frequency is dependent chiefly on the rate of the postfire recovery of the woody vegetation that will carry the fire through. It should ensure the complete removal of the woody canopy and encourage the fast development of a dense grass cover for at least a couple of years. For a well developed maquis stand in northern Israel, the interval between such “efficient” burning could have been more than 15 years, but for highly inflammable dwarf shrub communities, or for mixed shrubs and dwarf shrubs, dominated by *Cistus* species, with an upper layer of pine trees, even less than 10 years.

In many cases the unfortunate combination of tree and woodcutting, fire, and grazing certainly caused gradual landscape desiccation, especially in drier regions and on steeper and less fertile slopes. However, as long as the woody vegetation served as the main source for fuel and construction, it was vital for the rural as well as for the emerging urban population to ensure their sustainable supply by the introduction of rotational burning and cutting systems. However, for the reasons mentioned previously, it is impossible to attain reliable pollen samples of the trees and shrubs, which could indicate their true abundance and structure in archeological sites, and, therefore, even less of such rotational management systems.

Therefore, we should be aware of the danger in being misled by the above-mentioned sweeping generalization of the “ruined landscape” theory and the wholesale condemnation of fire, goat, grazing, and woodcutting on Mediterranean uplands. There were great differences between countries and even between adjacent sites and their response to the greatly varying land use pressures. Most shallow and rocky slopes, which were neither terraced nor cultivated, have probably not undergone any extreme change since postglacial and early historic times. The fertile and fine-structured brown rendzina and terra rossa soils have suffered much less from erosion than has been generally assumed, as long as their sclerophyll - woody vegetation canopy has not been uprooted and the upper soil mantle has not been disturbed. Due to the great resilience and recuperative powers acquired during their coevolution, which took place under continued pyric, ungulate, and human pressures, the hardy vegetation provides efficient soil protection, as long as the woody plants can regenerate vegetatively from their extensive rootstocks; the herbaceous perennials from their underground bulbs, rhizomes, and other regenerative tissues; and annuals can draw from sufficient seed reserves (Naveh, 1975, 1994; Naveh and Lieberman, 1994).

Since the downfall of the Byzantine Empire, the historical changes in political regimes and population densities led to great fluctuation in human land uses and their pressures on the landscapes, soils, and vegetation. These induced a series of longer lasting cycles of anthropogenic degradation, re-vegetation and aggradation functions (Naveh and Dan, 1973; Naveh and Kutiel, 1990). Bottema and Van Zeist (1981) and Baruch (1987) found the resulting, rather dramatic changes reflected in the palynological findings in Israel. During periods of very intensive agricultural activities and heavy human population pressures, the natural vegetation receded in the face of the extension of cultivated crops. Ecological deterioration further increased during periods of instability, warfare, and agricultural and population decay such as what occurred in the last Ottoman Empire in the nineteenth century. Baruch (1987) showed that the composition of early postglacial forests and woodlands differed from that of the recent maquis and shrublands and that the abrupt increase in *Sarcopoterium spinosum* dwarf shrub formations in ancient times was connected with the abandonment of olive groves. A similar process could be observed in the first years after the establishment of the State of Israel in olive groves of the Arabic villages, which were abandoned during the Independence War in 1948. From this time onward – and until very recently - the release of the heavy pressure of grazing, burning, cutting, and coppicing on the denuded agro-pastoral upland landscapes of Mt. Carmel and the Galilee experienced a dramatic "regreening" process of rapidly regenerating woody vegetation.

From a hierarchical point of view, the shaping of this Total Human Agro-pastoral Landscape in the Mediterranean has taken place on a larger spatiotemporal scale, superimposed upon the much smaller and shorter local farming and land management practices. The former was dictated by the political rulers of the region and the resulting fate of the people and the land. The several hundred years establishment of a flourishing agro-pastoral landscape in Israel was replaced by a long period of decline, starting after the Muslim conquest (64 A.D.) and lasting for about 1300 years throughout the Arab, Crusaders, and Mameluke and Turkish rules. In many locations, pastoral nomadism gradually replaced settled crop and animal husbandry. The abandonment and neglect of terraces was the main cause for the catastrophic erosion, flooding, and siltation leading to badlands and swamps (Naveh and Dan, 1973). The metastable stage of the homeorhetic flow equilibrium and its thermodynamic consequences of the Pleistocene maintained this dual hierarchical position during the Holocene. On top of both, natural and chiefly climatic longer- and shorter-term annual and seasonal fluctuations were superimposed. The resulting defoliation pressures were, therefore, incorporated in the landscape at these different spatiotemporal scales. In this way these human-perturbation dependent Mediterranean landscapes acquired their long-term adaptive resilience and evolutionary metastability, lacking in all other Mediterranean-climate ecological systems.

6. THE TOTAL INDUSTRIAL HUMAN LANDSCAPE OF THE LAST CENTURY

In contrast to the gradual transformation from the agricultural to the industrial civilization in Europe, starting already in the 18th century, the industrial revolution was introduced to Israel (or to “Palestine” as it was called then) by the Jewish colonizers, inspired by the Zionist movement, only after World War I. As described in more detail elsewhere (Naveh and Dan, 1973; Naveh and Kutiel, 1990; Naveh and Lieberman, 1994; Naveh, 1998a), the creation of the present Total Industrial Human Landscape started after World War II and the foundation of the State of Israel in 1948. It reached its peak with the combined and synergistic processes of intensification of traditional and modern agricultural land uses and urban-industrial expansion, driven by exponentially growing populations and leading to increasing pressures on the remaining seminatural and agro-pastoral landscapes. Here, like in other industrialized Mediterranean countries, the bifurcation between the solar energy powered autopoietic biosphere landscapes and the fossil energy powered agro- and urban-industrial landscapes resulted in the most adverse effects both on human health and nature chiefly in the densely populated coastal Mediterranean region of central and northern Israel. In the uplands, also, the rapid loss and fragmentation coupled with biological and cultural impoverishment and ecological disruption by accelerated erosion and by soil and water pollution endangers the future of these biosphere landscapes and their organismic evolution. Here the severest repercussions have been caused by the disruption of the agro-pastoral homeorhetic flow equilibrium. This is the result not only from heavy grazing, cutting, and recreational pressures; but also from the complete cessation of traditional agro-pastoral activities and the disruption of the rotational prescribed pastoral brush fire cycles. On Mt. Carmel, these activities have been replaced by the planting of dense monospecies and highly inflammable pine forests on one hand and on the other hand by the noninterference policy in the nature reserve of the Carmel National Park, thereby radically changing the fire parameters. The increase in the amount of fuel, and especially that of highly inflammable pine trees, resulted in higher fire intensities and greater destruction.

This is true for all other Mediterranean countries, wherever the initially vigorous vegetative regeneration of sclerophylls from stunted and almost imperceptible rootstocks was followed by the gradual encroachment of the woody canopy and the almost total suppression of the herbaceous understory in undisturbed and protected maquis. It turned from a blessing more to a curse, when the denser brush thickets became stagnant, and possibly senescent (Naveh, 1971; Naveh and Lieberman, 1994).

Fortunately, the danger of the paradoxically unnatural “nature protection” policy has been recognized by the Israel Nature and Parks Authorities after the disastrous wildfire in the Carmel National Park in 1989, which severely damaged 300 ha of mixed pine and oak forest and maquis including one of the few remaining natural pine forests in Israel. As a result, a great number of studies were carried out after this fire, with very useful management implications for sustainable fire and fuel management, summarized by Neeman et al. (1997). These findings should become part of a dynamic conservation policy aimed at the restoration of the homeorhetic flow equilibrium to ensure the sustainable adaptive resilience and evolutionary metastability, threatened also by the dangers of climate changes facing this region (Naveh, 1995). However, such comprehensive dynamic conservation strategies have not yet been widely adopted neither in Israel or elsewhere. There are many alarming signs that the scenario we predicted 30 years ago seems to have come true. We warned that if these threatening trends of “neotechnological” landscape degradation proceed unhampered, then the few spots of remaining unspoiled open landscapes could be turned into “overcrowded recreational slums” (Naveh and Dan, 1973). Therefore, the need for a diversion of the evolutionary trajectory from breakdown and extinction towards breakthrough and evolution during the present macroshift from the industrial to the post-industrial information society is now more urgent than ever.

7. RESULTS OF POSTFIRE REGENERATION STUDIES AND THEIR EVOLUTIONARY SIGNIFICANCE

To support our contentions on the great postfire regeneration powers, further developed in part 2, some results of the fire ecology studies in the western Galilee and on Mt. Carmel, in the vicinity of paleolithic archeological sites as well as by many other, more recent studies carried out on Mt. Carmel are presented. In several representative sites on Mt. Carmel of biodiversity studies (Naveh and Whittaker, 1979) and fire ecology studies near Nahal Me'arot and Nahal Sefunim (Naveh, 1984, 1994), we counted close to a hundred herbaceous species in gaps of relatively small grassy patches and their ecotones. Of these, about two-thirds had edible parts or were of other human uses, which could have been also of great economic value for the paleolithic food gatherers (see Table 1).

The rapid vegetative regeneration of sclerophyll woody plants and the striking temporary post fire flush of herbaceous plants has been observed in all of our earlier fire ecology studies in the Western Galilee (Naveh, 1960, 1973, 1974) as well as in the most previous one on Mt. Carmel (Naveh, 1999).

This study included a comparison between an open pine forest with a dense shrub understory burned by a hot wildfire and an adjacent unburned site in the summer of 1973.

As shown in Table 3, like in all our other fire ecology studies, we observed the vigorous postfire regeneration of all sclerophyllous trees and shrubs (or phanerophytes) as well as of climbers and of almost all dwarf shrubs (or chamaephytes), geophytes, and hemicryptophytes. We observed the same, almost dramatic increase, in the herbaceous plant abundance and in floristic diversity from less than 7 to 52 species.

The striking rise of the economic value of the burned site, both for humans and wildlife is implied by the fact that out of these 52 herbaceous species 15 have high pasture values and 25 are valuable for human consumption because of their edible bulbs, shoots, leaves, fruits, or seeds. In addition, 5 woody species greatly increased their browsing values because of their lush young leaf growth.

As **obligatory root resprouters** these sclerophyllous woody plants as well as the climbers regained almost one-third of their original dense cover. Their fire-stimulated vegetative regeneration is closely linked with their hydro-ecological behavior as drought-enduring and summer active plants. Since they rely on deep and well-branched root systems, they are capable of starting resprouting immediately after the fire, even in the middle of the summer by the mobilization of stored carbohydrates and possibly also of metabolized water in the roots. Due to their year-round intensive photosynthetic post fire activity, they can recover their former ground cover most approximately 10-15 years later, depending on the site, climate conditions, and prevailing post fire grazing pressures.

Table3. Woody plant cover in unburned and burned 1000 m^2 of open *Pinus halepensis* forest with a dense shrub and dwarf shrub understory
(Average of 40 plots of 5X5 m; x = no cover value)

	UNBURNED	BURNED
Calycotome villosa	2.00	0.70
Cistus salvifolia	0.20	0
Crategus azarolus	0.19	0
Pinus halepensis	0.20	0
Pistacia palaestina	0.35	0
Rhamnus palaestina	x	0.25
Teucrium creticum	0.40	0
SUBTOTAL	**3.34**	**0.70**
Trees, Shrubs and Dwarf Shrubs 0.5-1m		
Calycotome villosa	6.65	7.55
Cistus salvifolius	55.80	2.35
Cistus villosus	4.60	6.00
Hypericum serpyllifolium	x	0
Olea europea	0	0.25
Osyris alba	0	0.50
Pinus halepensis	0.7	0
Pistacia lentiscus	9.75	6.30
Pistacia palaestina	0.20	0.60
Rhamnus palestina	x	0.25
Salvia judaica	0	0.80
Salvia triloba	1.05	1.10
Sarcopoterium spinosum	0.50	1.00
Satureja thymbra	0	0
Teucrium creticum	2.60	1.35
SUBTOTAL	**82.70**	**28.25**
Shrubs and Dwarf Shrubs 0.5m		
	UNBURNED	BURNED
Ajuga chia	0	x
Calycotome villosa	0	0.90
Cistus salvifolius	0	0.75
Fumana arabica	0.65	x
Helianthemum lavandulifoliu	0	x
Hypericum serpyllifolium	1.35	0.10
Osyris alba	0.02	0
Phagnalon rupestre	0.01	0

Pistacia lentiscus	1.45	3.30
Salvia triloba	0.10	0.50
Sarcopoterium spinosum	2.16	2.45
Satureja thymbra	0.31	0.26
Stachys distan	0	x
Teucrium creticum	0	0.35
SUBTOTAL	**x**	**0**
Cistus salvifolius	x	3.65
Cistus villosus	x	x
Pinus halepensis	0.10	4.70
Pistacia palaestina	x	0
SUBTOTAL	**0.19**	**8.35**
Climbers		
Asparagus palaestinus	x	x
Hedera helix	x	0
Rubia tenuifolia	0.60	1.0
SUBTOTAL	**0.60**	**1.00**
TOTAL WOODY PLANTS	**92.17**	**46.41**

These factors have to be taken into consideration in the assessment of the evolutionary strategies. Post fire foraging and especially browsing pressures could have acted together with gradually increasing drought periods as additional powerful selective agents. They favored those woody species and biotypes, which very soon after the fire developed hard, thorny or distasteful leaves and twigs together with the highest vegetative regeneration capacities to overcome these defoliation stresses. This recoding of information from fire and grazing may have also pre-adapted them to further defoliation catastrophes from cutting and coppicing. Outstanding examples of such successful evolutionary strategies for maximization of overall survival potentials on Mt. Carmel are the east Mediterranean Kermes oak - *Quercus calliprinos*, and the Eu-Mediterranean Pistachio shrub - *Pistacia lentiscus.* The Kermes oak is distinguished by vigorous resprouting from root crowns and suckers and adventive roots, but *Pistacia lentiscus* branches off laterally from prostrate leafy twigs that send roots and quickly form a dense, compact shrub canopy with high soil- and water-conserving features. As one, if not the most tenacious of the evergreen shrubs, it responds in the first few days after a fire by intensive cambial activity from the root tips and buds (Naveh, 1960). In the drier ecotones of the xero-thermo Mediterranean zone in Israel, on the semi-arid slopes of Mt. Gilboa, an even more drought-enduring ecotype developed than those found on Mt. Carmel (Swarzboim, 1978). Its small sclerophyllous leaves are highly resinous and very soon become distasteful. Therefore, it can withstand even very heavy browsing pressures and because of these high recuperative powers, it has remained on Mt. Carmel and elsewhere as the last woody survivor in frequently burned and heavily grazed pine forests, maquis, and woodlands.

On the other hand, *Calycotome villosa* as well as *Cystus salvofolius, C. villosus,* and all other chamaephytes including *Sarcopoterium spinosum* are **facultative root resprouters.** They can regenerate both from root crowns and from fire-stimulated seed germination, followed by vigorous growth. Most of these species also produce seeds from resprouting plants in the first year after the fire. This explains their relatively large cover values in the burned site. Perennial herbaceous plants, namely, hemicryptophytes and geophytes, have similar dual vegetative and reproductive post fire regeneration mechanisms. Like these chamaephytes, they are typical drought evaders adapting to the dry summers by more restricted physiological activity and especially by reduction of their transpiration surface. They commence resprouting only after the first winter rains from fire-avoiding underground stem bases, bulbs, tubers, and corms as well as from fire-stimulated growth from seeds. These are coupled with morphological and physiological plasticity and aggressiveness in colonization of newly opened, fire-denuded, and mineral-rich patches (Naveh, 1960).

Pinus halepensis is the only coniferous tree found in Israel, with Mt. Carmel as one of its last refuges, occupying a special status among the Mediterranean trees with respect to its response to fire. It relies solely on vigorous seed germination from cones that burst open from the heat of the fire and is, therefore, an **obligatory seed regenerator,** which can undergo natural regeneration after a fire under a dense maquis understory. Like the reseeding chamaephytes, its heliophilous seedlings are capable of establishing themselves on poor, exposed, rocky sites. This is in contrast to the above-described sclerophyll obligatory resprouters requiring more favorable, sheltered, and humus-rich seedbeds, which are not provided by the fire. As a typical pioneering colonizer the lack of resprouting ability is compensated fully by post fire germination of the great number of seeds benefiting from the temporary removal of the competition of the dense maquis understory. This is followed, in general, by a process of natural thinning out, similar to that of most chamaephytes seedlings. It leaves a scattered, rejuvenated stand of pine trees under the regenerating shrub canopy, or in the case of burned planted pine forests, more or less dense, even-aged pine stands. In this study, we found several tall (natural) *Pinus halepensis trees* in the unburned site and even more dead ones in the burned site and as shown in Table 2, we also found numerous seedlings. It can, however, be expected that only a few seedlings growing in suitable regeneration niches will survive and develop into taller trees.

In general, the rate and extent of the post fire herbaceous plant colonization is determined chiefly by the few perennial shade-tolerant herbaceous plants that survived in the dense brush cover as shade-tolerant relicts, together with the availability of seeds from their seed banks and other invading plants. As mentioned above, important seed sources for these post fire colonizers in other sites of Mt. Carmel were small, grassy patch openings and edge habitats as well as adjacent fields and waste heaps near human habitations. However, because of the rather heavy grazing pressure by cattle to which this slope was exposed, several geophytes and hemicryptophytes, especially *Carlina* sp., and other low or unpalatable herbs such as *Anthemis melanolepis, Cephalaria joppica,* and *Linum nodiflorum* had a high constancy. Otherwise, we could have encountered a much higher abundance of grasses, especially *Pipthaterum miliaceum,* and other highly palatable perennial and annual grass fire-followers, as in our previous studies of post fire protected maquis shrublands.

The latter are major components of Mediterranean woodlands and grasslands as well as of the semi-arid Steppe grasslands of the xeric Mediterranean ecotones, which are even more fire-prone and may burn year after year and are also the most successful fire-followers. In all these plants, adaptive responses to fire and its avoidance as well as to drought and grazing stresses, are centered naturally around reproductive and growth behavior. Thus, early and prolific seed production, early seed shedding, and distribution by efficient dispersal mechanisms, seed dormancy, and polymorphism – especially in legumes – increase the chances to escape fire and environmental rigor. A good example for the coupling of such survival mechanisms is 'trypanocarpy' – namely, the development of hygroscopic awns, callous tips, and other torsion mechanisms enabling to drill and bury several centimeters deep into the soil the dissimulates of many grasses. Thus, the seeds escape fire, grazing hazards and, at the same time, benefit from more favorable moisture and temperature regimes for germination. Among these grasses are *Hordeum spontaneum*, *Triticum dicoccoides* and *Avena sterilis*, the progenitor of domesticated barley, wheat, and oats and all endowed with big seeds. In these woodlands and grasslands, perennial grasses and geophytes also demonstrated the most successful strategies for maximizing overall drought, fire, and grazing survival potentials and resilience. *Hordeum bulbosum* and *Poa bulbosa*, which are also very abundant on Mt. Carmel, combine all these reproductive adaptation strategies of the annual grasses with vegetative post fire resprouting from underground bulbs. Dominating even the most heavily grazed and degraded stages of these grasslands, woodlands, and dwarf shrub bathas contribution to the stability and resilience of these grasslands is most significant. It is very unfortunate that these perennial grasses unlike the successful annual grass invaders, have not been introduced to Californian grasslands and woodlands, which are lacking similar resilient perennial pasture plants (Naveh 1967, 1973; Naveh and Dan, 1971).

More recently, on the basis of extensive fossil records in California, Axelrod (1989) also reached similar conclusions for the evolutionary role of lightening and volcanic fires together with the increasingly stressful environments during the late Pleistocene and Quaternary in pre-adapted sclerophyllous taxa and on fire-favored speciation. He rightly maintained that in countries with Mediterranean climates it was the elimination of summer rain that imposed strong selective factors, including increased fire frequency on sclerophyllous vegetation.

In general, this post fire flush of herbaceous species is only temporary and after 3-5 years the woody brush cover will take over again. This temporary post fire flush of herbaceous plants and the fire-stimulated vegetative and reproductive regeneration dynamics, is very similar to that of the California chaparral, where it has been called "*autosuccession*" by Hanes (1971). In northern California, controlled burning of dense chaparral is used as a common practice to raise its carrying capacity for hunting deer as a sport and has resulted in a manifold increase of their carrying capacity (Biswell, 1989). After the hot wildfire on Mt. Carmel in 1986, these ruderalic plants spread from the waste heaps of Kibbutz Beth Oren to several adjacent forest gaps and dominated the herbaceous fire-flush. Here, *Hordeum spontaneum* and *Piptatherum (Oryzopsis) miliaceum* were most abundant. The latter is also the most prolific shade-tolerant fire-follower perennial grass, and is one of the last herbaceous survivors in the maquis thicket regenerating after fires as on Mt. Carmel (Naveh, 1984) and in the western Galilee (Naveh, 1974). Its plentiful millet-like seeds can be baked and used as staple food, in a similar way to its American counterpart *Oryzopsis hymenoides*. The latter is called "Indian Rice" because the Indians of the drier western ranges gathered its seeds in quantities by cutting wild stands. The same practice may have been applied to *Piptatherum miliaceum*, growing in dense and stout bunches, which can be cut shortly before ripening, i.e., annual grasses. In *Hordeum spontaneum,* this has been demonstrated by Harlan (1967) with the help of a flint-sickle of the type found in the Natufian layers of the El-Wad cave on Mt. Carmel. The same may also be true for *Triticum dicoccoides,* the most important progenitor of wheat of which several relict populations can be found on open grassy sites and near rock outcrops on Mt. Carmel. In its major natural habitat on the fire-swept slopes of the eastern Galilee hills facing the Jordan Valley, this grass, together with *Stipa tortilis, Avena sterilis* as well as many others re-colonize after fire year to year. The latter is also the most important grass component of the open Tabor oak savannas and other grasslands whose germination is stimulated by the heat shock of the grass fire (Naveh, 1973).

The above-mentioned fire ecology studies further revealed that these herbaceous fire followers serve as an efficient sink for the follow-up post fire flush of nutrients released in the first winter rain season. In brown rendzina soil, collected two months after a hot wildfire in 1983 on Mt. Carmel, in an open pine forest with a dense and well-developed maquis shrub cover, we found a striking increase in water-soluble nutrients, especially of nitrogen and phosphate in the first winter and spring after the fire in the upper centimeters of the soil (Kutiel and Naveh 1987a,b; Kutiel et al., 1990). This post fire nutrient flush was rather short-termed, but it could be utilized by the herbaceous fire followers for proliferous forage and seed production. These plants, and probably also the rapidly regenerating dwarf shrubs, serve as an important link in the recycling of these nutrients to the soil from which the resprouting, deep-rooted, woody plants can benefit in the following years. In one experiment, pot-grown wheat in the upper 2cm layer of this burned brown rendzina soil, produced 6 times more phytomass and 12 times more seeds. Of special significance for the enhancement of nutrient cycling is the 4.5 times increase in root production, facilitating the manifold increase in nutrient accumulation in the plants. The striking post fire increase in seed production leads strong support of our above-mentioned hypothesis that such favorable ash seedbeds served as triggers for domestication of cereals and their incipient cultivation in slash-burn rotations on Mt. Carmel and elsewhere in the early stages of the agricultural revolution.

This process most probably reached its peak by the Epipaleolithic cultures, and probably had a much greater impact on the vegetation and, therefore, on the landscape as a whole, converting these into seminatural landscapes. Human uses and impacts were further intensified from the Neolithic agricultural revolution onward in which many of these landscapes were converted into agropastoral landscapes and the “humanized” Total Human Landscape was created.

We can, therefore, also safely assume that in addition to other, more or less catastrophic natural perturbations and to increasing drought, as well as human and wildlife foraging, fire originating from volcanic activities and lightening, and from long-lasting human interventions acted as a strong selection force. Those woody and herbaceous genotypes, which developed the most efficient physiological and morphological evolutionary strategies for active and passive vegetative and reproductive regeneration mechanisms had the best chances to overcome the natural and human-induced fire stresses. This occurred most probably during the drier, warmer interpluvials in which the Mediterranean climate patterns became established. It created favorable conditions for the germination of light-demanding woody plants such as *Pinus halepensis* and most chamaephytes as well as for the above-mentioned herbaceous plants facilitating their spread over vast areas.

8. RESILIENCE TO GRAZING

Because of their adaptation to high light intensities (Langer, 1979) wind pollution, and seed dispersal (Stebbins, 1972), we assumed that Mediterranean grasses have evolved in the drier, more open ecotones, in fire-opened gaps, in more humid forests, maquis, and shrublands. According to Stebbins (1981), they coevolved with grazers and have adapted to being grazed. However, as Belsky (1986) has shown, these adaptations suggest an antagonistic relationship and not with deleterious effects of herbivores. These may have contributed to the evolution of effective structural, chemical, and phenological defense mechanisms. Following the arguments of Axelrod (1959, 1989), both the Mediterranean and the Californian sclerophylls adapted to fire. This may have also pre-adapted them to grazing and browsing. But, as will be discussed below, it has not yet been confirmed that this is also true for the Californian sclerophyll.

On the other hand, in the case of these Mediterranean grasses, there seems to be no doubt that the adaptive defense mechanisms against grazing have also been effective against cutting and fire. As discussed already in part 1 of this essay, in annual grasses as well as in the legumes and other highly valuable pasture plants, these adaptive responses are centered naturally around early and prolific seed production, early seed shedding, distribution by efficient dispersal mechanisms, seed dormancy, and polymorphism – especially in legumes – increasing their chances to escape fire, grazing, and environmental rigor. Of special selective advantage, in this respect, is the capacity to drill and bury their dissimulates several centimeters deep into the soil by trypanocarpy and this may be one of the reasons why *Avena* and *Erodium* species became such successful invaders of California grasslands, in spite of their high palatability.

The same is also true for their ability to compensate fully or partly for lost tissue of biomass production both to grazing and fire with increased tillering, protected ground level meristem, and in perennial plants also with vigorous vegetative reproduction (Stebbins, 1972). *Hordeum bulbosum* and *Poa bulbosa* are the most resistant perennial grasses against heavy grazing pressures in the Mediterranean because they combine all these vegetative and reproductive adaptation strategies, which are apparently lacking in Californian perennial grasses. If they would have been introduced accidentally, like so many annual grasses, they could have contributed much to a better resilience of the Californian grasslands (Naveh, 1967).

At the same time, grazers and browsers together with natural and human-set fires may have helped in the creation and maintenance of open vegetative canopies. Therefore, they may have also played an important role with fire and the paleolithic G-H in the cross-catalytic network of the previously described coevolutionary process.

We have no reliable information on the actual animal husbandry and herding practices not only for prehistoric times, but also for most of the Holocene until the last centuries. Tchernov and Horowitz (1990), in their attempt to fill up this gap, assessed the effect of herding practices by relating fossil remains of goat + sheep (caprovines)/cattle ratios to current pasture carrying capacities in the regions of these bone findings in the last 6000 years. They claimed that the tendency of increasing frequencies of caprovines reflected lowered-carrying capacity associated with “overgrazing”.

It is outside the scope of this essay to discuss in detail the results of this 1990 study. However, the major handicaps for the conclusions are: (1) It is impossible to apply modern carrying capacity standards to traditional, and even less to ancient ones, especially since the survey took into consideration the requirements chiefly for modern beef cattle ranching. (2) The results of this survey on carrying capacity in the northern and central Mediterranean parts of Israel, carried out about 50 years ago, were determined to a great deal by the amount of the shrub cover, which is much less valuable for this purpose. The woody-herbaceous vegetation layers relation are highly dynamic and change according to the prevailing homeorhetic flow equilibrium, as described in part 1. (3) “Overgrazing” is a very vague term and can hardly serve as an indicator for the decrease in productivity of these ancient pastures. We can, however, safely assume that these pressures on the open pasturelands increased gradually together with the increasing population densities on one hand and that of expansion of the cultivated land in the uplands, on the other. This happened most probably from the Iron Age onward and after the domestication of fruit trees in the Bronze Age, reaching its first peak in the Hellenistic and Roman periods. But at the same time, stubble grazing of the fields after the harvest, together with other agricultural residues could have partly compensated for these losses. These pressures were most probably considerably reduced during the periods of receding agricultural activities and the abandonment of fields and olive plantations, leading to a new, longer-term cycle of the homeorhetic flow equilibrium. At that time, the neglect of terraces in the uplands and their ‘invasion’ by grazing livestock and their shepherds could have accelerated their destruction and the resulting erosion events described by Naveh and Dan (1973).

The short-term homeorhetic cycles were maintained chiefly by annual and seasonal climatic fluctuations, by determining the quantity and quality of the available forage and by herding practices. It is very probable that these, like the field crop and horticultural practices, have not been very different from those practiced by the Arab Fellahin and pastoralists until the middle of the last century. The same may be true for most other Mediterranean pastoralists. Contrary to colder temperate regions, where the livestock has to be kept inside and stall-fed in the winter, here they have been grazed all year round without the need for any substantial nutritious supplementary food. Therefore, the availability of fodder during critical periods of drought and dry seasons, before the onset of the heavy winter rains, became a major limiting factor for the number of cattle, sheep, and goats that could survive between years, i.e., wild herbivores. For seminomadic and nomadic pastoralists from the drier regions, the availability of water became an additional severely limiting factor, but on the other hand, they were more flexible in the movements of their herds than the sedentary Mediterranean farmers.

The latter could not allow themselves to keep their livestock numbers for maximum exploitation of the peak spring pasture productivity, but had to adjust these more or less to its lowest levels to get any reasonable economic return from animal products for his family and the market. For the same reason, grazing pressures at the spring peaks were never heavy enough to prevent efficient seed production of most annual pasture plants, on which future productivity depends, especially, since these have developed such efficient autopoietic pathways throughout their long evolutionary history ensuring their high reproductive regeneration capacities.

On the other hand, “overgrazing” leading to irreversible degradation and productivity is typically only for modern livestock husbandry in Mediterranean pastures as well as in California. This additional energy input goes into the trophic pasture-herbivore system by supplemental fodder to overcome the natural limits of biomass production of these seminatural biosphere landscapes. Therefore without special rotational-deferred grazing management, the heavy exploitation during the whole growth and reproduction cycles of the palatable pasture plants can lead even to their complete destruction. The artificial removal of the above-described limiting factor by supplemental food and water supply is also the main cause for “desertification” all over the world.

9. COMPARISON OF VEGETATION REGENERATION POTENTIAL BETWEEN THE MEDITERRANEAN REGION AND CALIFORNIA

Convergent evolution is commonly defined as the expression of a similar set of characteristics among organisms or ecosystems that are phylogenetically unrelated or geographically disjunct when subject to similar agents of natural selection (Cody and Mooney, 1978). The comparative study of Mediterranean-type ecosystems is prominent among studies of convergent evolution (Richardson et al., 2001). Naveh (1967) described similarities between plant species and vegetation formations in California and Israel noting many important differences. Zinke (1973) found resemblance between soil-vegetation relationships in Italy and California. Evidence has been provided for similarity in plant anatomy (Kummerow, 1973) and successional trajectories (Armesto et al., 1995) within Mediterranean regions in Chile and California. Fuentes and Munoz (1995) have argued that convergence between Mediterranean-type eco-systems would have been even stronger if not for the disparate nature of human effects on the landscape in these ecosystems. Reviewing many studies of convergence in Mediterranean-type ecosystems, Cody and Mooney (1978) concluded that much of the similarities can be interpreted in terms of convergence, and much of the biotic dissimilarities can be explained by the many environmental and historical differences between the disparate continents. However, in all these and many other studies, one common conclusion is that dissimilarity among systems is common regardless of the chosen ecological attribute used to examine convergence.

Given this equivocal support for convergence, some studies have claimed that the notion of convergence is imaginary with no basis in reality (Shmida, 1981; Barbour and Minnich, 1990). We believe, however, that the question of convergence cannot be addressed with simple binary (true or false) answers. Rather, it is one of degree, where the strength of convergence is dependent upon the degree of similarity in environmental factors (through evolutionary time) and the degree to which these factors affect the evolution of species and ecosystem traits. Climate is considered the major factor that drives convergence in Mediterranean-type ecosystems (Di Castri and Mooney, 1973). Thus, the amount of convergence between two specific systems is a function of the similarity between their climates and of the degree to which climate determines the character of each trait considered in the assessment of convergence. We hypothesize that strong convergence is expected for traits determined largely by climate (e.g., plant phenology), and nonconvergence is expected for traits determined largely by edaphic or historical factors (e.g., reproductive strategy).

Ecosystem resilience (i.e., ecosystem behavior following disturbances) is an important trait of ecosystems (Likens, 1992). Westman (1986) reviewed concepts and measures of resilience, which he defined as the degree, manner, and pace of change of recovery properties following disturbance.

In particular, woody vegetation regeneration following disturbance can show characteristic rates and spatial patterns within different ecosystems (Glenn-Lewin and van der Maarel, 1992). As a characteristic of ecosystem, resilience is clearly determined by the evolutionary history of the region rather than by its climate. Thus, in different Mediterranean type ecosystems, even with similar vegetation structure, dissimilarity is expected for rates and patterns of vegetation regeneration.

Our chapter has thus far indicated in numerous ways that the evolutionary history of the Mediterranean region has diverged to a new, distinctive path of total human impact during the early Holocene, some 10,000 YBP, while in California, human impact on the land was limited to G-H cultures until 160 years ago (Axelrod, 1977; Mensing, 1998). We envisage that the divergent evolutionary history of the two ecosystem types is reflected in the regeneration potential of the system, both at the landscape level and at the individual level. In order to test if this is indeed the case, we compare the results of available studies of vegetation dynamics in Mediterranean type ecosystems.

We searched the literature for studies that quantified vegetation change following disturbances in California and Mediterranean systems. Quantitative studies of vegetation change at the landscape scale and changes across several decades are not common. The studies we found varied in their spatial and temporal scales and reported results in ways that often differed from our study. Yet, for four studies from California and five studies from the Mediterranean basin we were able to calculate a common system attribute, the average annual change in tree cover as an indicator of vegetation regeneration rate. The studies of Mediterranean ecosystems that provide quantitative data on vegetation change on the landscape scale indicate rates larger than those in California **by a factor of 2 to 20** (Table 4). These results are consistent even when high precipitation areas in California are compared with low precipitation areas in Israel regardless of the type of disturbance from which the area is recovering.

These results strongly suggest divergence rather than convergence in vegetation resilience between the two regions. We interpret these surprisingly profound differences as an indication of the crucial role of evolutionary history in shaping ecosystem characteristics.

A definitive test of our hypothesis may be a controlled experiment in which species from both regions are growing in the same controlled environment under treatments that mimic various natural disturbances. In an effort to address this issue experimentally, we have recently initiated a mutual transplant experiment involving acorns from several Mediterranean and Californian species in order to compare seedling growth rate and responses to various types of experimental disturbance. This study should help determine whether Mediterranean species are inherently capable of more vigorous regeneration than California species in response to various disturbance types.

Table 4. Average annual change in tree cover, calculated using data from different studies of vegetation dynamics in California and in the Mediterranean basin (Carmel and Flather, 2003)

Region	**Source**	**Site name (recovering after)**	**Precip-itation**	**Study period (in years)**	**Average annual change in tree cover**
California	Brooks and Merenlender, 2001	Hopland area (clearing)	900	28	0.11%
California	Scheidlinger and Zedler, 1979	San Diego County (not specified)		42	-0.05%
California	Callaway and Davis, 1993	Gaviota State Park, nongrazed (heavy grazing, fire)	600	42	0.43%
California	Callaway and Davis, 1993	Gaviota State Park, grazed (fire)	600	42	0.20%
California	Carmel and Flather (in press)	Hastings Nature Reserve (abandonment of agriculture, fire)	600	56	0.25%
Mediterranean	Paraskevopoulos et al., 1994	Mt. Pilion, Greece (clearing)	475	30	2.03%
Mediterranean	Samocha et al., 1980	Adulam, Israel (heavy grazing)	450	22	1.59%
Mediterranean	Samocha et al., 1980	Bar Giora, Israel (heavy grazing)	550	22	0.92%
Mediterranean	Preiss et al., 1997	Montpelier, France (agricultural practices)	1150	33	0.95%
Mediterranean	Kadmon and Harari-Kremer, 1999	Mt. Carmel, Israel (agricultural practices, heavy grazing)	700	32	1.06%
Mediterranean	Carmel and Kadmon, 1999	Mt. Meron, Israel (agricultural practices, heavy grazing)	900	28	1.3%

10. DISCUSSION AND CONCLUSIONS

We have presented here the evolution of the cultural Mediterranean landscape in Israel, especially on Mt. Carmel, as an integral part of the evolution of the ecological, social, and economic system of the Total Human Ecosystem (THE). In this THE, the natural landscape elements evolving from the geosphere and biosphere and the cultural artifacts resulting from the evolution of the human noosphere are together forming a hierarchical structured interacting network along multiple nested scales of this Total Human Landscape(THL). I used “cultural” landscapes in the broadest sense, for those landscapes in which human habitation and activities have modified the pristine, natural Pleistocene landscape first into a subnatural, then into a seminatural, and finally into an agropastoral landscape. As a coevolutionary process, it occurred simultaneously with the cultural evolution of the paleolithic G-H, namely, the development of his cognitive and spiritual facilities of thinking, speaking, and acting clearly distinguishing him from his hominid ancestors and relatives.

There seems to be a general consensus that the Neolithic Agricultural Revolution was the first major wave of change in the life of the paleolithic food gatherers and hunters. The Neolithic Revolution has been regarded, also by Laszlo (2001), as the first major bifurcation “that rocked stone-age societies”. We do not agree to lump together the hundreds of thousands of years that passed since the arrival of *Homo erectus* in Israel and the Mediterranean basin until the emergence of *Homo sapiens sapiens* into a linear process of cultural and socio-economic evolution. Although we cannot state their exact timing and duration and we know very little of the temporal and spatial dynamics of previous bifurcations, we assume that these occurred as definite phases in the advancement of the G-H and their economies to higher levels of complexity. These are well reflected in the different phases of the evolution of the Pleistocene “cultural” landscapes and proceeded according to Laszlo's (2001) description in several stages. They include innovations in tools and operational devices of greater efficiency that induced changes in social and environmental relations, and brought a higher level of resource production, a faster growth of the population, greater social complexity, and an increased impact on the environment. These new social and environmental conditions catalyzed changes in social organization and economic systems, and in the last stage a new set of values and world-views were introduced to readapt society to new conditions.

In our opinion, such different phases of bifurcations of human cultural evolution more or less characterized these earlier bifurcations of landscape transformations, which led to a more “humanized” seminatural THL. However, contrary to all later bifurcation whose durations have accelerated from thousands to hundreds of years and presently even to less than half a century, they were much slower lasting for very long, geological periods until their impacts left traces in archeological and other findings.

We claim that in this coevolution the use of fire could have been the first technological invention that triggered mutually reinforcing auto-and cross-catalytic feedback loops forming a closely interwoven network with the impacts of human habitation and foraging activities. It led to the expansion of the first small-scale, open, “cultural”, habitat patches of ecotopes and of the fire-opened forest, maquis, and shrubland gaps in space and time.

This could have been, therefore, the first major bifurcation changing the life of the primitive paleolithic humans together with the transformation of the Pleistocene pristine landscape into a mosaic of natural and subnatural THL ecotopes. As previously mentioned it was most probably a very slow process, occurring in the Upper Paleolithic, described in subchapter C1. This bifurcation probably led to a new, more dynamic level of self-organization of this evolving subnatural THL. As indicated by the finding of the Neanderthaloids Shanidar cave, this was closely coupled with a higher level of self-organization of these people.

A further major bifurcation, much shorter in time and probably much more extensive in space, occurred during the transition from the Upper Paleolithic to the Epipaleolithic, 20-15,000 years ago. It led to the creation of the intensively managed seminatural landscape of the Natufians. In this case, human impacts caused more far-reaching changes and more complex interacting cross-catalytic loops. In the long-range, human-set fires probably became more important than natural fires and the advanced technologies of food collecting, storing and preparing and for hunting introduced new perturbation factors, which were incorporated in the landscape system and its metastable homeorhetic flow equilibrium. Among these was the selection of preferred grasses for cutting and for seed collection as well as the more intensive grazing by ungulates and especially gazelles, which had replaced the bigger extinct mammals.

The third major bifurcation occurred during the Neolithic Revolution together with the gradual conversion of larger and larger pieces of arable seminatural landscapes into agropastoral ones, simultaneously replacing the coevolutionary symbiotic relationship between people and their landscapes and nature by human dominance. However, the replacement of the productivity of the spontaneous flora and fauna of autopoietic and regenerative biosphere landscapes with the much larger, but less reliable biomass production led to a new, much narrower coevolution between the farmer and his domesticate plants and animals. Although it advanced the efficiency of energy extraction from his crops and animals, it did not ensure more sustainable, natural, renewable resource utilization. On the contrary, it caused many great environmental upheavals, which were not only prevented, but were further aggravated by the most dramatic agrotechnological advances of the modern, intensive, agricultural industry of the last century. This third major bifurcation is missing completely from California that 'jumped' directly into the agro-industrial age almost 10,000 years later.

It is the choice of human society and its leadership to prevent further biotic degradation and extinction and to mobilize all its political, scientific, economic, and spiritual forces to ensure a better sustainable future for nature and humankind. This is also the choice for further biological and cultural evolution (Laszlo, 1994; Naveh, 2003). The hope for a sustainable future of our biosphere landscapes and our post-industrial Total Human Ecosystem as a whole has been expressed lucidly by Laszlo (2000, p.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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