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This paper has been contributed in honor of Azaria Alon on the occasion of his 90th birthday.

Forest management in Israel—The ecological alternative

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ABSTRACT

Forest management (silviculture) is a long-established applied science, but also a field whose sustainability and ecological implications have been questioned. In this paper, we present the basic features of commercial forestry together with a review of novel approaches for ecologically oriented forestry. The "new forestry" advocates for multiple-species and structurally complex forests, and is directed toward a diverse array of objectives (ecosystem function, biodiversity conservation, wildlife habitats, visual quality, nutrient recycling, water retention, soil productivity, carbon sequestration, and amenity values), in addition to the provision of classic economic forestry commodities.

In temperate forests, economic goals have not been abandoned. The challenge in these systems is to develop a new silvicultural approach that will keep forests sustainable and also fulfill their traditional timber production function. In Israel, the majority of forests are not economic in the traditional sense; therefore, the shift toward more ecological management should be easier. We discuss the applicability of ecological forestry to Israeli forests, suggesting ways by which forest management can be adapted for the new forestry objectives. The scientific community can aid this process by providing technical expertise to help bridge knowledge gaps. We hope that this discussion will help to create some common ground for discussions between conservationists and foresters in Israel in years to come.

Keywords: biodiversity, ecological services, ecosystem management, forest management

INTRODUCTION

Azaria Alon, to whom this issue is dedicated, was one of the prominent leaders of the Israeli conservation movement from the early days of the country. The extensive afforestation activity that was carried out by Keren Kayemeth LeIsrael (KKL, the Jewish National Fund)—the forest authority of Israel—in the 1950s and 1960s, was a very hot issue on the agenda of what later became the "green" organizations. As a matter of fact, the essence of this argument can be easily observed from Azaria's home—Kibbutz Beit Hashita—which is located in the Jezre'el Valley in northeastern Israel. Overlooking the valley from the west is the Gilboa Ridge, a lofty, rocky, bare structure. The semiarid climate and the karstic landscape of the Gilboa support an herbaceous steppe, with scattered trees that bloom impressively in the spring, but soon wither and give the mountain a barren look for most of the year (reminiscent of the Biblical verse: "Ye mountains of Gilboa, let there be no dew, neither let there be rain, upon you" (II Samuel 1: 21).

Afforestation of the Gilboa Ridge began in 1945, but the massive campaign (~1000 ha) took place from 1960 to 1966. The purpose of this activity was to change the Gilboa landscape and to return its "historic" green

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cover, even though it is not clear whether such vegetation ever existed at this site. Moreover, the foresters decided to plant a dense Aleppo pine (*Pinus halepensis* Mill.) forest on top of the mountain, since this tree grows quickly, is well adapted to dry habitats, and can quickly provide shade for recreation. Conservationists advocated leaving the mountain in its natural, somewhat bleak state. The current look of the Gilboa—covered partly by pine groves and partly by the natural herbaceous vegetation—is the compromise between the two conflicting approaches. This debate has continued in other parts of the country ever since. At present, the uncultivable countryside in Israel is clearly divided between afforested areas and nature reserves, much like the Gilboa ridge itself. The planning process regarding open spaces in Israel is almost complete, and it is time to examine the actual management practices that have been applied in the field and their respective outcomes. For a similar discussion concerning the management of nature reserves in Mediterranean landscapes, see Perevolotsky (2006).

Forest management in Israel is largely based on classical, timber-oriented silviculture, even though it has been clear for years that most Israeli forests do not produce enough wood to become an economic source of timber (Amir and Rechtman, 2006). Many conservationists still perceive the monoculture pine forests as inappropriate for the local natural conditions and foreign to the natural landscape of the country. In recent years, the ecological aspects of forestry, including the management of timber-oriented forests, have received much public, professional, and scientific attention, particularly in Western Europe and the US. In this paper, we review the ecological approach to forest management (also known as "New Forestry") and discuss its applicability to Israeli forests. We hope that our discussion will contribute to create a common ground for discussions between conservationists and foresters in Israel in years to come.

CLASSICAL FORESTRY—AN OVERVIEW

Humans have been using natural wood for fuel and building since ancient times all over the world. In our early history, the demand for wood was constrained by the small size of most human populations and their limited needs and by the technology available at the time, thus making timber use fairly sustainable. Forest management was first initiated as timber demands increased, with the understanding that uncontrolled exploitation of forests leads to drastic changes in forest composition and quality and, later, to the degradation and extinction of the forests. Therefore, forests must be continuously managed in order to secure sustained and constant growth while ensuring good wood yield.

Commercial forestry is based on the idea of sustained yields—removing amounts of wood from the forest that are commensurate with new growth. This production system is meant to maximize and sustain the yield of a single resource—commercial timber—and is also meant to reduce insect, disease, and fire risks (Behan, 1991; O'Hara et al., 1994). Once demand for wood grew and economics became a leading factor in forestry, mono-specific, even-aged plantations were favored. Such homogeneous stands are particularly useful because they allow efficient harvesting of entire stands at a suitable age or when a certain yield has been reached at the end of the forest cycle. Timber-oriented forestry encouraged the development of agricultural-style management strategies involving site preparation, planting, and clear-cutting, and the introduction of exotic species, which doubled and even tripled the productivity of the natural forest (Spurr, 1979). Consequently, many forests today are man-made monoculture and not natural.

Over time, silvicultural management of commercial forests has improved and is termed "scientific forestry", as it is based on forest ecology (silvics) and applied modern crop science (breeding, genetics, pest management, and modern agricultural techniques including replanting, fertilization, pruning, and thinning). This knowledge is then applied for rapid production of timber (Baker, 1950; Brooks and Grant, 1992b).

Classical forest management (silviculture) focuses on the stand level, a fairly broad term usually referring to an even-aged plot with similar composition and general appearance (Baker, 1950). The tools of commercial forest management are mainly designed to create and maintain monoculture, even-aged stands that provide quick-growing, easy-to-exploit, and inexpensive-to-manage timber yields that will maximize economic profits. Such forest stands are supposed to be free of competition from other trees or shrubs (Smith, 1972). The main practices of commercial forestry are site preparation and planting, the maintenance of stand structure through regular pruning and thinning, and tree harvest. Forest planning is mainly concerned with the selection of tree species and provenances to be planted and planting techniques and practices (density, locations). The trees to be planted are grown in nurseries from seeds, usually collected from selected seed-trees that display favored phenotypes (i.e., large trees with a straight trunk). Ideally, seed-trees should also be well adapted to the ecological conditions present at the planting site. However, in many forest plantations around the world, including Israel, nursery stocks are created from seeds of foreign provenances, and in many cases, they include exotic tree species that are known to give good results. For example, most Aleppo pine plantations in Israel were grown from seeds of tree provenances imported from Greece, Italy, and other countries in the Mediterranean Basin (Schiller, 2000). Most other planted trees are exotic to Israel (e.g., eucalyptus, *Acacia saligna* (Labill.) Wendl., and *Pinus brutia* Ten.).

Silviculture uses tools such as mowing, mulching, mechanical cultivation, burning, and the application of herbicides to remove competing vegetation while preparing a site for planting. Sometimes planting is followed by a period of weed control and even additional irrigation to improve tree establishment, especially on poor-quality sites.

Pruning, the removal of side branches, is done to maintain a single central leader, repair storm damage, or to promote clear trunks and hasten the production of high-grade lumber logs. Pruning mimics the natural process of self-pruning, by which old and heavy branches die and break off over time.

Thinning is the removal of selected trees to reduce tree density and competition while improving growing conditions for the favored trees in the stand. Silviculture attempts to follow the process of natural competition and selection by dense planting, which speeds up the selection of tall and strong individuals as the trees compete for light and other limited resources, followed by thinning of the less competitive or successful individuals. Silviculture emphasizes the importance of proper forest thinning, postulating that unless the stand is thinned, densely growing trees cannot continue to develop optimally. Thinning improves tree growth rates, economic potential, disease and insect resistance, and the visual appearance of tree stands. In most cases, a growing commercial forest has to be continuously or routinely thinned to assure the achievement of its yield goal by the scheduled harvest date. Management is also routinely engaged in preventing possible disturbances (pest outbreaks, wildfires, and tree collapse from windthrow or heavy snow cover) (Smith, 1972).

Commercial forest management calls for adequate forest structure: a network of forest roads to allow access for management teams, effective fire control, and frequent forest inspections. Forest management should include monitoring of the forest inventory at different developmental stages. A forest inventory based on commercial goals focuses on calculations of timber volume and quality. Yield tables are developed from forest inventory, and foresters use them to predict the future growth and yield of the forest and determine the optimal harvesting time.

In traditional forestry, regeneration of forests occurs at the end of the forest rotation and is generally dependent on spontaneous regeneration or the replanting of the desired species (Baker, 1950). In many cases, commercial forestry does not rely on natural regeneration processes, since it aims to create even-aged, monospecific stands.

Criticism of classical forestry, especially by environmentalists who object to monocultures, introduction of exotic species, soil damage, impact of machinery, burning and other forestry activities, was dismissed as marginally relevant and “abusive criticism that may only be the static that accompanies the message” (Smith, 1972).

AFFORESTATION AND FOREST MANAGEMENT IN ISRAEL

Afforestation is considered a part of the Zionist project of developing and inhabiting the Land of Israel. The KKL, which planted forests prior the establishment of the state of Israel, acts as the national forestry department today. The first Israeli government discussed how to create forests on bare land unsuitable (or not wanted) for housing or agriculture (Weitz, 1970). Gindel (1952) claimed that Israeli forests should fulfill three basic roles: (1) environmental regulation—climate amelioration, preventing soil erosion, and increasing water reserves in ravines and ground reservoirs; (2) provision of commercial products—supplying products needed by the wood industry; and (3) cultural–aesthetic—beautifying the landscape.

Afforestation of bare and deserted landscapes (“greening the country”) has been the driving goal of the last 100 years of forestry in Israel, often accompanied by other economic, political, and ideological goals, such as preventing soil erosion and dust storms and providing rural employment and climate moderation (Liphschitz and Biger, 2000; Gafni, 2005). Throughout this period, the forests provided some economic benefits, as well as a source of income for the residents of neighboring towns engaged in afforestation and forest management. Gafni (2005) claims that the byproducts of silvicultural activities (thinning and felling) in Israeli forests provided only low-value products that seldom reached the economic profit levels of even medium-return commercial forestry. As the economic level of the population increases, forests are being used more for recreation (Ginsberg, 2000).

The economic role of Israeli forests in the eyes of the forests’ founders is not fully clear. Gottfried (1982) cites managers of the Israeli Forest Authority—(KKL) who claimed in the early 1980s that the forests would be able to fill up to 30% of the country’s wood needs. These plans never materialized, and today it is widely acknowledged that most Israeli forests cannot provide material suitable for a timber industry. Nevertheless, Israeli forestry adopted the traditional, commercial silvicultural model, as was implemented in Europe and North America. Until recently, afforestation has been conducted mainly by planting even-aged and usually monoculture stands. Since the stated aim of early forest management was to achieve maximal timber yield (Gindel, 1952), management programs were designed to maximize forest productivity by improving the trees' growing conditions.

Over the last 60 years, forestry policy and practices in Israel have shifted, following both silvicultural and political developments. With wood production as a main objective, Aleppo pine (*Pinus halepensis*) was vigorously planted between 1948 and the 1970s (Bonneh, 2000). By the mid 1990s, at which point most open areas in the Mediterranean region of Israel had already been planted, the rate of afforestation declined, shifting the main effort to forest maintenance (Gafni, 2005). Following a massive collapse of *P. halepensis* stands that occurred in the 1990s, mainly as a consequence of attacks by the pine blast scale (*Matsucoccus josephi*), Aleppo pine was gradually replaced by *Pinus brutia* Ten. (a species common in the eastern Mediterranean Basin, but foreign to Israel) (Bonneh, 2000).

During the late 1990s, the Forest Authority acknowledged a long-held criticism of its practices and changed its policies and management strategies, adopting more ecological approaches. The organization declared the monoculture pine forests as pioneer forests that will be gradually replaced by sustainable mixed forests, and began testing methods for creating mixed forests combining pines and native broadleaf trees (Ginsberg, 2000). Saplings of oaks (*Quercus calliprinos* Webb and *Q. ithaburensis* Decne.), pistachio (*Pistacia palaestina* Boiss. and *P. lentiscus* L.), carob (*Ceratonia siliqua* L.), olive (*Olea europaea* L.), arbutus (*Arbutus andrachne* L.), buckthorn (*Rhamnus alaternus* L.), and other Mediterranean tree and shrub species were planted in mixed stands and, in later plantings, in patches. As part of this trend, significant improvements in seedling quality, site preparation, and weed control techniques were adopted, based on both ecological and economic considerations (Bonneh, 2000).

In 2006, 60,000 ha of planted forests covered less than 10% of the central and northern Mediterranean regions of Israel (www.kkl.org.il). These forests are dominated (~75%) by conifer species (mainly *Pinus halepensis* and *P. brutia* and some *Cupressus* species), and the rest of the area was mostly planted with eucalyptus, some local broadleaf forest trees, orchards, and natural vegetation (in decreasing order) (KKL website, 2007 data).

Fire, mostly caused by humans, is one of the main threats to forests in Israel. This problem is mainly controlled through the maintenance of a relatively dense network of forest roads and by skilled personnel equipped with adequate equipment and aided by aircrafts.

ECOLOGICAL FORESTRY—A HISTORICAL PERSPECTIVE

The concept of ecological forestry is not new. It has its roots in the mid-19th century in the mountainous regions of central and southern Europe, where the principal goal of the forests was protection against avalanches and soil erosion (Gamborg and Larsen, 2003). By the end of the 19th century, the German forest scientist Gayer had introduced the notion of mixed forests into commercial forestry in order to strengthen forest stability and continuity (Schütz, 1999). Gayer's work should be viewed in light of the then-prevailing philosophy of "returning to nature" (Schütz, 1999). The emergence of the discipline of ecology in Germany at that time helped, we believe, to encourage the view of the forest as an "organism" and to define the "Dauerwald" (permanent or continuous forest) as the best silvicultural model, as opposed to the previously prevailing clear-cutting approach (Troup, 1927, cited in Helliwell, 1997). The main principles of "Dauerwald" silviculture were avoidance of clear-cutting to preserve continuous "forest conditions"; retention of vigorously growing trees and the removal of trees that had ceased to grow; disregarding the concepts of age-class and rotation; selective removal of only infested, malformed, or non-vigorous trees; the decision to let regeneration drive forest management; leaving fallen branches on the ground to help regeneration; and replacement of annual yield surveys with periodic monitoring of tree status as a basis for management (Helliwell, 1997).

At the same time in Switzerland and France, a similar silvicultural methodology the "Plenterwald" was also developed within the context of timber-oriented forestry. This approach advocated avoiding clear-cutting, abandoning the age-class system, and encouraging spontaneous regeneration of multi-aged stands (Gamborg and Larsen, 2003). The overall goals of this system were the establishment of mixed stands and the promotion of stand irregularity (Schütz, 1999). It is worthwhile to keep in mind that these principles did not imply that the forest should be abandoned by foresters and allowed to develop into a nature reserve, but rather that commercial forestry should be continued in more diverse and complex forests. Maintaining a mixed forest requires skillful and continuous intervention because the natural tendency is for the most dominant and competitive species to take over the stand. No wonder that European virgin forests are mostly monospecific (Schütz, 1999), and it takes natural disturbance or management intervention to increase their diversity and complexity.

The forestry establishment of the time rejected all of the proposed theories of ecological forest management as false and based on incorrect calculations. For them, achieving the stated ecological goals simultaneously with commercial timber production was an unrealistic and hopelessly romantic goal (Gamborg and Larsen, 2003).

In recent years, the concept of sustainable forestry has become the focus of much discussion (Andersson et al., 2000a). Sustainable management means not only the careful harvest of wood so that yields can be sustained over the long term, but also includes a wide range of forest goals, including the establishment of wildlife habitats, visual quality, biodiversity, nutrient recycling, water retention, soil productivity, carbon sequestration, and amenity values (Franklin, 1989; Farrell et al., 2000; Puettmann and Ammer, 2007). This new approach to forest management seeks to conserve the forest ecosystem, protect soil and climate, produce timber and other products, and provide recreational and other social and cultural services, while maintaining a sound balance between these goals (Gamborg and Larsen, 2003).

Over the past two decades, the concept of "back-to-nature" silviculture (also known as "close-to-nature silviculture", "nature-based silviculture", "nature-oriented silviculture", "near-natural silviculture", "continuous cover approach", and "biodiversity-oriented silviculture", as well as "ecological silviculture", "forest ecosystem management", "ecologically sound forestry", and "holistic forestry") has received growing attention in Europe and the US (Gamborg and Larsen, 2003). For example, in 1989, in a revival of the "Dauerwald" concept, foresters from ten European countries established the "association of foresters practicing management which follows natural processes" (ProSilva) (Helliwell, 1997). Their new approach seeks to maintain "healthy" forests through the creation of the "right ecological balance" and "proper" composition and structure (Gamborg and Larsen, 2003). In parallel, the Continuous Cover Forestry Group was established in Britain (Lähde et al., 1999) and the New Forestry approach was developed in the US (Franklin, 1989). These approaches place equal importance on what is kept in the forest and what is taken from it. It is obvious that these new approaches stand in contrast to the timber-oriented management policy that dominated American and European forestry for more than a generation.

In the US, the debate over forest management started in the 1970s as a result of conflicts between different groups interested in making use of existing forests. These conflicts stimulated the creation of the "multiple-use" concept in forestry (Behan, 1990; Salwasser, 1990). Preserving the forests' biological value was only one of the many, sometimes conflicting, interests which foresters were supposed to manage (Brooks and Grant, 1992b). Nevertheless, in the early 1990s, the conflict over the management of vast forest areas in the US became stronger and more bitter, probably due to public interest in the growing environmental movement. Brooks and Grant (1992a) claimed that "forestry appears to be in the midst of a revolution", while the topic was barely mentioned in the scientific literature of the time. If 20th century forestry was about simplifying systems, producing wood and management at the stand level, the forestry of the 21st century will be defined by understanding and managing complexity, providing a wide range of ecological goods and services, and managing across broad landscapes (Kohm and Franklin, 1997).

Today, it is widely agreed that the traditional approach to forest management, based on clear-cutting of even-aged, monospecific stands, does not support other forest functions and values, such as biodiversity, nutrient cycling, or ecosystem stability; thus it cannot support real forest sustainability. Ecological silviculture seems to be a promising alternative approach for meeting these goals (Emborg et al., 2000).

ECOLOGICAL FORESTRY—THE CURRENT STAGE

The new paradigm that presently prevails in forestry emphasizes the balance between sustainable timber production (and other provision services), biological diversity, and multiple-use potential (O'Hara et al., 1994). One of the principal components of the new paradigm is the holistic perception of the forest as an ecosystem—a single biophysical, ecological system that responds as a whole to the disturbance or manipulation of any of its parts (Behan, 1990; Larsen, 1995). Consequently, management plans and decisions should be based on an ecosystem perspective, rather than on a tree- or stand-based perspective, emphasizing the complex interrelations within the forest system (Brooks and Grant, 1992b). It is time to integrate traditional forestry and ecosystem and landscape ecology and their components, to connect forestry with the principles of ecosystem and adaptive management (Walters, 1986; Campbell and Kittredge, 1996).

Over the last decade, foresters worldwide have started to pay more attention to the maintenance of biodiversity and forest ecosystem health. Even the rather conservative Society of American Foresters has acknowledged that "biological diversity is essential in healthy, productive forest," that "forest managers have a role in maintaining biological diversity," and that "sustainable forest utilization requires looking beyond today's harvest and tomorrow's stand of trees" (SAF, 1992). The current consensus is that silviculture should simulate natural processes (Lähde et al., 1999). Therefore, mixed, uneven-sized forests are favored, as they are more resistant to natural disturbances (Larsen, 1995) and support greater biodiversity (Gustafsson and Hallingbfick, 1988; Lähde et al., 1999, 2002).

According to List (2000), the two primary concerns in North American forestry are mitigating the impact of previous silviculture practices and preserving existing natural values. In Europe, the emphasis is on the conversion of even-aged, production-oriented, and intensively managed plantations into a new type of diverse forest (Gamborg and Larsen, 2003).

Franklin (1989), a US Forest Service scientist, described New Forestry as an approach for "a kinder and gentler forestry that better accommodates ecological values, while allowing for the extraction of commodities". The issues that first triggered this change were concerns of floods following forest clear-cutting and the effects of debris management on fire threat and the forest ecosystem. Franklin and his team were among the first to realize the unique role of developed old-growth forests in ecosystem functioning and presented empirical evidence of the high level of biodiversity present in natural old forests, in comparison with young, even-aged stands. Others proposed new silviculture methods that emphasized hydrological and nutrient-cycling aspects (Hornbeck and Swank, 1992).

Schütz (1999) defined a "close-to-nature" forest in terms of three dimensions: naturalness, structural diversity, and degree of silvicultural interventions. It is obvious that there may be numerous types of "close-to-nature" forests, while maximizing all dimensions implies the conversion of a forest into a nature reserve. The recognition of the relative importance of the non-consumptive and non-utilitarian value of forests has grown in recent decades. The focus on commodity production within the forestry practice has blinded many professional foresters to aesthetic, spiritual, and amenity values as well as to the ecosystem aspect of forests, namely the maintenance of a healthy and resilient ecological environment (Bengston, 1994).

Even though the concept of ecological forestry has gained popularity in recent years, it still raises significant questions and criticism. The timber yield of forests managed according to the new approach has not yet been determined quantitatively under realistic conditions (Larsen, 1995). There is also no consensus as to the definition of a healthy forest, so comparing different management schemes is not easy. While classical forest management has been geared toward operating according to clear objectives and specific methodologies, ecological forestry provides only general objectives (that are not easily quantified) and does not yet provide clear, applicable guidelines. At present, ecological forestry is still at the stage of a developing theory, and is not yet an applied doctrine that can be easily and unequivocally practiced.

APPLIED ECOLOGICAL FORESTRY

Forestry is currently faced with the challenge of reconciling the traditional objective of timber production with new objectives; most of these are ecological and a few are social (Schütz, 1999). Meeting the goals of the new forestry paradigm, namely biodiversity maintenance and ecosystem health, requires a conceptual change in silviculture (O'Hara et al., 1994). Below, we attempt to summarize some of the applied aspects of ecological forestry.

Management objectives

(A) **Creating diverse, "close-to-nature" forests.** The New Forestry approach encourages the development of mixed, diverse and uneven-aged, and multi-sized forests. Forest management plans should include strategies to conserve and enhance biological diversity (SAF, 1992). The quest for diverse forests should take into consideration species and structural diversity, as well as attempt to maximize the spatial complexity of the forest floor (e.g., De Grandpré and Bergeron, 1997). Leaving dead tress and clipped branches on the ground rather than removing these materials should be a part of the ecological management toolbox (Franklin et al., 1987).

(B) **Integrating across landscape mosaics.** Forest stands are not independent entities, but a part of larger units: large forests, watersheds with characteristic water and soil flows, parts of the local (and external) inhabitants' environments and/or components of interacting land-use mosaics. The management of any stand should take all of the above into consideration. Forest management must act to maintain not only within-stand diversity, but also a diversity of stands, increasing landscape diversity, and account for wildlife habitats, aesthetics, and abiotic (mostly hydrological and soil) parameters. All of these activities should be carried out with a broad perspective in mind.

(C) **Increasing and diversifying non-timber forest goods and services.** Modern forest management should adopt a broad perspective, embracing all goods and services that forests can yield, including value-loaded parameters, such as amenities, ecosystem functioning, and regulation of natural processes, depending on a sociopolitical consensus (Farrell et al., 2000). Manipulations of stand structure may be based on considerations of the regional landscape, the improvement of wildlife habitat, or the enhancement of hydrological processes. Part of the fulfillment of this objective lies in involving the public in decision-making processes (see next objective). A broad range of forest users should actively participate in planning, decision-making (broad support on management objectives, the evaluation of the consequences of previous management activities), and applied management activities (Piussi and Farrell, 2000).

(D) **Adopting environmentally sound policies.** Many foresters worldwide see themselves as part of the growing "green movement" rather than part of the wood industry. If foresters continue to identify themselves with this ideology, some aspects of traditional forestry practices are likely to change. For example, clear-cutting; the burning of all residual material; aggressive removal of competing vegetation; chemical treatments; and even the removal of decayed branches, whole trees, and snags may be avoided because of the harm they cause to the forest ecosystem and its natural dynamics (e.g., Martin et al., 1985; Stevens and Hornung, 1990; Lähde et al., 2002).

Management scale

There is a broad consensus that modern forestry should consider scales larger than the individual stand as management and restoration plans are developed (Nordlind and Östlund, 2003). The forester should look beyond the stand to the regional landscape and watershed of which the forest is just one of a number of different functioning components (Andersson et al., 2000b). This approach is exemplified by Humphrey's (2005) proposition that the planning and design of forests in Britain should include a consideration of the landscape scale and ensure an appropriate balance between old growth and other types of woodland and non-woodland habitats.

Forest composition

The New Forestry philosophy advocates the conversion of monocultures to mixed forests that are as similar as possible to the natural forests of the area, promoting higher diversity at different spatial scales, such as maintaining stands or landscape patches at different seral stages (Hansen et al., 1991) or with different species composition.

Management practices

Foresters may continue using basic silvicultural methods, such as thinning and plantation planting, but the goals of these activities will change.

(A) **Forest regeneration.** Much of the practice of forestry in industrial and non-industrial contexts is based on the conceptual model of the "forest cycle", which was developed in the first half of the 20th century by Watt and others. This model is based on the natural creation of gaps in the forest by disturbances, tree mortality, and, if control over the forest is sought, human intervention. These gaps serve as sites for tree regeneration (Emborg et al., 2000). Once the desired forest composition and structure is no longer an even-aged monoculture, the use of the principles of gap dynamics should change as well (for an interesting case study, see Emborg, 1998). An ongoing process of gap creation, tree regeneration, maturation, and aging assures the development of a complex and healthy stand, as well as a heterogeneous landscape of a shifting mosaic at larger scales (Shugart, 1984; Remme, 1991, in Emborg et al., 2000). Post-disturbance regeneration may still be supported by planting, particularly when dealing with anthropogenic disturbances.

(B) **Thinning and debris management.** Selective thinning, which is the principal silvicultural practice, can be applied in various ways, some of which may be more ecosystem-oriented than others. For instance, a specially designed diversity-promoting thinning procedure was experimentally shown to improve diversity in the forest itself (Lähde et al., 1999), as well as the diversity of bird species (Hagar et al., 2004) and the diversity of other wildlife communities (Wilson and Puettmann, 2007). A review of empirical papers found that the availability of microhabitat features in managed plantations is below the levels required by many vertebrate species (Hansen et al., 1991). That study concluded that in situations in which the maintenance of diversity and productivity is a goal, the structural complexity of the forest should be enriched by leaving woody debris, live trees, snags, dead material, and fallen trees in clear-cut areas, retaining structural legacy from the preharvest stand (Franklin, 1989; Brooks and Grant, 1992b; Hodge and Peterken, 1998). Wilson and Puettmann (2007) suggested the use of variable density thinning and gap sizes to provide a range of food sources and microclimate conditions capable of supporting a diversity of species from different seral stages.

(C) **Coping with disturbances.** Disturbances, either of natural origin or man-made, have always been a threat to forests. Extensive resources have been invested to protect against the destructive impact of such disturbances. The economic burden that disturbances impose on a timber-producing forest made such investments worthwhile. However, ecological forestry treats disturbances as a major force directing forest development, structure, and function (Attiwill, 1994). Many consider the restoration of the natural disturbance regime to be a key factor in close-to-nature forestry (Bengtsson et al., 2000) and the restoration of degraded forests (Korpilahti and Kuuluvainen, 2002; Nordlind and Östlund, 2003). Advocates of this approach have suggested investigating the effects of disturbances on the forest in order to understand their function in forest development so that their impact may be mimicked. However, strict adherence to a silvicultural regime that closely parallels a natural disturbance regime may not always be necessary for maintaining forest biodiversity (Palik et al., 2002).

(D) **Forest density.** Traditionally, forest density was determined and maintained in order to support maximal tree growth according to commercial demands. The new ecological approach suggests manipulating forest densities in order to achieve other (or additional) goals.

(E) **Preserving forest biophysical structure.** Soil is the most prominent component of forest habitats. It is the basis for tree development and functions as a source of nutrients and water. The New Forestry philosophy calls for a careful treatment of forest soils, namely preventing the adverse effects of conventional tree harvesting and minimizing soil compaction, the avoidance of extreme microclimatic conditions, the creation of a habitat suitable for re-colonization by native biota, and, if required, the introduction of desirable microflora and fauna (Marshall, 2000). Such practices not only ensure tree growth, but also maintain soil-dwelling decomposers, plant biodiversity, and ecosystem function.

Forest monitoring

Management, in general, and forestry, in particular, require monitoring (Christensen et al., 1996). The routinely measured parameters are supposed to help in determining the state of a forest before and after any management activity, and in evaluating the success of any particular management regime. Monitoring is an essential component of all types of ecosystem management, and is particularly necessary when new management practices are introduced under the adaptive management approach (Johnson, 1999). The effects of forest management strategies should be evaluated over a range of spatial (tree, stand, site-habitat, forest, watershed, region-landscape) and temporal (natural and planted vegetation succession, disturbances, life cycle of dominant species) scales.

No single measure (age, size, density, etc.) can encompass the broad perspective accompanying the ecological approach or management of multi-use forests. Stem diameter distribution combined with species composition is a key parameter for classifying stands, both for commercial purposes and within the ecological management framework. Various other indices are used to determine stand structural diversity (Lähde et al., 1999; Neumann and Starlinger, 2001). Assessing forest health requires the monitoring and integration of a wide range of tree parameters (e.g., annual height growth, live crown ratio, leaf area, and needle retention for the single tree and leaf area, diversity, dominance, and productivity for the stand) (Smith, 1990). Monitoring the state of a whole system that is being managed according to the principles of ecological forestry requires the addition of ecosystem parameters (e.g., soil properties, nutrients), biotic components (birds, mammals, etc.), and structural indices to the regular monitoring scheme (e.g., Lindenmayer et al., 2000; Pommerening, 2002).

Conservation value

Conservationists often claim that unmanaged (i.e., undisturbed, "old growth") forests maximize nature conservation (Schütz, 1999). However, others believe that management interventions are necessary to promote structural and hence biological diversity, since new habitats are formed and a wider range of abiotic conditions is created. Carey (2003) argued for the importance of biocomplexity in forest management in order to preserve biodiversity. He believed that by inducing spatial heterogeneity through thinning, more of the forest diversity could be conserved than would be expected from the conservation of individual habitat elements. In fact, the diversity of the forest ecosystem is based on variation in age, size, spatial distribution, and the amount of decaying and fallen trees (Lähde et al., 1999). Therefore, a regional mosaic of forest stands differing in their composition, dense and sparse forests, even-aged, and complex-structured forests makes the greatest contribution to conservation efforts ("the principle of diversity by diversification"—Schütz, 1999).

Koehler and Brittell (1990) provided a nice example of the use of forests in a regional plan for the conservation of lynx and snowshoe hares in the northwestern US, in which a specific temporal and spatial mosaic of forest age classes supported the needs of these animals. This perception was also behind Harris' (1984) recommendation that nature reserves be complemented with a matrix of "semi-natural" lands, including forests.

Mediterranean forests have a relatively high conservation value since they contain significant plant and animal diversity, as exemplified by the large number of tree species found in these forests, relative to temperate forests (Merlo and Croitoru, 2005). Mediterranean forests are also characterized by relatively high genetic diversity due to the survival of many conifer and broadleaf species in the region during glacial periods.

Knowledge gaps

It seems that, for the moment, the concept of ecological forestry raises more questions than it answers. Lack of scientific and subsequent practical knowledge are characteristics of periods of paradigm change (Farrell et al., 2000). It is clear that both more scientific knowledge concerning forest ecosystem function and biological diversity, as well as programs for integrating this knowledge into forest management, are required (SAF, 1992. For an interesting case study see Hansen et al., 1995).

A detailed understanding of the intrinsic stabilizing and destabilizing processes of the forest ecosystems, including their regulatory interactions and their responses to exogenous disturbances, is necessary (Führer, 2000). In this regard, scientific knowledge may help to identify the consequences of management actions, in order to define options and frame decision-making processes so as to prevent mistakes and unintentional damage (Behan, 1990). Other open questions include the questions of how to reintroduce natural disturbance regimes (fire, herbivory by large grazers) into forests; what is the actual relation between biodiversity and the forest ecosystem; how climate change will affect the forest; and how this impact can be mitigated (Bengtsson et al., 2000).

It is obvious that not only is forest management being revolutionized, but also forestry science is being asked to adapt. We should be able to account scientifically for the complexity of the forest ecosystem and to propose scientifically sound plans for the ecological management of forests (Brooks and Grant, 1992b).

Similar knowledge gaps were identified by Scarascia-Mugnozza and colleagues (2000) in their study of ecological forestry in the Mediterranean region: (1) The structural and functional interactions between forest stands and biological diversity; (2) The genetic variation of tree species; (3) The effects of climate change on Mediterranean forest ecosystems; (4) The contribution of traditional forestry to wood production, carbon sequestration, and improvement of environmental conditions (biodiversity, erosion control, nitrate absorption, and landscape amelioration); (5) Identifying the effects of landscape structure on the functioning and resilience of forest ecosystems in relation to natural and man-made disturbances; (6) Definition of the soundest utilization of forests under Mediterranean conditions; (7) Development of sustainability indices for Mediterranean forests.

Burley (2004) takes an emphatic stand, calling for "restoration" in forest research that is "both proactive and reactive to policy and public issues and uses modern techniques of information technology and networking. Current human demands for forests of social, environmental and economic benefits require new, interdisciplinary approaches to research and rapid implementation of relevant results by appropriate stakeholders."

ECOLOGICAL FORESTRY AND ITS APPLICATION IN ISRAEL

The conversion of natural degraded broadleaf tree communities into planted conifer-dominated forests in Israel has been largely criticized. Critics have claimed that this approach was responsible for having reduced the resilience of local forest systems and having promoted the collapse of non-natural systems (Gindel, 1952; Liphschitz and Biger, 2000).

In light of the worldwide paradigm shift in forestry and with the understanding that many of the forests in Israel (especially *P. halepensis* stands) are approaching the end of their growing cycles, the time is ripe to propose some new guidelines for ecological forestry in Israel. This set of criteria is relevant for all planted forests that are not subject to intensive recreational use. For recreational forests, a special set of criteria should be developed.

Changing forest management objectives

Most Israeli forests are located on rough topography in the Mediterranean climate zone with 400–800 mm of rainfall during a short (four months) winter and a contrasting long (six months) hot and dry summer. It is clear today that these forests cannot produce economic timber yields. However, these forests can provide some woody biomass that can be used to partially cover forest maintenance costs. These forests also supply a wide range of other goods and services (see Ginsberg, 2000; Gafni, 2005). Within the ecological forestry framework, we propose a shift toward social–environmental forest objectives, some of which have already been theoretically embraced by the Israeli Forest Authority—(KKL):

(A) **Creating a diverse forest.** After almost a million years of extensive, and millennia of intensive, human impact (since the introduction of fire and agriculture to the region), none of the existing vegetation formations in the eastern Mediterranean can be considered natural or pristine. Moreover, the true nature of the indigenous forests of this part of the world will probably stay unknown forever. We know, however, that pines and oaks (mostly *Pinus halepensis* and *Quercus calliprinos*) have been present in the area for a long time. Therefore, it seems correct to propose that future Israeli forests be managed in a way that will yield mixed stands that are dominated by pine and oak species, but also display a diversity of other Mediterranean broadleaf trees and shrub species.

(B) **Integrating stands into a regional landscape mosaic**. Most forest stands in Israel are relatively small (mean stand size is 3 ha), thus it is strongly recommended that future forest plans integrate stands into a broader landscape perspective, at the regional or watershed scale. Interrelations between different land-use units should be considered, even if not all of them are under the jurisdiction of the Forest Authority.

(C) **Diversifying the goods and services provided by the forests.** To some extent, this objective has already been achieved. Recreation, carbon sequestration, erosion control, climate amelioration, forage for livestock, and firewood are already considered important services for which Israeli forests are managed. The challenge for the future lies in optimizing the provision of these services. Scientific knowledge, as well as an applied management strategy for the pursuit of biodiversity maintenance in Israeli forests are still lacking. A stronger emphasis on forest ecosystem health and functioning is also required.

(D) **Adopting environmentally-sound policies**. The Israeli Forest Authority considers itself an environmental ("green") organization. Although some of the forestry practices of the organization have been modified in recent years (Bonneh, 2000) (probably also due to pressure from other green organizations), we believe that there is still more room for improvement. Aggressive land treatments (e.g., site preparation, massive planting and thinning, thinning of natural regeneration, and road formation) should be revised, and the removal of decayed branches and dead trees should be reconsidered in light of the potential contribution of this material to the forest ecosystem.

Forest composition

The New Forestry philosophy encourages the conversion of monocultures into mixed forests that are as similar as possible to the natural forests of the area. In Israel, as well as in other Mediterranean environments, we are lucky to have such a process occurring as part of the secondary succession of natural Mediterranean vegetation within planted forests (Zavala et al., 2000; Pausas et al., 2004; Osem et al., 2008). Pines colonize broadleaf woodlands, and at the same time, oak and other natural broadleaf Mediterranean trees and shrubs create a dense and rich understory in the pine forests. For traditional forestry, this phenomenon is considered negative, disturbing the development of the forest and a potential disturbance source for future thinning. Ecological forestry will reconcile this dilemma, as it views such a process as a positive one that should be encouraged since it increases biodiversity. Despite the inherent conflict, the present Forest Authority policy encourages, in most cases, the development of broadleaf species and even protects them.

Management practices

(A) **Forest regeneration**. *Pinus halepensis* is an early-successional species. As such, its dispersal, establishment, and colonization outside of the planted forests is remarkably fast and efficient (Lavi et al., 2005). The common natural broadleaf species in the Israeli natural landscape are also well adapted to dispersal and recovery after disturbance, through both vegetative re-growth and (the slower) sexual reproduction. We believe that it is only a matter of time until mixed oak–pine forests develop naturally across most of the Mediterranean landscape of the country. Foresters can help encourage these processes in cases in which some components may be missing. Forest management activities, especially thinning and monitoring, should be geared toward promoting and encouraging the self-regeneration of the desired species (see also Osem et al., 2008). The first steps toward this regeneration policy have already been taken (Bonneh, 2000).

(B) **Forest thinning.** Here, we believe, lies one of the most revolutionary challenges to Israeli ecological forestry. The prevailing thinning scheme is based on the classical tree-development concept applied in monospecific stands. This scheme should be revised to create a practice that supports the self-regeneration of both conifers and broadleaf species. The modified scheme should also take into consideration the effects of thinning on biodiversity and amenity aspects. There is very little professional information to support such change. Therefore, accompanying applied research should be initiated.

(C) **Forest density.** This issue is closely related to thinning practices. The desired forest density is currently determined by the assessed requirements for tree development. Ecological forestry recommends incorporating other factors into the decision-making process, especially the requirements of diverse forest flora and fauna. Creating stands of varying densities will increase structural forest complexity, help create different habitats, and increase biodiversity.

(D) **Forest fires.** Fire is the major disturbance in Mediterranean ecosystems. Much forest management (the network of roads, pruning, clearing understory vegetation, removal of dead material) is motivated by the desire to prevent and control forest fires. Ecological forestry calls for a reconsideration of some of these practices. There is only little direct economic loss associated with some of the fire damage, especially when considering the expenses of fire fighting. In the long run, fires may serve to diversify the landscape; thus, perhaps some forest fires should not be considered to be catastrophes for the forest. The small size of the country and its afforested areas and the close proximity of forests to urban centers make this suggestion hard to apply, but we believe that there is room for change. Ne'eman and Perevolotsky (2000) suggested ecologically-oriented pre- and post-fire management treatments that are less drastic than the strict fire mitigation policy currently in effect.

(E) **Preserving forest biophysical structure.** Although *P. halepensis* is known to improve soil fertility (Maestre et al., 2003), this aspect has been overlooked in the management of forests in Israel and has only received scientific attention in semiarid forests (Gruenzweig et al., 2007; Gelfand and Yakir, 2008), even though control of soil erosion and water leakage were clearly stated as important goals of afforestation at its early stages (Weitz, 1970). We should increase our basic knowledge of these issues in order to develop appropriate practices that can be integrated into management systems, especially as regards thinning practices.

Forest monitoring

At present most, if not all, of the monitoring efforts in Israeli forests are geared toward observations of tree-related parameters (density, height, basal area—"dbh"), in a method adopted from timber production systems. The collected data are used to calculate wood biomass yield. It is important to note that the forest survey results are important for the Forest Authority, even though there is no conventional timber industry in the country. Calculated wood yield is the basis for engaging the contractors who thin the forests and provide other maintenance services (pruning, discarding undesired young trees, chipping branches, etc.). On the other hand, the structure of this forest inventory hardly promotes quantitative monitoring of spontaneous regeneration, densities of native broadleaf species, or ecological parameters (e.g., soil-related factors), not to mention measures of biodiversity. If an ecological approach to forestry is to be implemented, a revised and more elaborate forest monitoring system will have to be adopted.

Conservation value

Ecologically-managed forests can contribute to nature conservation in Israel in various ways: (1) On a regional basis, forests may enhance nature conservation by serving as additional habitats complementing the net area of small, fragmented reserves in the Mediterranean region. (2) Well-managed forests can serve as corridors for wildlife that live in large areas or are in the process of being dispersed. (3) These forests can also contribute to the overall national biodiversity by functioning as distinctive habitats. Tall forests provide habitat features not present in the Mediterranean woodlands. Therefore, forest management should aim to produce and maintain a layer of tall trees that will complement the ecological complexity of the rather low and dense oak maquis. (4) Forests can also serve as buffer zones between nature reserves and agricultural or urban areas.

Because forests in Israel are still young in ecological terms (most of them are less than 60 years old), and their management has not been ecologically oriented, we have not been able to grasp their full potential. Scientific information on the dynamics of faunal populations, both invertebrate and vertebrate, in the developing forests is currently starting to be gathered.

Knowledge gaps as targets for better management

Israeli planted forests are unique in their nature (Osem et al., 2008), and there is little similarity between them and other forests in the Mediterranean Basin, which has been the subject of intense investigation, or elsewhere in the world. It is obvious then that a special effort should be made to lay the scientific groundwork for recommended changes in forest management. The knowledge gaps identified by Scarascia-Mugnozza and colleagues (2000; see p. 43, bottom left column of this paper) can serve as a good starting point for defining the agenda for ecological research in Israeli forests.

CONCLUSIONS

The tension that has characterized the shift in conceptual paradigms in Western forestry is partially due to a lack of communication between ecologists and foresters. Since this discussion has only recently begun in Israel, we should take the opportunity to learn from the experiences of others and start an intensive dialogue between the two groups of professionals in order to develop an ecological management system that is appropriate for Israeli forest conditions. Such processes have recently been initiated and we hope that this paper will help leverage and encourage this newly emerging process.

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