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ISRAEL

Integrated Forest Fire Management in Israel
A 15 Year Review (1987-2002)

1. Introduction

The dramatic growth in afforested areas in Israel since the 1950's and associated accumulated fuels in mature forests sharply increased the likelihood of high-intensity fires with the potential to cause heavy damage to forests and adjacent neighbourhoods. Wildland fires and forest fires in particular, now threaten residential areas on a daily basis during the fire season, and pose new challenges to the development and evolution of fire management strategies.

Over the past 15 years, Israel's landscape has undergone a dramatic demographic transformation. Massive building and development projects proceeded at the expense of the nation's open space resources, with numerous residential quarters bordering upon forests, pasturelands and native woodlands. One result of this rapid growth process is a complex urban/wildland interface found throughout the country's most populous regions.

One such consequence of this high level of interaction and conflict on the land were a series of large forest fires. During the 1980s and 1990s, several devastating fires occurred on the Mount Carmel Forest Reserve (near Haifa) and the forests along the Tel Aviv - Jerusalem highway. As a result, increased public awareness brought about the establishment of a public inquiry committee (Ministry of the Interior 1995), a consultative program with the US Forest Service, and the allocation of special funds for rehabilitating and researching burnt forests.

The integration of fire pre-suppression operations, fuel management, other silvicultural treatments, and data management is a central aspect of forest management and its implementation takes place by various means. This paper reviews changes to the Keren Kayemeth Leisrael's Forest Department's fire management strategy during the past 15 years, and describes the integrative process of forest fire management it underwent.

2. Literature Review

Mediterranean forestry and forest management is recognized as a separate field of world forestry and received international attention since 1948 in the form of the FAO Sub-Commission on Mediterranean Forest Problems (Morandini 1999). Recently, MEDPINE1 and MEDPINE2 conferences focused in depth on the ecology, biogeography, management, conservation, fire ecology, restoration and regeneration of Mediterranean pine species (Ne'eman et al. 2000b, Thanos 2002). Forest fires and forest fire management receive a particularly large amount of attention, due to their central role as natural and anthropogenically induced events in Mediterranean ecosystems and forests (Alexandrian et al. 1999, Calabri 1983, FAO 1977, Leone et al. 2000, MIO 2002, Naveh 1975, Pausus et al. 1999, Velez 1990a, 2001).

Derman et al. (1986), Kliot (1996), Kutiel (1992a) and Naveh (1973, 1974, 1977) document the ecological role of fire in Israel’s ecosystems and forests. Fire and fuel management techniques employed in Israel are described by Bonneh (1996), Brandel et al. (1988), Eshet (1988), Ne'eman et al. (2000a) and Woodcock (1996). Research on the behavior, techniques and ecological effects of prescribed burning are documented by Kutiel (1989), and Zohar et al. (1988, 1990a, 1990b, 1994, 1996). A 1992 issue of *Horizons in Geography* is devoted to research conducted on forest fires and their effects in Israel (Kutiel 1992b). The 1996 issue of *Ecology and Environment* is entirely devoted to research conducted on the post-fire effects of a devastating 1989 wildfire on Mt. Carmel. It contains 18 papers detailing the physical, botanical, zoological, managerial and social effects of the fire (Perevolostky et al. 1996).

3. Background

Israel is located at a junction of three continents where climatic and geobotanical zones coincide. In the northern Mediterranean geobotanical zone – an area covering half of the country (10,500 km^2) - native evergreen and deciduous forests, as well as planted conifer and mixed forests, exist. At present, 150,000 hectares (ha.) of both planted (90,000 ha.) and native forest (60,000 ha.) cover 7% of Israel's total area, or 15% of the Mediterranean region of Israel. Most of these forestlands grow in an area that receives annual precipitation levels of 300 to 900 mm (Orni and Efrat 1980).

Also located in this precipitation belt are all of Israel's major metropolitan centers: Haifa, Tel Aviv, and Jerusalem, with a very large number of associated suburban and rural communities. Therefore, urban growth, development and expansion occur concurrently and frequently threaten the nation's forests resources. The population of Israel grew from 500,000 at the beginning of the 20th century to over 6,700,000 today. According to an interim report (KKL 1994), the population within this belt of afforestation, precipitation and urbanization is amongst the densest in the world (638 inhabitants/km^2). A complex and dynamic matrix of forest/urban area interactions characterizes the present Israeli landscape.

Climate: The climate of Israel's geographic areas with afforested landscapes is typically Mediterranean in nature: cool, wet winters and hot, dry summers (UNESCO 1963). Mean annual temperature ranges between 19-21°C. On average, January is the coldest month (8-10°C) and August the hottest (26-28°C) (Survey of Israel 1985). Relative humidity averages 55-60% with the lowest levels in May-June and the highest levels in December-February. (Orni and Efrat 1980). The main rainy season extends from October to May, with 75% of the rain falling from December to February (Gottfried 1982). In Israel, there are two distinct wind regimes during the dry season. Most days are characterized by a regime of a constantly blowing, onshore, moist breeze, from the west (Mediterranean Sea) to the east. A few critical days are marked by extremely hot, dry winds (sharav) originating in the eastern deserts. These conditions encourage the spread of large fires and impose a great threat to forest and property alike (Horowitz et al. 2002, H. Kutiel 1992).

Topography: Israel has three longitudinal topographic belts: the coastal plain, the central and Galilean mountain regions and the Jordan Valley (Zohary 1962). Main population centers are primarily located on the coastal plain while rural settlements, agricultural lands and open space (forests, rangelands, and nature reserves) typify interior sections. Mountain ranges are characterized by rolling hills, terraced mountainsides and steep, rocky slopes dissected by numerous intermittent watercourses. Situated in the foothills and mountainous regions of Israel are the majority of Israel's natural and planted forests.

Geobotany of Natural and Planted Forests: Plant communities typically associated with the Mediterranean region of Israel are low woodlands comprised of mixed evergreen, sclerophyllous tree and shrub species and deciduous tree species of the Class Quercetea calliprini [Braun-Blanquet method](Zohary 1962). The four most prominent and important associations of forest trees found within this afforestation zone are the: 1) Aleppo Pine Forest (*Pinus halepensis*, *Quercus spp.*, *Pistacia spp.*, *Arbutus andrachne);* 2) Evergreen Oak Forest and Maquis (*Quercus calliprinos* and *Pistacia palaestina*); 3) Deciduous Tabor Oak Forest (*Quercus ithaburensis*, *Styrax officinalis* and *Pistacia atlantica*); and 4) Evergreen Carob – Lentisk Maquis (*Ceratonia siliqua* and *Pistacia lentiscus*).

Associated secondary tree species include hawthorn (*Crataegus* spp.), laural (*Laurus nobilis*), redbud (*Cercis siliquastrum*), phillyrea (*Phillyrea media*), buckthorn (*Rhamnus palaestinus*), Syrian pear (*Pyrus syriaca*), almond (*Amygdalus communis*), strawberry tree (*Arbutus andrachne*) and storax (*Styrax officinalis*) (Waisel et al 1980). Evergreen scrub and low shrub communities, termed "garrigue" and "batha" respectively, are also present. Species typically associated with them are thorny burnet (*Sarcopoterium spinosa*), *Calycotome villosa*, *Cistus* spp., sages (*Salvia* spp.) and, annual and perennial legumes and grasses.

The Keren Kayemeth Leisrael (KKL) is responsible for one hundred years of afforestation activity in Israel. [The KKL is Israel's largest and oldest NGO, responsible for afforestation, land reclamation and water resource development works.] Its efforts created approximately 90,000 hectares of planted forests in Israel's Mediterranean region. Pines (*Pinus halepensis*, *P. brutia*, *P. pinea*), eucalypts (*Eucalyptus camaldulensis*, *E. gomphocephala*), cypress (*Cupressus sempervirons*) are the principal species found, selected for their adaptability to a wide range of site conditions throughout the country (Bonneh 2000). National Master Plan No. 22: Forest and Forestry, approved by the government, guarantees their statutory position as forestlands (KKL et al 1995).Currently, Israel's forest resources provide a large and varied number of social goods and services to the citizenry (Ginsberg 2000).

Forest Fuels: Both natural and planted forests contain tree species with high oil, wax and terpene contents, making them highly flammable and predisposed to fire. The majority of them matured into dense and often untreated forests with very heavy fuel loads. The quick growth rates of conifers and eucalypts, in particular, contributes to a rapid rate of fuel accumulation in the forest – live, green fuels on the trees, dry fuels (needle and leaf litter) on the forest floor, and dead branches on the trees. Zohar et al. (1990b) measured fuel loading on 15 planted pine sites in northern and central Israel, as detailed in Table 1.

Table 1. Average fuel biomass characteristics of 15 planted pine sites aged 24-31 years in the Ben Shemen, Baram and Mt. Carmel forests (Zohar et al. 1990b).

Fuel Component	Ave. Fresh Weight (kg/ha)	Percentage of Total Biomass
Small branches (diameter < 1 cm)	2,100	15.3 %
Large branches (diameter > 1 cm)	3,150	22.9 %
Needle litterfall	4,140	30.2 %
Cones	4,340	31.6 %
TOTAL BIOMASS	13,730	100.0 %
RANGE OF TOTAL BIOMASS	10,000 – 30,000	

Bark thickness of Aleppo and Brutia pines vary and affect their relative susceptibility to scorching and heat damage. The former is more sensitive, with an average thickness ranging between 0.2-1.1 cm, and the latter is more resistant, with an average thickness ranging between 1.4-2.1 cm (Zohar et al. 1992). Measurements were made at 1.0 m trunk height.

In combination with topographic and climatic factors associated with forestry, and the relative closeness of these forests to residential areas, it is clear that fuel and forest fire management are urgent and pressing challenges.

4. Fire Statistics

The data presented here represent a summary of fire occurrence over a fifteen-year period from 1987 to 2002. For purpose of this analysis, the fire data was divided by type of forested area into the two categories mentioned in the "Background" section above: 1) planted forest and 2) natural forests and woodlands. The definitions of these two types confirm to those of the FAO’s (2000) FRA Project for "forest" and "natural forest".

In Figure 1, the number of forest fires in Israel ranges from about 500 to 1100 per year, with the majority occurring in planted forests. When normalized to take into account the relative cover of these two categories (see above), there are still some four times more fires per year in planted forests (4-10 per thousand hectares) relative to natural forests (1-3 per thousand hectares).

The total area burned by forest fires (Figure 2) has greater variability than the number of fires, reflecting a dependence on seasonal fuel and climatic conditions. In addition, despite the far greater number of fires in planted forests noted above, the relative yearly area burned for the two forest types shows no clear distinction. There are years where the area burned in natural forest exceeds that in planted forest, and vice versa. The average yearly area burned (960 ha for planted and 819 ha for natural forest) in the two forest types is in fact not significantly different.

As the yearly data on number and burned area indicate, fires in natural forests tend to be larger in Israel than those in planted forests. The difference in average fire size is more than four-fold: 1.6 ha for planted forest versus 7.0 ha for natural forest.

A somewhat deeper look at the result of this size difference is seen in Figure 3, which compares the average number of fires each year in four different size categories differing by orders of magnitude. In Figure 3 the number of fires occurring each year is plotted on a log scale by the four size categories. This graph indicates very clearly how forest fire history in planted forests is dominated by smaller fires (< 10 ha) in contrast to natural forests which have much less of their yearly burned area contributed by small fires.

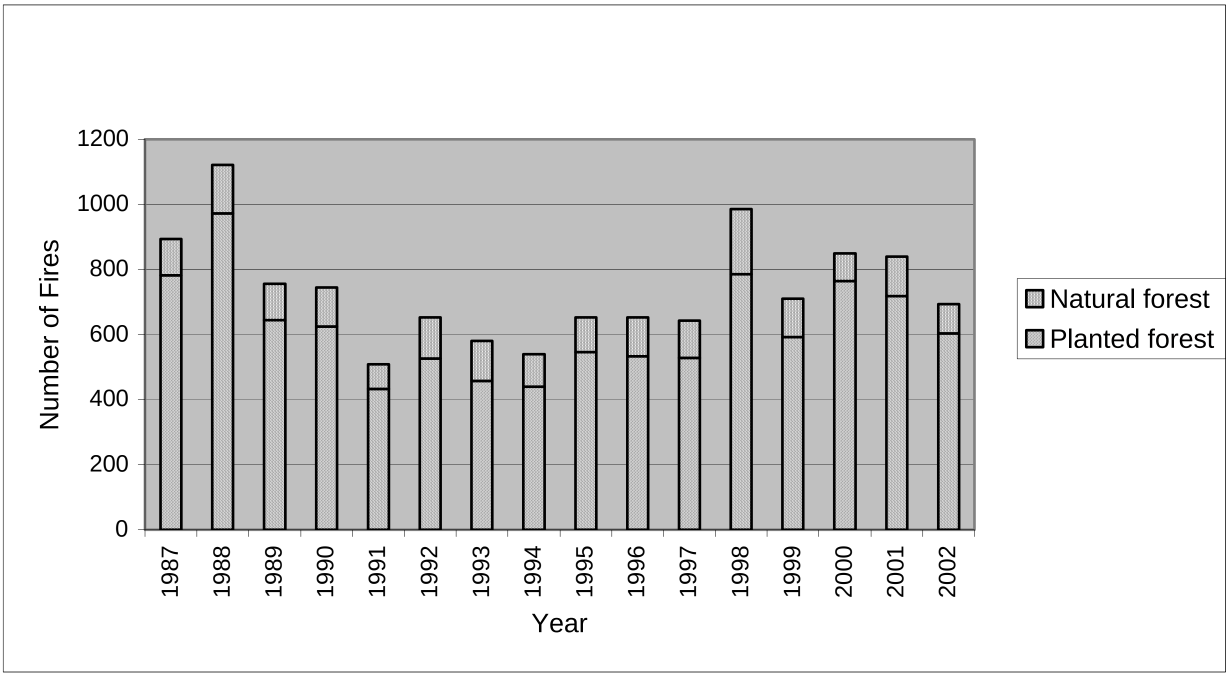

Figure 1. Fifteen years forest fire history in Israel (1987-2002)

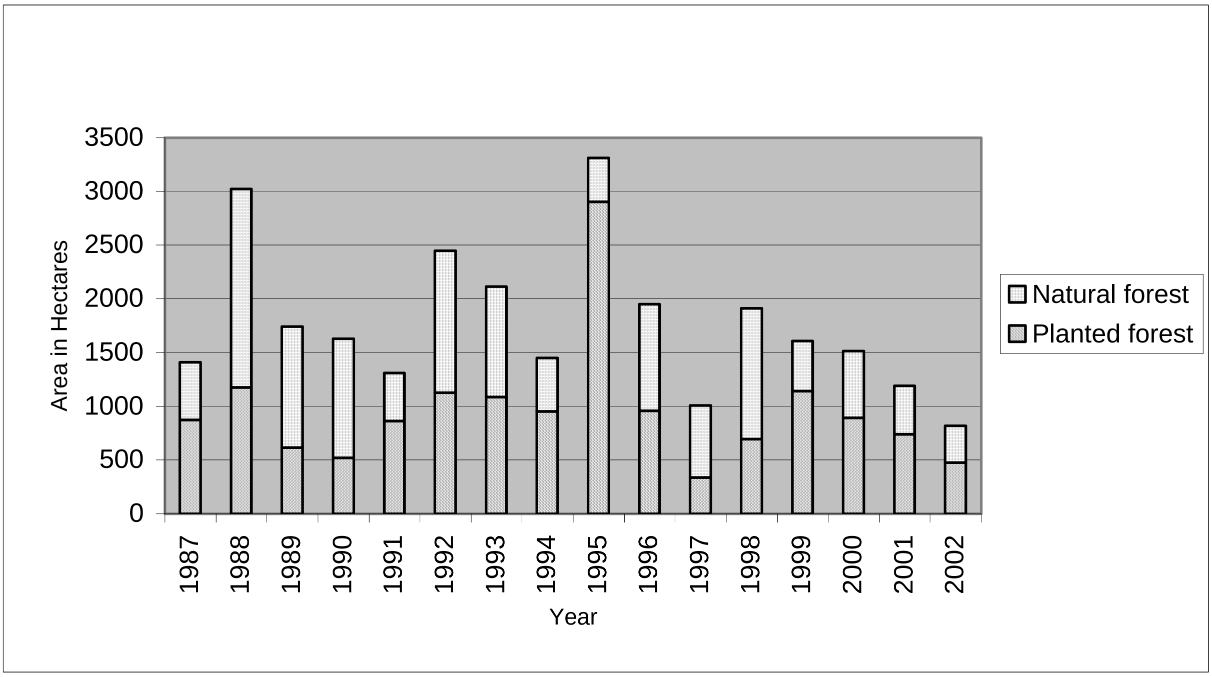

Figure 2. Total area burned in planted and natural forests of Israel (1987-2002)

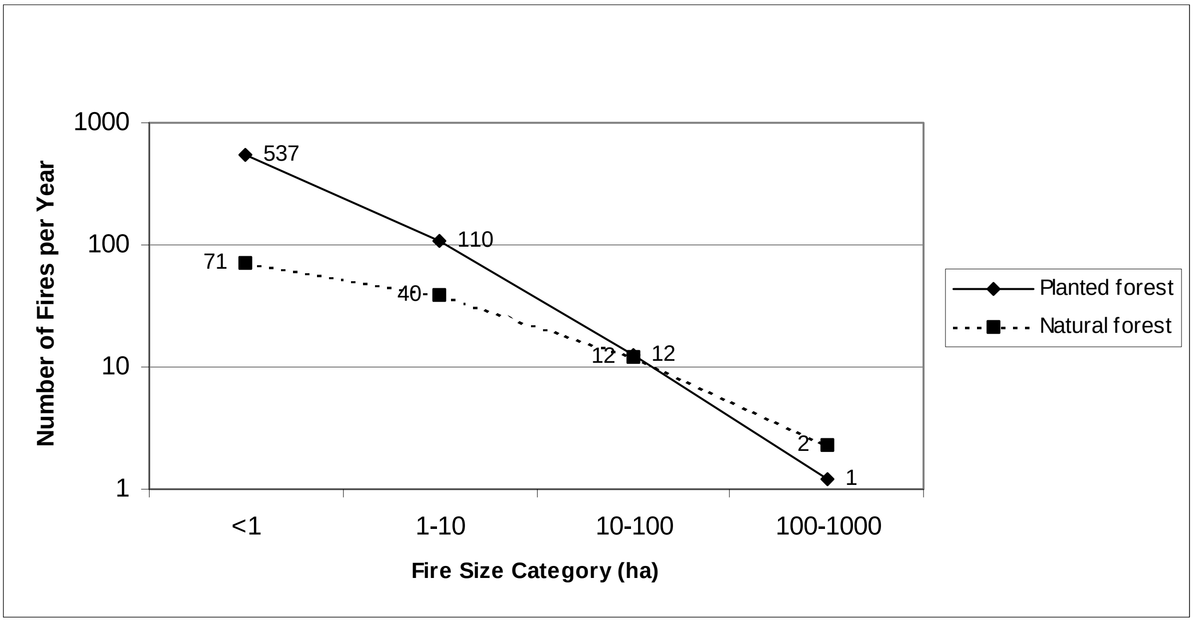

Figure 3. Average yearly number of fires by size category (1987-2002)

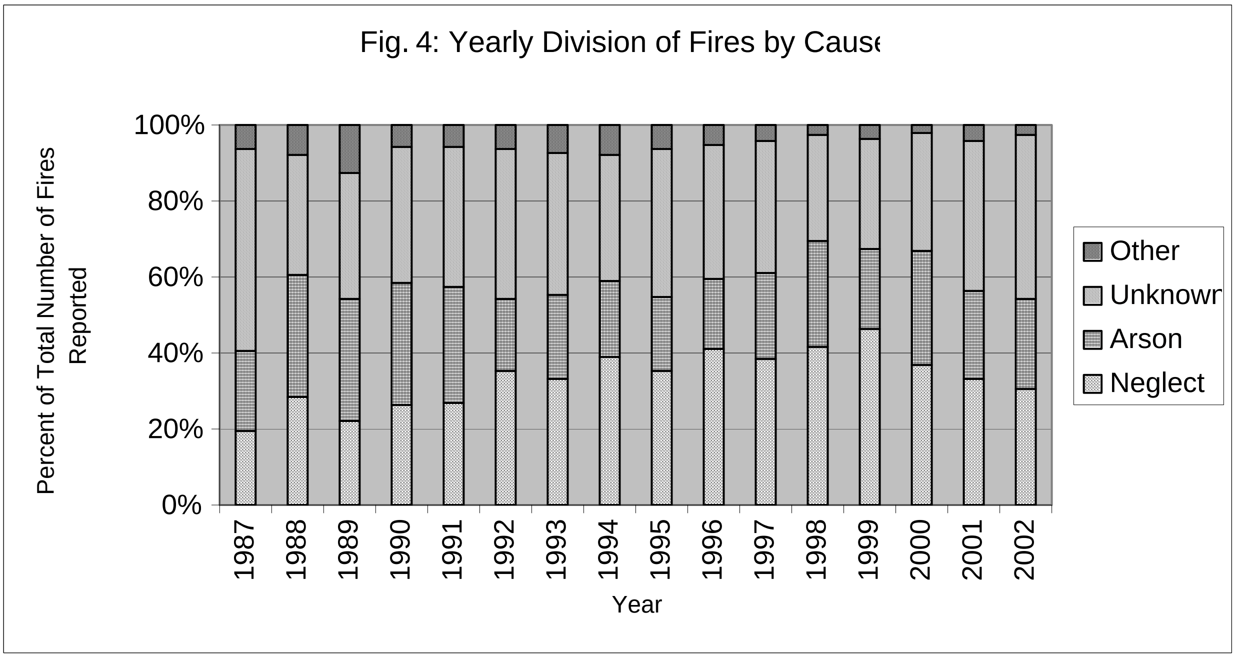

Figure 4. Distribution of fire causes in Israel by year (1987-2002)

It may be hypothesized that both the greater number and smaller size of fires in planted forests arises from a higher level of management intensity practiced on them relative to natural forests. Fuel management practices and road network densities characterize this well (discussed below).

The final characteristic of forest fires discussed here is the causes of fires. Fire cause data was divided into four groups, as a simplification of the data allows easy comparison with other countries. Naturally-caused fires are conspicuous in their absence here, since all lightning storms occur in the winter and are associated with heavy rain. The four groups are: 1) *Arson*: all fires proven or suspected to be intentionally lit; 2) *Negligence*: unintentional fires caused by campers, hikers, military training and garbage dumps; 3) *Unknown*: cause undetermined or unreported; and 4) *Other*.

Figure 4 illustrates the constancy of the fraction of the total number of fires associated with each cause: negligence 30-40%, arson 20-30%, unknown 30-40% and other causes 10% or less. Two exceptions stick out. In 1987, over 50% of the fires reported were of unknown cause. Also, between 1988 and 1991 the fraction of fires attributed to arson rose to over 30%. The latter may be explained by an increase in politically motivated arson associated with the Israeli-Palestinian conflict.

5. Pre-Suppression Operations and Fuel Management

"Protective silviculture", as termed by Velez (1990b), shapes and manages Mediterranean forests by giving it the capacity to protect itself from catastrophic fires. The author suggests an integrated strategy to hamper the spread of forest fires "by creating discontinuities, avoiding very extensive, monospecific surface areas and creating patchworks of different inflammability levels that "disturb" the fire." These actions "should aim to create mosaics of species, by integrating other activities that give rise to discontinuity, such as roads, electricity line fuelbreaks, cultivations and recreational areas." Below is a review of how Israel adapted this strategy.

5.1 Alteration of Surface Fuels

Grazing: Up until the establishment of the State of Israel in 1948, goat grazing on public lands was intense and relatively unregulated. A degraded landscape of overgrazed Mediterranean maquis was a common sight. The “black goat law”, imposed by the government in 1950, caused a gradual reduction in the number of goats and grazing pressure. A further reduction occurred in the 1980’s for socio-economic reasons. In some forest areas, grazing pressure even decreased much below the desirable level for effective elimination of dry herbaceous vegetation and regenerating evergreen shrubs and trees. This changeover from goat to cattle grazing encouraged the expansion and invasion of thorny shrubs formerly eaten by goats (*Sarcopoterium spinosa, Calycotome villosa)* into the forest’s understory and open patches, thus resulting in dangerous levels of accumulated forest fuels.

At present, beef cattle occupy most of the grazed forestland, though a small percentage of sheep and goats graze as well. The JNF Forest Department encourages controlled grazing in planted and native forests (see Photo 1). The issuance of licenses according to herd size and carrying capacity of the grazing area restricts grazing to specific areas, timeframes and pressures. During the last two decades, silvopastoral management of large, planted forests developed (Etienne 2000; Tsiouvaras 2000). The Forest Department carries out infrastructure development (fencing, watering and tending compounds) for herd owners in or nearby the forest. This aims at avoiding any legal tenure of the herd owners on the forestland, which is national property. These activities are financed by the KKL, the Ministry of Agriculture and the Israel Lands Administration through a joint administrative body known as the “Pasture Authority”.

Herbicide Application: The use of herbicides for vegetation control of forest fuels is primarily utilized along forest road corridors, forest edges and the perimeters of intensive recreational zones – areas in which grazing is not possible or where total control is desired from the time of the target vegetation's emergence (early winter). Weitz (1974) reports the spraying of firebreaks commenced in the early 1960's. Now, as then, applications typically employ a combination of non-selective pre- and post-emergent compounds to eliminate unwanted annuals and perennials. Simazine, sulfometuron (Oust) and glyphosate (Roundup) are the most commonly applied materials, at rates of: Simazine - 5000 grams/hectare; sulfometuron - 20 grams/hectare; glyphosate – 2000-3000 cc/hectare.

Slash Treatment: A major source of fuel build-up in the forest is slash and wood residues from silvicultural treatments, such as pruning, thinning and clearcutting, and accumulated fuels in untreated, overstocked stands. In the past, all practices to reduce fuel loading were manually done – forest residues were removed and burned solely by forest workers. The high cost of this practice led in many cases to its discontinuation, with much slash remaining untouched in the forest. Thereafter, “whole tree” logging by contractors began in thinning and clear-cutting operations. In this practice, delimbing and bucking of logs takes place along a roadside or outside the forest, with the residues burned, chipped or removed from the site.

Prescribed Burning: In the late 1980s and early 1990s the use of broadcast prescribed burning as a tool to reduce fuel loading on the forest floor received attention. In 1987, a KKL-USDA Forest Service cooperative exchange program came into being. Forest Service specialists made five advisory missions to Israel: 1987 (fire management team; Brandel et al. 1988), 1989 (forest fire protection), 1990 (prescribed burning), 1991 (fire weather team) and 1992 (prescribed burning), and in 1993, two specialists conducted a two-week prescribed burning seminar and workshop in the north and central regions (Carlton et al. 1993). Conversely, KKL specialists attended USFS sponsored courses on firefighting techniques (Avni et al. 1990) and technology such as fire behaviour modelling (Woodcock 1991).

Photo 1. Intensively managed grazed fuelbreak.

Photo 2. High-pruned fuelbreak surrounding an industrial site

The parameters for a successful and efficient prescribed burn under the condition of planted pine forests in Israel were determined (Kutiel 1989; Zohar et al. 1988, 1990a, 1990b, 1994, 1996). The use of this method has remained limited to sites for renewal plantings, remote sites around military firing zones and garbage dumps that occasionally burn unaided. Most of the forest areas in Israel are located close to villages and cities, therefore complaints by the public regarding smoke from prescribed burns resulted in its confinement.

5.2 Firebreaks

Isolation of forest stands from surrounding open area fuels and prevention of fire spread between stands traditionally involved the construction of a network of vertically oriented firebreaks. Firebreaks were originally established throughout forests at the time of their planting (1950s to 1960s). A dense network of vertically arranged strips were located across forest landscapes and served their purpose to slow down or halt ground fires. The use of manual hoeing and annual herbicide applications created clean, vegetation-free zones. Once the majority of these forests matured to heights of over 12 meters, firebreaks were no longer an effective means of preventing the spread of fires, particularly the spread of crown fires. In addition, their maintenance became too expensive to sustain. Therefore, KKL abandoned the continued use and construction of vertically-oriented firebreaks on an intensive scale, except on sensitive forest borders and edges.

5.3 Forest Roads

In light of the lessons learned about firebreaks, a relatively high-density forest road network was constructed (0.09 kilometer of forest road / hectare of planted forest, and 0.02 kilometer of forest road / hectare of natural forest). They function as firebreaks as well as access points for fire crews and fire engines. Motor graders and herbicides maintain peripheral roads on a yearly basis and interior roads on a rotational bi- or tri-annual basis.

5.4. Breakup of Fuel and Landscape Continuity

Pruning: The removal of live and dead branches from the bole increases height to the base of a tree's live crown and removes ladder fuels that carry a ground fire into the forest canopy. Young conifers are pruned to a height of 1/3 total height and mature trees to a height of between 2-2.5 meters. Trees along main forest roads, recreational sites and certain borderlands receive a high pruning of 4 meters (see Photo 2).

Thinnings: The manipulation of stand density and tree spacing is utilized to maximize growth and survival of forest trees, to remove dead and dying trees, to open and create discontinuous canopy gaps and to facilitate access to ground crews. It is the primary silvicultural tool employed to manipulate vertical and horizontal changes to forest structure and fuel dispersal throughout a forest. Not only are tree fuels affected but ground fuels and understory plants as well. Extensive opening of the forest canopy encourages vigorous understory growth, thus increasing hazardous fine fuel build-up, compared to dense forest stands. Zohar et al (1988) found a positive relationship between stand density levels and rate of fire spread, and a negative relation to tree age and to the percentage of tree canopy cover. This tradeoff must be balanced with the application of controlled grazing to keep understory biomass at a safe level.

Planted Fuelbreaks: Planted fuelbreaks are a strategic form of tree planting incorporated into standard forest plantings. Conceived and utilized as important landscape elements, they break up forest fuel continuity in an aesthetic and ecologically sensitive manner (see Photo 3). They replace barren fuelbreaks with living forest elements functioning as green barriers to a fire's advancing movement. Chandler et al. (1983) describe it as "a greenbelt – a strip that has been converted to a non-flammable cover-type and is maintained in that state by irrigation and mechanical treatment". Some examples include:

- Cultivated, non-irrigated groves of Mediterranean fruit trees (olives, figs, almond, dates, pomegranate, pistachio etc.) (Zeidan 2000);
- Strips of low flammability trees (*Casuarina*, *Cupressus sempervirons*) throughout the forest and alongside forest roads, separating flammable stands from each other or from recreational areas (Zohar et al 1988);
- Low-density, open, park-forest formations (oaks, carobs) interspersed throughout a forest;
- The retention of small, unplanted, herbaceous, open patches located throughout the forest.

Shaded Fuelbreaks: The establishment and maintenance of shaded fuelbreaks in Israel shows promise as an integrative solution protecting human settlements, and the forests surrounding them, from devastating forest fires (Perevolotsky et al. 1996). A shaded fuelbreak is defined by Agee et al. (2000) as “an area manipulated for the common purpose of reducing fuels to reduce the spread of wildfires”. It is “created by altering surface fuels, increasing the height to the base of the live crown, and opening the canopy by removing trees". The authors envision them as a type of managed buffer strip constructed between built structures and the forests surrounding them. Based on the integration of ecological, biological, mechanical and chemical control techniques, they embody Wagner's (1994) concept of an "integrated forest vegetation management" approach to the specifically oriented goal of fuel reduction and management.

Photo 3. Planted fuelbreak of widely-spaced olive and cypress trees

The use and construction of shaded fuelbreaks around villages, towns and settlements has received wide attention during the past five years. Weatherspoon et al. (1996) attribute the following major benefits to them: 1) reducing severity of wildfires within treated areas; 2) providing broad zones within which firefighters can conduct suppression operations more safely and more efficiently; 3) effectively breaking up the continuity of hazardous fuels across a landscape; 4) providing "anchor" lines to facilitate subsequent areawide fuel treatments; and, 5) providing various non-fire benefits.

Several rural settlements in the Galilee have shaded fuelbreaks around them (see Photo 4). They were constructed to a depth of 100 meters from the external home borders by the following stages:

- intensive thinning of planted and natural forests surrounding the settlements created an open park-forest formation of 200-300 trees/hectare (6-7 meters between individual trees);
- high pruning of conifers to 4 meters and native trees to 50% of their height;
- complete removal of unwanted stump sprouts, shrubs, vines and low trees in the understory;
- complete slash treatment and removal through fire or chipping;
- fencing of the treated area;
- high intensity grazing of beef cattle and/or goats to remove fine fuel build up and prevent closure of the understory;
- periodic spraying of systemic herbicides to control problematic perennials not sufficiently eaten or trampled by the livestock.

Photo 4. Shaded fuelbreak of low density pines surrounding a rural community

5.5 Fire Prediction and Detection

National Fire Danger Rating System (NFDRS): In 1992, the KKL and the Israel Meteorological Service established a NFDRS with assistance from the United State Forest Service (Bradshaw et al. 1978, Woodcock 1993). On a daily basis, meteorological data is gathered. Forest fires indices [IC (Ignition component) and BI (Burning index)] are calculated on a regional basis, and alert readiness levels of fire suppression teams are accordingly declared. Three forecasted fire danger levels (regular, high, and extreme) provide the basis for determining the size of stand-by initial attack crews, the number of additional personnel to recruit for patrols, the number of lookout towers to activate, and the positioning of fire trucks and other equipment.

Fire Lookout Towers: First established in 1957, a complex of early lookout towers numbered 14 by 1967 (Weitz 1974). As forest area increased, the incidence and frequency of forest fires increased along with it. At present, a network of 40 lookout towers covers most of the country's forested areas (see Photo 5). The majority are staffed everyday during the fire season, between 09:00 and 19:00, with the remainder operated on “Red Flag” days. The Nature and Park Authority operate additional lookouts within nature reserves and national parks, thus complimenting the KKL's network. On average, observers on our lookout towers discover some 43% of reported fires with another 16% called in by KKL field workers.

Photo 5. Achihud Forest fire watchtower

6. Coordination, Computerization and Finances

Coordination: In 1988, a special unit was established in the Forest Dept. to coordinate activities nationally concerning fire prevention strategy (Kaider 1986). Areas of responsibility include: developing fire-fighting management strategies, overseeing the adoption and implementation of new techniques and technologies, development of a centralized in-house training program, supervising the adoption of a integrated communications technology, establishing a unified chain of command and control, and equipment acquisition.

Data Management: Since 1987, reports of forest fires enter a computerized database. Data on fire size, timeframe, location, type, cause, vegetation type, labour and equipment usage is recorded and stored for future statistical analysis. Annual reports summarize the past year's events and present trends concerning the effectiveness of pre-suppression and suppression strategies. These reports are an important management tool for tracking a strategy's effectiveness and its implementation, helping to identify strengths and weaknesses, and areas for improvement. The data format has changed several times but sufficient consistency was maintained to allow analysis.

Since 1995, fire data is managed in a centralized database, with access at any PC on the KKL's national network. This allows direct data input and updating from any of our eight district forestry offices as well as on-line summary reports at all management levels (see Chevrou et al 1995).

Geographic Information System: In 1995, the KKL launched a national forestry GIS project. This began with the complete remapping of our forested areas beginning with aerial photography and including extensive ground checking. The GIS layers of significance to fire management created in the framework of this project include forest stands, forest roads, lookout towers, recreation sites, and fire fighting logistics sites. A special, fire management map at a 1:25,000 scale was produced and distributed within the Forest Dept. and among other organizations involved in fighting open area fires (Police, Fire Brigades, Military, Governmental agencies, Local and Regional Councils, etc.), and include hydrant locations, rural airfields and pre-designated logistical meeting points for coordinated command and control operations.

Beginning in 1991, fire reports included the "x" and "y" coordinates of the burned area's center. Thus, from this time onwards, fire occurrence (point) layers are created from this data and used for statistical analysis of fire location and frequency on a geographical basis.

Fire Suppression Finances: An analysis of fire suppression expenditures for the years 1994-2002 reveals that they comprise, on average, 9-14% of the Forest Department's total annual operating budget (Figure 5), exclusive of pre-suppression expenses (pruning, road and fuelbreak maintenance, etc).

Whereas total forestry operating budgets have decreased over the last decade, fire suppression's share has increased proportionally (Figure 6), with most of the budget allocated to manpower costs, both internal (KKL workers) and external (outsourcing from contractors; KKL's contribution to an interagency aerial attack fund). It can be concluded that fire suppression expenditures for this time period comprised a fixed expense component of the annual budgets and were relatively inflexible to change in relation to overall budget changes. The question of whether or not to maintain a minimal level of uncompromised protection to our existing forest inventory is now under consideration.

7. Fire Suppression Organization

Fire suppression strategy bases itself upon a rapid, initial attack of small fires. Chandler et al (1983) describe the principles of initial attack as: 1) "sizing up" the fire before attack; 2) determining manpower requirements; 3) attack; and, 4) mop up. Each forest management area (25 nationwide) functions as an autonomous unit. A small crew of 3-5 workers is outfitted with two-way radios and cellular phones, and equipped with a small wildland fire truck (250 gallon water tank + fire retardant system) including tools and gear (hoses, nozzles, backpack sprayers, chain saw, drip torch, fire rakes, fire swatters, hoes, drinking water, gloves, goggles, helmets, and smoke masks). There is a program to replace some of these small trucks with larger capacity ones (500-750 gallons), thus enhancing our capability to deal with medium sized fires.

Employing an "initial attack strategy" (Wenger 1984), these crews usually arrive at a fire scene within 20 minutes of receiving a call, and successfully control between 80-90% of all fires unaided (Rosenberg 1986). The combination of high accessibility to forests and short detection times of forest fires has proven to be a successful recipe for minimizing damage to our forests from fire. In addition, our initial attack strategy gives the fire boss time to rapidly assess the situation and organize enlistment of additional KKL crews and/or municipal fire brigades in the case of medium- and large- sized fires. The employment, in some cases, of helicopters and small, fixed-wing, agricultural aircraft happens when ground crews cannot reach the fire or when weather conditions demand a massive attack on the fire front.

On "Red Flag" days, additional lookouts, mobile patrols and suppression crews operate, with aircraft held in ready for rapid deployment at local airfields located throughout the country. Mobile crew deployment is flexible. They can move between different forest management areas, districts and even regions according to logistical needs. Larger blazes necessitate an "expanded attack strategy", contingent on the employment of additional small crews, local fire brigades and/or other open space management agencies, and the use of bulldozers and/or aircraft (Wenger 1984).

Exceptionally large conflagrations, which can rage over the course of several days and require simultaneous operations on several fire fronts, are treated as "project fires" (Wenger 1984). The current suppression and attack strategy for large-scale fires predicates itself upon interagency coordination and cooperation between the KKL, municipal fire brigades, Nature and Parks Authority, the Israeli Air Force, Israeli Police and emergency medical services, and the division of operations into separate sectors of responsibility. Establishment of a mobile joint command center facilitates open and clear lines of communication between all participating agencies and gives an overall, real-time picture of fire events to managers. Common radio frequencies facilitate clear contact between ground crews and aircraft pilots.

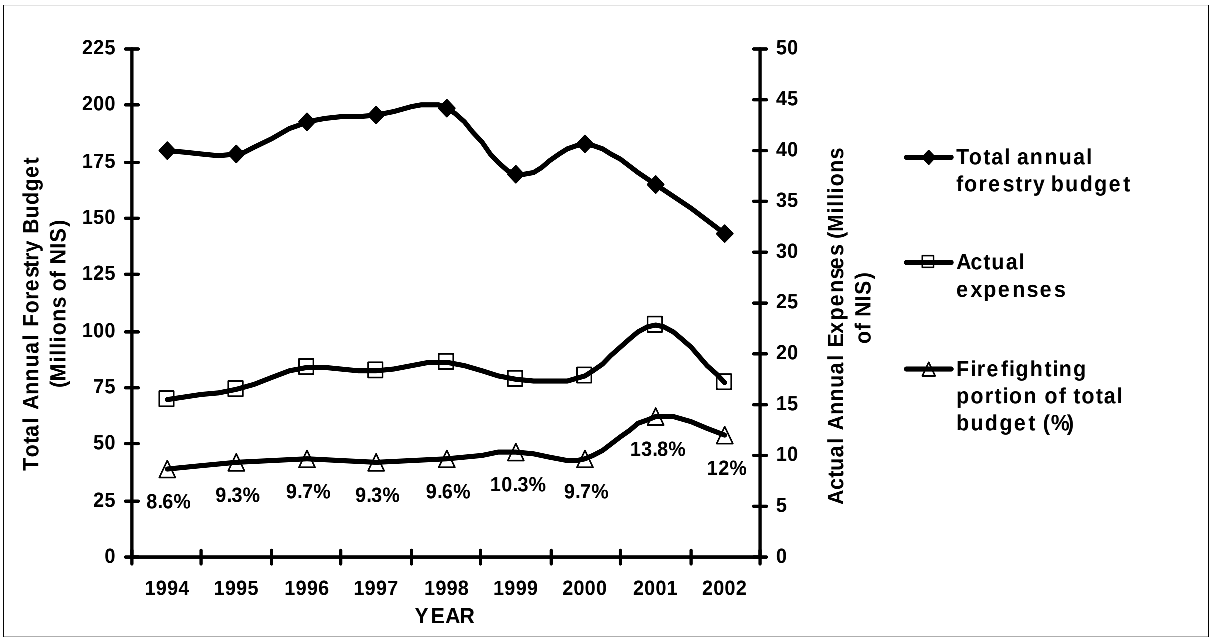

Figure 5. Fire suppression expenses as related to total annual budget (1994-2002)

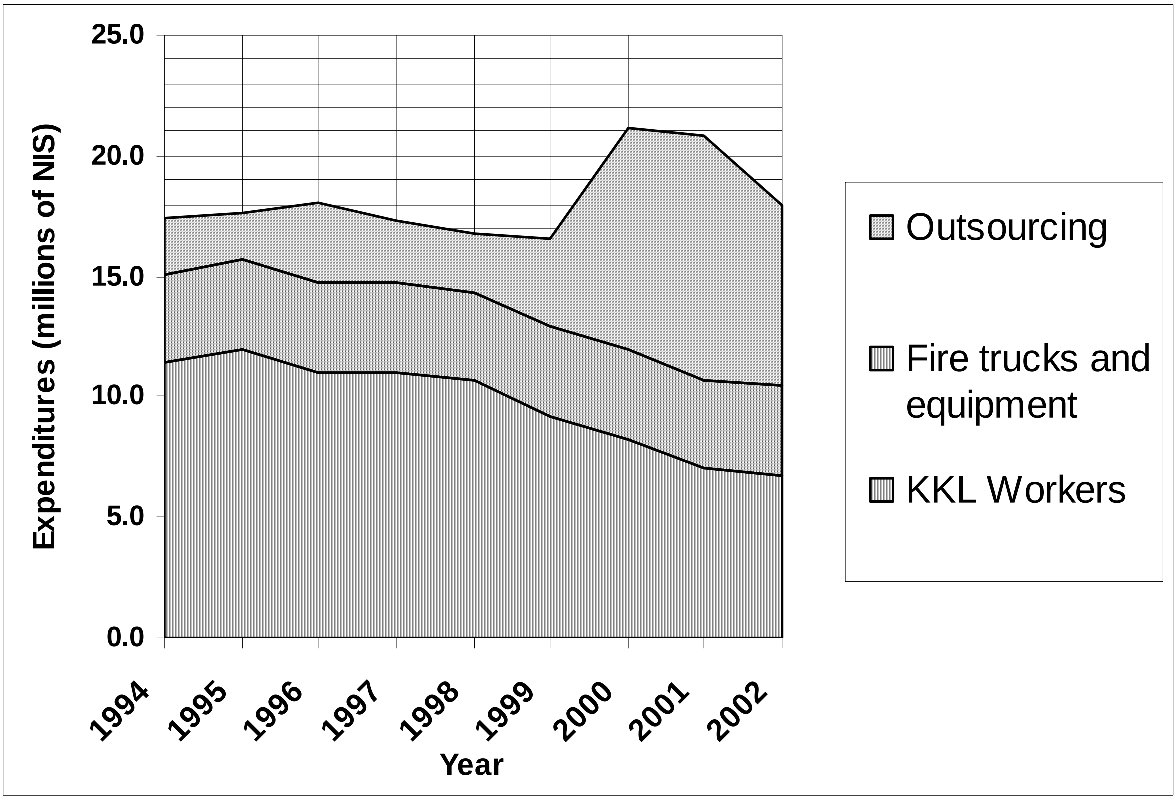

Figure 6. Allocation of annual fire suppression expenditures (1994-2002)

8. Conclusion

Dramatic and significant changes occurred to the fire fighting structure of the KKL Forest Dept. in Israel over the past fifteen years. As part of the natural growth cycle and maturation of first generation afforestation plantings and regenerating natural oak forests, catastrophic fire events became more and more predominant, and gripped the public's attention.

Today, all of Israel’s forests, cities, towns and villages lie on the urban/rural interface. Demographic trends and intense land use pressures are contributing factors in a nationwide challenge to deal with forest fires along this interface. Experience has shown that the integrated application of fuel reduction methods in pine forest management can effectively reduce fuel loading in Israel’s forests and the subsequent fire hazards associated with it.

Integrated management of pre-suppression measures linked to a continuously updating data and financial management system, and an updated GIS, provide very powerful tools for managing and evaluating fire fighting strategy in the short-, medium- and long terms. Managerial and silvicultural decisions are interdependent and linked to the analytical ability of the organization to self-evaluate and self-improve, based on its long term strategic goals.

Shaded fuel break construction is the most integrated form of fuel management employed, using silvicultural and ecological techniques of combined land management to create living buffer strips around rural communities threatened by wildfire.

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