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Guidelines on Fire Management in Temperate and Boreal Forests

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The purpose of these papers is to provide early information on on-going activities and programmes, and to stimulate discussion.

Comments and feedback are welcome.

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FAO GUIDELINES
on
FIRE MANAGEMENT
in
TEMPERATE AND BOREAL FORESTS

1. Preface

Destructive wildfires have been increasing in occurrence across global temperate and boreal zones during the past two decades. These fire outbreaks are the result of increasing human populations and land-use change. Conversely, societies have become more vulnerable to the direct damages caused by wildfires and the consequences of secondary disasters occurring after forest destruction by fire.

On the other hand, it has become common knowledge that, in the history of boreal forests and in some temperate forest types, natural (lightning) fires and traditional burning practices of humans have significantly shaped stable forest ecosystems. Changing fire regimes as a consequence of forest use are often associated with forest and site degradation.

In addition, burning of forests and other vegetation exert impacts at different levels on local, regional, and global environments. Smoke from large-scale wildfires also reduces the safety of air, land and coastal marine traffic, with attendant human health problems. Fires in the interface between wildlands and residential areas often cause the loss of human lives, property, and other values-at- risk.

The primary concerns of forest managers and policy makers focus on questions concerning the local to global impacts of excessive and uncontrolled burning, broad-scale trends over time, and the options for instituting protocols that will lead to improved control. Other key questions involve determining in what circumstances fires pose a sufficiently serious problem to require action; what factors govern the incidence and impacts of fires in such cases; and what might be the relative costs and benefits of different options for reducing adverse impacts?

The majority of nations in the temperate and boreal zone have systems in place that permit appropriate fire management actions. However, in some countries there is still a deficiency in systematic approaches to fire management due to a lack of guiding policies or shortcomings in funding. In other places, traditional misconceptions in fire prevention are inefficient or expensive. Unchecked rural human population shifts, urbanization, and civil and frontier wars have also been identified in developing countries as significant contributors to degrading practices and increased fire risk in temperate forests. There are large forest areas in which natural or human-set fires have beneficial effects and improve ecosystem stability and diversity. The exclusion or suppression of fires in these ecosystems may have detrimental consequences, particularly because of a build-up of fuels and an increase in wildfire hazard. As a consequence, high-intensity and high–severity wildfires occur that are often difficult or even impossible to control.

These fire management guidelines are designed to provide a base for policy makers and managers at various levels to develop programs and projects in which the specific national, socio-economic, and natural problems related to fire in temperate and boreal natural and planted forests will be addressed. The scope of the guidelines is to assist countries in developing programs for reducing damage caused by fire; and to help forest managers and rural residents to safely use and take advantage of the beneficial effects of fire in land-use systems. The guidelines are in accordance with the FAO policy and take into account the recommendations of the FAO Meeting on Public Policies Affecting Forest Fires (FAO 1999) and the FAO/ITTO International Expert Meeting on Forest Fire Management (FAO 2001a) and Legal Frameworks for Forest Fire Management: International Agreements and National Legislation (FAO 2002a).

The guidelines also address the objectives of the United Nations International Strategy for Disaster Reduction (ISDR) that has been established by the UN Economic and Social Council (ECOSOC) and the General Assembly of the United Nations (UN 1999), particularly the ISDR Interagency Task Force on Natural Disaster Reduction, Working Group on Wildland Fire. The Working Group on Wildland Fire supports the UN and other international stakeholders by providing an inter-sectoral and interdisciplinary global platform for policy support.

The guidelines recognize that many forest fires originate in agricultural and pastoral systems; and in degraded vegetation, outside of forest areas. Therefore, fire management on former and degraded forest lands may help to re-establish productive forests and to safeguard the success of reforestation programs.

The FAO Guidelines are complementary to:

- the ITTO *Guidelines on Fire Management in Tropical Forests* (ITTO 1997)
- the FAO *Handbook on Forest Fire Protection as a Technical Guide For The Mediterranean Basin* <FAO/Cemagref: Guide technique international Protection des forêts contre l'incendie. Fiches techniques pour les pays du Bassin Méditerranée> (FAO 2002b)
- the WHO/WMO/UNEP Health Guidelines for Vegetation Fire Events (Schwela et al. 1999)

The FAO guidelines have been drafted by Johann G. Goldammer (Global Fire Monitoring Center, Germany), Cornelius de Ronde (SILVA Forest Services, South Africa), Brian J. Stocks (Canadian Forest Service), and Eduard P. Davidenko (National Aerial Forest Fire Center *Avialesookhrana*, Russian Federation). The following scientists contributed to the Fire Management Options tables in ANNEX III: Norman L. Christensen (Duke University, U.S.A.), Stanislav N. Sannikov (Institute of Forest, Ural Division of Russian Academy, Russian Federation), Valentin V. Furyaev, Anatoly I Sukhinin, Peter Tsvetkov and Luda Zlobina (Forest Fire Laboratory, Sukachev Institute for Forest, Russian Academy of Sciences, Siberian Branch). Some of the materials used in the guidelines are based on the "Sub-Sahara Africa Forest Fire Management Handbook" (J. G. Goldammer and C. de Ronde, eds.) which had been in preparation at the same time these guidelines were prepared.

2. Fire Ecology and Fire Management Principles: Selected examples

Before considering the role of fire ecology and fire management options, it is necessary to investigate specific fire requirements such as optimum fire intervals, fire frequency, fire season and type of fire, required to maintain biodiversity, management and social requirements. These characteristics and needs by region are summarised in examples below for some of the important biomes of temperate and boreal forests, and expanded in the attached Appendices.

2.1 Fire Management in Temperate Africa

2.1.1 Woodlands (Table 1a)

Characteristics

Most African woodlands are deciduous or semi-deciduous, but nearly all types contain a few evergreen species. The field layer is usually dominated by herbaceous tussock grasses, which are usually perennial. Annual grasses are predominant in certain transitional types, especially under the influence of heavy grazing. In most types there is an incomplete understorey of small trees, or large bushes of variable density and fire tolerance. The functional role of fire and fire impacts in woodlands are related to the availability of fuels in the grass layer. As a consequence of climate variability including, El Niño / La Niña, large inter-annual variability of fire extent has been observed in the semi-arid areas of Southern Africa Africa's woodlands. Drought and increasing grazing pressure lead to reduction of fuel loads available to be burned, and to a large variability in burning patterns (no fires or smaller burns). On the other side a wet year with reduced fire activity is often followed by an extreme fire year due to the higher availability of combustible materials.

Management Implications

The biggest problems, facing fire managers in woodlands, are to find ways to meet the ecological requirements and also to supply sufficient grazing. Too frequent fires will reduce the overstorey and degrade the system, while grazing pressure can disturb the ecological balance.

2.1.2 Natural Forests (Table 1a)

Characteristics

The temperate natural forests in Africa can be found within the Afro-montane forests, and occur in an archipelago-like pattern. Generally, non-degraded afro-montane forests do not readily burn due to their structure, separation from the litter layer, and higher fuel moistures. Crown fires in afro-montane forests are extremely rare. However, fire does play a significant role in controlling the extent of afro-montane forests.

Management Implications
Although climax forests are seldom exposed to major wildfires, transition zones are subject to disturbance that can systematically reduce these decreasing ecosystems. Protection measures are thus required where these occur.

2.1.3 Industrial Plantations (Table 1b)

Characteristics
Most even-aged *Acacia*, *Eucalyptus* and *Pinus* plantations have been established in Southern Africa, in areas where rainfall is exceeding 750 mm per year. As most species planted originate from fire-related natural ecosystems and are established mostly in dynamic montane or savannah grasslands with an equal need for regular fire occurrence to maintain biodiversity, fire is playing an important role, and total fire exclusion normally results in common wildfires. Fuel management is normally required in the form of slash burning after clearfelling, but sometimes prescribed burning under the trees is required to solve specific fuel accumulation or weed problems.

Management Implications
Where fire is excluded for too long, large plantation areas can be destroyed by wildfires. Regular fuel reduction is required, and special fire protection measures are needed to protect plantations in areas, which have a high fire hazard. More use of prescribed fire is also required to meet these challenges.

2.1.4 Fynbos and Sub-Alpine Moorlands (Table 1b)

Characteristics
The fynbos biome is a fire-prone shrubland in the wetter areas along the coast, and in the mountains of the southwestern part of South Africa. Fynbos, a vernacular term for fine-leaved shrubs, is vegetation-dominated by evergreen shrubs. Two other major vegetation types are included in the fynbos biome. These are renosterveld and strandveld. Renosterveld is also an evergreen, fire-prone shrubland. Strandveld is a mix of thickets made up of broad-leaved shrubs and small trees, fynbos, and renosterveld. These broad-leaved elements also occur in fire-excluding thickets and scrub forests, in summer rainfall regions. They are not flammable, have fleshy fruits (rare in fynbos) and exclude low intensity burns.

Management Implications
Burning of fynbos and other moorlands, at specific intervals and season, is required to maintain biodiversity. These prescribed fires have to be applied at regular intervals, as fire exclusion will result in high intensity wildfires and subsequent biodiversity disturbance.

2.1.5 Grasslands and Savannahs (Table 1c)

Characteristics
Two main types of grassland may be distinguished:

- Climatic climax grasslands where succession does not normally proceed beyond the grassland stage because the climate is too cold to permit the development of woody communities, even in the absence of fire.
- Fire climax grasslands where the climate will permit succession to proceed beyond the grassland stage into shrubland or forest, but which are maintained as grassland by biotic factors such as fire and grazing. These grasslands are also referred to as "secondary" grasslands, or "false" grasslands.

Management Implications
Fire managers are faced with the challenge to satisfy ecological requirements for savannah and grassland, for specific burning rotations, fire intensities and burning seasons. They need to provide grazing resources in rural and agricultural areas and, in certain districts, they face increased population pressure.

2.1.6 Kalahari Grasslands and Shrub lands (Table 1c)

Characteristics
The grasslands and shrub lands of the southern Kalahari cover a major portion of Botswana (excluding the Okavango Delta, Chobe and Gabarone areas) and extend into parts of Namibia and South Africa. The Kalahari is a stark landscape dominated by sand dunes and plains, pans, and dry fossil riverbeds. There is a lack of surface water, as sand transports water to deep aquifers. Yet, fire is a significant part of this landscape, and under favourable conditions it can burn large tracts of land.

Management Implications
Irregular fire occurrence can lead to site degradation, and fire exclusion for longer periods is sometimes required, needing selective fire protection measures.

2.1.7 Fire Management in Nature Reserves, National Parks and other Protected Areas

Characteristics
This category covers all African ecosystems, each having its own fire-related ecological requirements. However, in the absence of urban-interface problems, forestry, agricultural and rural population needs, the emphasis can fall on ecological expects, with the exception of fire protection along strategic boundaries and roads. It is particularly in grassland and savannah-based nature reserves, with regular lightning occurrence and dense animal populations, that special attention is regularly required to check policy application, and for any disturbance of fire mosaics, as a result of too frequent or too little fire.

Management Implications
Although in many cases the natural occurrence of fire, as a result of *e.g.* lightning, should be encouraged, selective use of prescribed burning may still be required to adjust for problems introduced by man, such as fences and other obstacles that can produce a lack of escape routes for animals. This might lead to some significant adjustments of fire-related policies.

2.2 Fire Management in Temperate South America

2.2.1 Evergreen Mixed and Thorn Forests (Table 2a)

Characteristics
Maintenance of biodiversity is dependent on fire intensity experienced and burning intervals, and these biomes are susceptible to repeated high intensity fires, which can degrade sites, and which can lead to a decrease in grazing provision. Transition zones are most vulnerable. Fire damage to *Araucaria* and *Nothofagus* forests is dependent on the degree of disturbance. Small patches are particularly vulnerable. High intensity fires in Thorn Tree forests open up crown canopy and increase grass cover.

Management Implications
Fire protection, particularly along forest edges, can lead to improved biodiversity maintenance and sustainable grazing, provided this goes hand in hand with selective weed control where required. In Thorn forests, selective use of prescribed fire may be necessary for ecological reasons, as well as for biodiversity maintenance.

2.2.2 Industrial Plantations (Table 2b)

Characteristics
Most even-aged *Eucalyptus* and *Pinus* plantations, situated in the higher rainfall regions of South America, originate from fire-related natural ecosystems and are established in grasslands, woodlands and old forest land, which also needs regular fire occurrence to maintain biodiversity. Fire is thus playing an important role in these areas, and total fire exclusion normally results in regular wildfires. Selective fuel management is normally required in the form of slash burning after clearfelling, but sometimes prescribed burning under the trees is also required, to solve specific fuel accumulation or weed problems.

Management Implications
Where fire is excluded for too long, large plantation areas can be destroyed by wildfires. Regular fuel reduction is required, and special fire protection measures are needed to protect plantations in areas with a high fire hazard. More use of prescribed fire is also required to meet these challenges.

2.2.3 Sclerophyllous and Semi-Desert Scrub (Tables 2b and 2c)

Characteristics
Although most of times seldom reaching a wildfire climax, particularly in the case of Semi-Desert Scrub, some Sclerophyllous Scrub needs fire at specific intervals to maintain an ecological balance, depending on the climatic region where these biomes are situated. In the latter, uncontrolled fire may favour alien vegetation in some regions, and also disturb biodiversity.

Management Implications
Selective prescribed burning may be required in Sclerophyllous Scrub in the higher rainfall regions, while the selective use of exotic weed removal may also have to be implemented where needed, to maintain biodiversity.

2.2.4 Pampas and other Grasslands (Table 2c)

Characteristics
The Pampas occur on the lower altitude parts of the central and eastern parts of temperate South America, and prescribed fire requirements mainly depend on grazing intensity, type of grassland and climate. Fire history, biodiversity requirements, rainfall pattern, tree and bush regeneration requirements also influence successional development of the grassland.

Management Implications
Prescribed burning application should be considered by means of quantifying grazing intensity, fire history and successional needs. The correct prescribed fire application will ensure that the risk of wildfires is reduced, optimum grazing potential is provided, and the uncontrolled promotion of undesired species in restricted.

2.2.5 Fire Management in Nature Reserves, National Parks and other Protected Areas

Characteristics
This category covers most temperate ecosystems in South America, each having its own fire-related ecological requirements. However, in the absence of urban-interface problems, forestry, agricultural and rural population needs, the emphasis can fall on ecological expects, with the exception of fire protection along strategic lines.

Management Implications
Although in many cases the natural occurrence of fire as a result of *e.g.* lightning, should be encouraged, selective use of prescribed burning may still be required to adjust for problems introduced by man, such as fences and other obstacles, that can produce a lack of escape routes for animals, where applicable. This might lead to some significant adjustments of fire-related policies. However, in most National Parks, the uninterrupted allowance of natural fire will provide the best ecological environment.

2.3 Fire Management in Temperate Australasia

2.3.1 Evergreen and Sclerophyllous Forests (Table 3a)

Characteristics
In forest other than *Eucalyptus* forests, such as in the *Nothofagus* forests of Tasmania, fire may be a rare occurrence, but disturbance in the form of exploitation or grazing may create abnormal fuel levels and other damage to these forests, which may result in forest degradation. The protection of forest transition zones is important to avoid this.

Management Implications
Lack of forest edge protection may result in biodiversity loss and site degradation. Exploitation and other disturbance of these forests will also lead to abnormal fuel creation and a subsequent increase in fire hazard.

2.3.2 Industrial Plantations (Table 3b)

Characteristics
Most even-aged *Pinus* plantations, situated in the higher rainfall regions of Australia and New Zealand, originate from fire-related natural ecosystems and are established in grasslands, woodlands and old forest land, which also needs regular fire occurrence to maintain biodiversity. Fire is thus playing an important role in these areas, and total fire exclusion normally results in regular wildfires. Selective fuel management is normally required in the form of slash burning after clearfelling, but sometimes prescribed burning under the trees is required to solve specific fuel accumulation or weed problems.

Management Implications
Where fire is excluded for too long, large plantation areas can be destroyed by wildfires, particularly where species other than *Pinus radiata* are established. Selective fuel reduction is in most cases required, and special fire protection measures are needed to protect plantations in areas with a high fire hazard. More use of prescribed fire is also required to meet these challenges.

2.3.3 Scrubland in Lower Rainfall Regions (Tables 3b and 3c)

Characteristics
Normally only irregular fire is experienced in these biomes, the interval of occurrence depending on climatic factors. In Hummock Grasslands, wind-driven fires are more commonly experienced. If wildfires are too frequent, site degradation is possible.

Management Implications
Where fires are experienced more frequently than ecologically required, some fire protection measures may be required, to avoid site degradation.

2.3.4 Tussock Grassland

Characteristics
Tussock grasslands cover a substantial part of particular Australia. These grasslands normally require fire at various intervals, depending on the climate, grazing potential and grass type. Wildfires sometimes present a high risk, which can lead to serious loss of grazing potential. A suitable wildfire climax should be maintained, depending on the grazing intensity experienced.

Management Implications
Prescribed fire should be applied at the correct intervals, to promote optimum grass and tree/bush regeneration. Grazing potential will to a large extend determine the need for fire application, but species composition and climate will also contribute towards specific fire needs.

2.3.5 Fire Management in Nature Reserves, National Parks and other Protected Areas

Characteristics
This category covers most temperate ecosystems in Australia, Tasmania and New Zealand, each having its own fire-related ecological needs. Specific fire requirements, for specific ecosystem goals normally apply, including the need for fire protection.

Management Implications
Although in many cases the natural occurrence of fire as a result of *e.g.* lightning should be encouraged, selective use of prescribed burning may still be required, to adjust for problems introduced by man.

2.4 Forest Fire Management in Canada

With a total land mass of 921.5 million hectares, of which almost half (417.6 million ha) is covered by temperate and boreal forests, Canada is a vast country, largely dependent economically on forestry and forest industry. Forests considered capable of producing commercial forest products cover 234.5 million hectares across the country, primarily in the temperate and southern boreal forest regions, but only 119 million hectares are currently managed for timber production, with the remainder of the commercial forest being set aside for other purposes. Provincial governments own 71% of Canada's forest land, and are responsible for all aspects of forest management on this land base, including forest fire management. The federal government has ownership of 23% of the forested land, primarily in the Northwest and Yukon Territories, while private individuals, communities, and companies own 6%.

Individual provinces and territories have, over much of the past century, developed sophisticated fire management programs aimed at protecting human life and property, while maintaining the forest resource for public and commercial use. Fire management resources are shared between provincial/territorial agencies as required, and between Canada and the United States on occasion. Between 8,000 and 10,000 fires occur annually across Canada, but the area burned each year is highly episodic, varying by more than an order of magnitude, from 500,000 ha in low years to 7,500,000 ha in extreme years. On average, a total of $500 million is spent annually on fire management activities in Canada.

Due to aggressive suppression activities, only 3% of Canadian fires grow larger than 200 hectares in size, but these fires account for 97% of the area burned. The distribution of large fires is highly variable across Canada, due to differences in fire weather severity and forest fuel types, and to varying levels of fire suppression throughout the country. The fact that large parts of the Canadian forest landscape are essentially unprotected - fire being allowed to burn naturally when not a threat to values-at-risk such as communities, recreation, or forest industry interests, is a major contributor to large areas burned in Canada. An evaluation of fire activity across Canada is best accomplished at the ecozone scale. Forest fires are common within 11 ecozones across Canada (excluding the various Arctic ecozones, and the prairies), but their impact is highly variable. Due to distinct east-west differences in fire weather and fire regimes, the Taiga and Boreal Shield Ecozones are often subdivided. 39 years of fire data (1959-1997) was used to determine both the average annual area burned and the % annual area burned (PAAB - a function of both fire activity and ecozone size) for each ecozone.

2.4.1 Taiga Region

Taiga ecozones stretch across Canada from the northern Yukon through the Northwest Territories, northern Manitoba, and northern Quebec, and represent the transition zone between Arctic tundra and the Canadian boreal forest. This region consists primarily of non-commercial forest, with numerous aboriginal communities and natural resource extraction industries (primarily mining, and fossil fuel exploration).

Taiga Cordillera Ecozone
Located in the northern Yukon and northwestern Northwest Territories, this ecozone is mountainous with sparse forest cover, and is largely unpopulated. Vegetation is primarily comprised of arctic tundra, alpine tundra, and taiga species of shrubs, lichens and dwarf spruce and birch. Lightning fires dominate in this ecozone, burning over an average of ~20,000 ha annually, with a Percent Annual Area Burned (PAAB) of 0.184%. Suppression activity is minimal.

Taiga Plains Ecozone
Covering the southwestern region of the Northwest Territories, northeastern British Columbia, and northern Alberta, this ecozone is characterized by slow growing conifer forest, primarily black spruce. Population density is quite low, and lightning fires dominate. Fires are suppressed only when communities are threatened, and cover an average of ~366,000 ha annually (PAAB = 0.701%).

Taiga Shield Ecozone
This ecozone, heavily glaciated during the last Ice Age, stretching across Canada from the Northwest Territories through northern Manitoba, Ontario, and Quebec, is largely unpopulated. The Taiga Shield Ecozone can be subdivided into two sub-ecozones, separated by Hudson Bay, based primarily on distinctly different fire regimes due to variation in fire weather and climate.

> Taiga Shield West Sub-Ecozone
> Occupying portions on northern Manitoba, Saskatchewan, Alberta, and the southeastern Northwest Territories, this ecozone is dominated by dwarf conifer stands and lichen woodlands. Lightning fires predominate and population is low and centred around mineral and resource exploration. An average of ~243,000 ha burn annually in this ecozone, since a large proportion of fires are allowed to burn naturally, with a PAAB of 0.767%.

Taiga Shield East Sub-Ecozone

Covering central Quebec and Labrador, this ecozone has many features similar to the Taiga Shield West Ecozone, but a less continental climate, and generally less severe fire weather conditions. Population is low and scattered, and lightning fires dominate. Most fires are allowed to burn naturally. The result is an average annual area burned of ~117,000 ha (0.255% PAAB).

Boreal Region

Boreal ecozones stretch completely across Canada, representing a transition zone between taiga to the north and montane forests (British Columbia), grasslands (Alberta, Saskatchewan, and Manitoba) and temperate mixed wood forests (Ontario and Maritime provinces) to the south. It is in the boreal region, with its growing accessibility and natural resource-based development, where the full range of fire suppression options are utilized. The southern boreal, particularly in Eastern Canada, supports a fully developed forest industry, and active fire suppression is paramount. In northern boreal regions, however, fires are fought based on values-at-risk, with management decisions being made based on protecting communities or property versus permitting fires to burn naturally.

Boreal Cordillera Ecozone

Located in northern British Columbia and the southern Yukon, this ecozone is quite mountainous. Vegetation is often discontinuous and ranges from grasslands to open and closed cover forests. Population levels are low and protection efforts are modest and selective. Lightning fires predominate, contributing to an average annual area burned of ~ 106,000 ha (PAAB is 0.385%).

Boreal Plains Ecozone

This ecozone stretches from northeastern British Columbia across central Alberta and Saskatchewan to southeastern Manitoba, and was not glaciated during the last Ice Age. The region is essentially 100% developed and fire protection is maximized. Despite this level of protection, fire climate is often extreme, and large fires are common. The standard boreal species mix of spruce, pine, poplar, aspen and birch predominates. The average annual area burned is ~231,000 hectares (PAAB is 0.399%)

Hudson Plains Ecozone

This ecozone is largely centred in Ontario immediately south of Hudson Bay, but extends a small distance west into northern Manitoba and east into northern Quebec. The area contains extensive poorly drained wetlands dominated by a cold continental climate, which prevents the development of very large fires. Population levels are very low. The result is an ecozone with a low level of fire activity (annual average area burned of ~44,000 hectares (PAAB of 0.058%).

Boreal Shield Ecozone

This ecozone, the largest in Canada, extends from northern Saskatchewan through much of Manitoba, Ontario and Quebec to include Newfoundland. Also glaciated 10,000 years ago, but now over 80% forested, this ecozone is dominated by closed conifer stands of spruce, pine and fir, with some deciduous species such as aspen, poplar and birch. Much of the boreal shield ecozone zone is managed for resource extraction, particularly timber production, and has become much more accessible in recent decades. This is particularly true in the southern regions of the ecozone, while northern areas remain much less developed. The Boreal Shield Ecozone can also be subdivided into two distinct sub-ecozones with different fire regimes, which are separated by the Hudson Plains Ecozone in northern Ontario.

Boreal Shield West Sub-Ecozone

This sub-ecozone, covering northern Saskatchewan, central Manitoba and northwestern Ontario, has a strong continental climate and major fire activity. Although much of the region is managed forest, and population levels are moderate, there are still some northern areas where fire is not actively suppressed. As a result, the average annual area burned is ~516,000 hectares (0.769% PAAB)

Boreal Shield East Sub-Ecozone

Occupying much of the central and southern regions of Ontario and Quebec, and all of Newfoundland, this sub-ecozone is basically fully managed forest in which fire suppression activities are extensive and quite successful. The area is heavily populated by boreal standards. In addition the fire climate in this area of Canada is not as extreme as in the western shield region. The result is a much smaller average annual area burned (~155,000 hectares) and PAAB (0.167%).

Montane Cordillera Ecozone

Most of southern British Columbia and a portion of southwestern British Columbia are contained within this ecozone. It is the most diverse of all Canadian ecozones, ranging from alpine tundra to dense conifer forests. The climate can be quite dry in valleys due to mountainous rain shadow effects. Vegetative cover is extremely diverse and commercial forest operations are extensive, along with mining, energy production, and tourism. Protection efforts attempt to exclude fire across the complete ecozone, and are largely successful, but extreme fire danger conditions frequently create a challenge. The average annual area burned is ~24,000 ha (PAAB is 0.058%).

Pacific Maritime Ecozone

This ecozone covers the mainland Pacific coast and offshore islands of British Columbia. The climate is humid maritime with generally high precipitation levels. The area is heavily populated with an extensive forest industry. Protection levels are high, but the generally moist climate precludes much fire activity. The average annual area burned is only ~2000 ha with a PAAB of 0.013%.

Atlantic Maritime Ecozone

Covering the Maritime Provinces of New Brunswick, Nova Scotia, and Prince Edward Island, and a portion of southern Quebec, this ecozone is relatively small but highly populated with extensive forestry, mining, farming and fisheries industries. Forests are generally dominated by mixed stands of conifer and deciduous trees. Full fire suppression is practiced in this region, and this factor, in combination of generally modest fire danger conditions, results in a very low average annual area burned (~4200 ha) with a PAAB of 0.024%.

Mixedwood Plains
This small ecozone, located almost totally in southern Ontario, has been largely deforested over the past two centuries. Pockets of mixedwood stands exist, but deciduous species dominate. This is the most populated region of Canada, with all fires receiving a prompt response. This, in combination with a lack of fire-prone forest, results in the lowest fire activity in forested Canadian ecozones. The average annual area burned is ~190 ha with a PAAB of only 0.006%.

3. Fire Management in Plantation Forestry (Tables 1b, 2b and 3b)

3.1. External Fire Protection

In even-aged industrial plantations, fire protection is required on external plantation boundaries to protect *Acacia, Eucalyptus, Pinus* and other even-aged timber plantations, from wildfires originating from beyond these plantations' property boundaries. Many lands outside plantations consist of some form of natural vegetation (such as woodland, indigenous forest or grassland), nature reserves or agricultural land used for grazing or growing of short-rotation crops. Industrial plantations can also border public roads or railway lines, rural or farming communities, urban-interface areas of cities, or industrial sites. What these different types of land-use along plantation borders have in common is that they all present varying degrees of wildfire hazard to plantation timber resources.

External fire protection, in the form of firebreaks, can be provided along plantation boundaries in various ways, such as:

- Regular burning of grassland or other bordering vegetation.
- By adding prescribed burned plantation stands.
- Ploughing of firebreaks.
- Scraping of firebreaks.
- Hand-cleaning (or fuel removal within) fire breaks.
- Maintaining (or scraping) of roads on external boundaries.

Dynamic grasslands (such as Australian or African montane and savannah grassland) are normally burned after grassland curing has commenced. Before curing starts, tracer lines are prepared by means of chemical surface sprays, so that the grass within these lines can die before curing takes place, and to ensure that they can be burned prior to grassland curing. This is done to make certain that these lines are in place before the prescribed burning season, so that they do not take up valuable burning time after grassland curing. The grassland between these tracer lines is then burned on days suitable for prescribed burning; as soon as possible after grassland curing is completed. The burning of static grasslands (such as the Pampas) is regulated by grazing intensity, yearly biomass production (normally related to climatic factors such as rainfall) and age, as there are no clear seasonal fuel changes.

3.2. Internal Fire Protection

It is equally important to reduce fire hazard within plantations, than to provide external fire protection. Fires can originate within plantation blocks, or external wildfires can spot or burn across external firebreaks. If this happens, internal fire breaks will have to ensure that the spread of these fires within “plantation areas at risk” is restricted to the smallest area possible, and the smaller (and better protected) these plantation units are, the better will be the chances to bring these internal fires under control, and to minimize damage. Clean roads within plantation blocks, regularly-burned wetlands, indigenous forests, steep (rocky) terrain with low fuel profiles, rivers with riverine forests and slash-burned compartments, are all examples of suitable internal protective barriers that can be incorporated into internal fire break systems. The more continuous these lines are, the better the chances will be to restrict wildfires within plantation boundaries.

Watershed lines - also acting as firebreaks - can also be utilised as “wildlife corridors” and even facilitate optimised water runoff, thus forming multi-purpose fire management systems. Alternative firebreak routes should be investigated, where these requirements cannot be met.

3.3. Using Slash Burning, or Prescribed Burning inside Plantation Stands, as Fuel Management Measures

Because of the clearfelling regime applied in even-aged industrial plantations, slash is deposited in large quantities where mature trees are felled and exploited, prior to re-establishment. In many cases this litter-and-slash loading occurs in low quantities, which will not present tree re-establishment problems. However, in some areas, *e.g.* at some high altitude sites, the slash loading can be of such a nature that access and replanting is severely restricted. It is then that some degree of fuel reduction will be a required to make economical re-establishment of trees possible. Sometimes slash burning will have to be applied regardless whether the fuel loading is restricting access for replanting purposes or not, because the stand is either bordering a major fire protection bufferzone, or falls within a major bufferzone/fuel break area. It is important to evaluate slash features such as loading, spread and vertical distribution in clearfelled stands, to determine whether slash burning should be considered as a fuel reduction measure, or not. Slash burning should be avoided on sandy soils or other sites with low nitrogen levels. However, if slash burning cannot be avoided on these sites, the impact of these burns on nutrients should preferably be determined by means of the collection and analysis of surface soil samples (sampling to be applied before and after the burn). Slash burning on steep slopes should also be avoided to prevent erosion.

With regard to slash burning techniques to be used, broadcast burning of slash (after spreading the slash when timber removal is completed) is recommended in most cases because (a) it has proved to be the safest and cheapest method, and (b) stacking of slash in heaps and then burning the heaps has not only proved to be more expensive, but is also exposing the soil to high fire temperatures for longer periods of time, which can be detrimental to chemical and physical soil properties.

Selective use of prescribed burning inside stands can also be considered as a fuel reduction measure, particularly where a serious lack of decomposition of litter is experienced. This technique can also be used to combat certain weed problems, to eradicate insect pests and can even enhance nutritional availability. Specific species/age requirements and burning techniques are needed in this case.

3.4. Fire Application in Heritage Areas and Nature Reserves

Where natural heritage areas are situated within plantation boundaries, special care will be required when prescribed fire is to be applied. Where ancient rock paintings, prehistoric villages or other heritage sites are found, care should be taken to apply fire in such a manner that no damage (such as fire scorch) is caused. Preventative measures in the form of physical fuel removal around the site, or fire application only when the wind blows from a specific direction (away from the site), may be required, or will be stipulated in the form of written rules in the fire protection plan.

The creation of natural corridors through areas covered by plantations - many times making use of major wetland/river lines and mountain crests - should be considered where buffer zones (*sensu* fuel breaks) are placed and maintained. This will provide free access between forest and grassland sites for mammals such as grazers, within and outside plantation boundaries.

Other important issues to be considered are the protection of breeding areas for rare bird species within plantation boundaries, and to avoid any fire application too close to these nesting sites. Some species may prefer steep mountainous terrain for nesting platforms, while other species may prefer wetlands or marshes to breed. In each case it is important to identify and map these nesting sites, and to avoid any burning operations close to these sites during the breeding period.

Where nature walks and trails exist within plantation property boundaries, care should be taken to apply fire protection in such a way that the immediate area surrounding these routes is burned in a prescribed sequence, so that no large areas are blackened simultaneously, but rather burned in strips or blocks in rotation, with footpaths forming the fire break tracer lines, where possible.

3.5. Wildfire Bufferzoning and other Fire Protection Techniques

In many cases fuel-break systems or buffer zones along specific lines - normally facing the direction of hazardous wildfire threat at an angle - are constructed, of a width of up to 500 m or even wider, to replace inadequate fire breaks. A qualified fire management specialist, who can identify optimum routes in the landscape and calculate minimum fire protection requirements, should preferably do the placing of buffer zones. It is also important to start fire protection evaluation by considering regional requirements before changing any within-plantation firebreaks, and to make sure that these zones comply with ecological and riparian zone specifications.

Many times buffer zones will follow natural fire barriers, such as steep terrain, existing indigenous forests or major rivers with riverine forests, but where these are not available, man-made lines such as public roads, railway lines or powerlines can also be used as a bufferzone base. In most cases a combination of natural and man-made fire protection areas, with some form of fuel restriction, will be used for buffer zones, which will bypass artificial boundaries. Where plantation stands have been identified as forming rather weak links in firebreak or bufferzone lines, incorporation of these stands as prescribed burned areas should be considered. Sometimes species and/or stand age may not yet be suitable for prescribed burning application, in which case (temporary) alternative routes should be investigated until such time that these stands have reached the correct age, or species have been changed.

Fire protection techniques (or fire break management procedures) other than regular vegetation burning - such as slashing, hoeing or some forms of soil preparation - may sometimes present viable alternative options for fuel reduction, if regular prescribed burning is not possible. However, it must be kept in mind that these may still present some fuel residue, and *e.g.* slashing of fuel still presents the same fuel loading, although the depth of the fuel bed has been reduced. Methods such as ploughing or scraping of roads can also be used effectively to create fuel-free fire protection lines when applied correctly.

4. Fire Management in Rural Areas

A large share of wildfires in the temperate and boreal zone is human-caused and originates in the context of land use. Vice versa, many land-use systems in these regions are vulnerable to wildfires. Property, health and welfare of people living in these areas are negatively affected by direct and indirect consequences of fire and smoke pollution. Active involvement of the local people has therefore been recognized as a condition for the successful implementation of fire management programmes, especially at the interfaces between or in intermix situations of wildlands, land-use systems and residential areas.

4.1 Regulating Fire Application and Grazing in Rural Areas

Traditionally, the response of pastoral societies to variable forage availability, *e.g.* in the savannahs of Africa and the steppes of Asia, was to retain a high degree of mobility (nomadic pastoralism). Regular burning was practised by rural people, to stimulate a green flush of new growth for improving grazing and to aid hunting. Increased population pressure and political changes have contributed to the breakdown of this type of pastoralism in some regions of Africa. In other regions such as in Mongolia a new era of increasing pastoralism has developed as a consequence of the economic collapse of the country after the abandonment of the centrally planned economy.

The main objectives of burning by pastoralists are:

- To burn off unpalatable growth left over from the previous seasons to provide nutritious regrowth for livestock
- To stimulate out-of-season growth to provide fodder when no other fodder reserves are available
- To protect homesteads and property against wildfires.

Wildfires caused by pastoralists that are not purposely set are also a common phenomenon. They originate mainly from campfires (cooking, warming fires).

The regulation of the use of fire, in conjunction with grazing control, is in many cases a thorny issue, and not necessarily in line with ecological requirements. This is particularly true in the dynamic montane and savannah grasslands in temperate Africa, where a substantial percentage of the population is still resident in scattered rural communities, mainly being dependent on local livestock, with sustainable grazing quality and quantity. In most cases some form of compromise is required between fire applied for domestic purposes (such as grazing), and an establishment of ecologically based fire regimes, with careful consideration of fire frequency, interval, season and intensity needed.

4..1 Institutional and Social Issues: Integration of Local Communities in Fire Management

In many countries, in the past, the top-down approach to implement management strategies excluded the local people from decision-making. Participation will empower people and give them a sense of ownership in management decisions. New conservation policies in these countries should now be based on the need to adopt more socially responsible methods of conservation management.

Communities dependent on common property resources have adopted various institutional arrangements to manage these resources. The varying degrees of success that have been achieved is dependent largely on the effectiveness of the community leaders (or traditional leadership, *e.g.* tribal elders), managing the communities under their control.

The underlying concept of Integrated [Forest] Fire Management (I[F]FM), also referred to as Community-Based [Forest] Fire Management (CB[F]FM), is to better integrate both fire and people into sustainable land use and vegetation management systems. The approach is based on the following considerations:

- **Reasons:** Fire is a spatially and temporally disperse phenomenon; difficult to control centrally, particularly in developing countries; responsibility for control must be brought closer to those who benefit both from the use of fire, and from more control;
- **Objectives:** Rational, ecologically compatible, sustainable and safe use of fire; with few exceptions no attempt of complete cessation in the use of fire;
- **Impediments:** Difficulties arising from the definition of responsibility (or 'the community'); the need for complementary policy and legislative change; definition and supply of technical and other support communities need to enable them to assume a central role in fire management;
- **Entry points:** Definition of mechanisms, methods and policy instruments (incentives) to encourage communities to assume control and “ownership” over fire management;
- **Human rationale:** Community participation is not just an activity of participating in fire prevention, detection and suppression; but managing fire in terms of the needs of the community, which may include prescribed burning.

Definition and "design" of IFFM/CBFFM approaches clearly depend on the complex configuration of local cultural, social, economic, political and environmental conditions. However, in any case it is required to establish a dialogue and negotiation process among all stakeholders concerned from local to national. IFFM/CBFFM concepts can be successfully realized only if all stakeholders involved in fire management agree on a distribution of responsibilities, decision-making power and resources. The process of negotiation and consensus building requires careful consideration of different perspectives and also the pluriformity of the legal context. Existing rules are often of different and sometimes contradictory origins, *e.g*. laws and administration rules governed by centralistic legislation, traditional rules that may not have a legal recognition or weakening influence of traditional structures as a consequence of migration resulting in multi-cultural local societies or due to other impacts of "globalisation".

To overcome possible conflicts and deadlock situations - a combination of bottom-up and top-down approaches in defining the appropriate integrated fire management strategy - seems to be most effective to build consensus among stakeholder groups at different levels.

In addition, there is a need to establish baseline fire data at national, regional and district levels. This baseline data on fire will assist the national authorities in the preparation national strategies for fire management, including the defining of specific target groups for the national fire awareness programs, based on gender aggregated data.

In the past decade a number of national Integrated Forest Fire Management Strategies (or Action Programmes) have been developed based on multi-stakeholder consensus obtained by national or local *Round Tables on Fire Management*.

Appendix II provides examples of community participation in fire management and an incentive system for successful fire prevention by communities.

5. Remote Sensing of Vegetation Fires and its Contribution to a Fire Management Information System

5.1 Introduction to Remote Sensing

In the context of Earth observation remote sensing, an image is generally a picture received from a satellite or an airborne sensor. Digital images from satellite remote sensing are useful for fire monitoring because they:

- Allow low cost, rapid and regular coverage of the often extensive and inaccessible areas affected by fire.
- Permit capture of types of data that humans cannot sense, such as the near-infrared and thermal part of the electromagnetic spectrum, which may provide additional useful information.

Here we briefly introduce the general characteristics of digital images, mostly from space borne sensors, as a potential source of information for fire management. As different sensors provide images with different characteristics, we focus on criteria commonly used to evaluate and compare imagery from different sources.

5.2 Remote Sensing Products for Fire Management

Remote sensing data can assist fire management at three stages relative to fire occurrence:

(i) *Before the fire:* vegetation biomass, vegetation status and rainfall; monitoring pre-suppression / fire prevention measures;
(ii) *During the fire:* near real-time location of active fires;
(iii) *After the fire:* assessment of burned areas.

5.2.1 Active Fires

Active fires can be detected from satellite data because fire fronts are very hot and emit large amount of energy that can be observed by thermal sensors on board satellites or aeroplanes. The identification of fires in an image is now relatively well mastered, and remaining limitations are mostly due to the sensor in itself.

Active fire product in fire management
Once integrated into a fire information system, the list of fire locations can be used in two main ways:

a) In near-real time, to prioritise resources for fire fighting. Fire locations can also be used, on a daily basis, to monitor for example that planned prescribed burning is actually taking place.

b) As post-fire information, the active fire product can be used in several ways. First it can support a policing role. Secondly, active fire products can be used to document fire activity in a park, over a municipality or over a whole country. It may further document the extent of individual fire fronts and the size of fires that contribute to the burned area mosaic.

Operational active fire products
There are a number of satellite and airborne remote sensing systems which can contribute to fire monitoring from space, including NOAA AVHRR, Landsat TM and MSS, SPOT, GOES, DMSP, ERS-ATSR, and JERS.

High spatial resolution satellites, such as Landsat and SPOT, can contribute to fire monitoring, but their cost, their centralized receiving stations and especially their low temporal resolution, limit their use on an operational basis. Meteorological satellites are more appropriate because of their high repetition coverage. The Meteosat geostationary satellite series cover Africa and Europe, and provide images every 30 minutes (Meteosat Second Generation satellite is providing an image every 15 minutes, with improved channels for fire information). The polar orbiting NOAA series acquires images over the same area every 12 hours by the same satellite, and cover the entire world.

Product Interpretation
There are several points that are important to take into account when interpreting and using active fire products from AVHRR data. Most of them are linked to the intrinsic characteristics of

the satellite platform and its sensor. Detection algorithms are usually set to minimize the number of false detections. Consequently, some fires will also be missed.

5.2.2 Burned Areas

Burned area product principles
Burned areas are detected from remotely sensed data based on three main changes in surface properties following fire:

- Vegetation is removed.
- Combustion residues are deposited.
- During the day, the burned surface is hotter than surrounding vegetation, with a maximum contrast in temperature occurring around mid-day.

Burned area products in fire management
Integrated into a Fire Management Information System, burned area products are useful at all stages of the fire management loop:

Baseline Data
Burned area products can provide important baseline information on fire regimes (*i.e.* frequency, season and intensity). *Fire frequency maps* are obtained by superimposing burned area maps for successive years. *Seasonal fire maps* are produced using a number of successive burned area products.

Fire management
Both the block and patch-mosaic methods of prescribed burning require accurate records of burns in order to help plan ignitions. Mapping burned areas as the season progresses also allows areas that burn naturally to be incorporated into ignitions planning. Burned areas products can also be of value to fire suppression teams.

Monitoring and evaluation of management activities
The products can also help to answer management evaluation questions such as: How well did management fire lines stop fires (*i.e.* by overlay of burned areas and fire lines); have management efforts reduced the areas that burn each year; or - more generally - how well are desired fire regimes realised?

Refining Policy
All the data above are then used to refine fire management policies. Fire frequency maps can also help identify areas where high intensity fires are burning frequently, as foci for field visits to investigate the causes and fire effects.

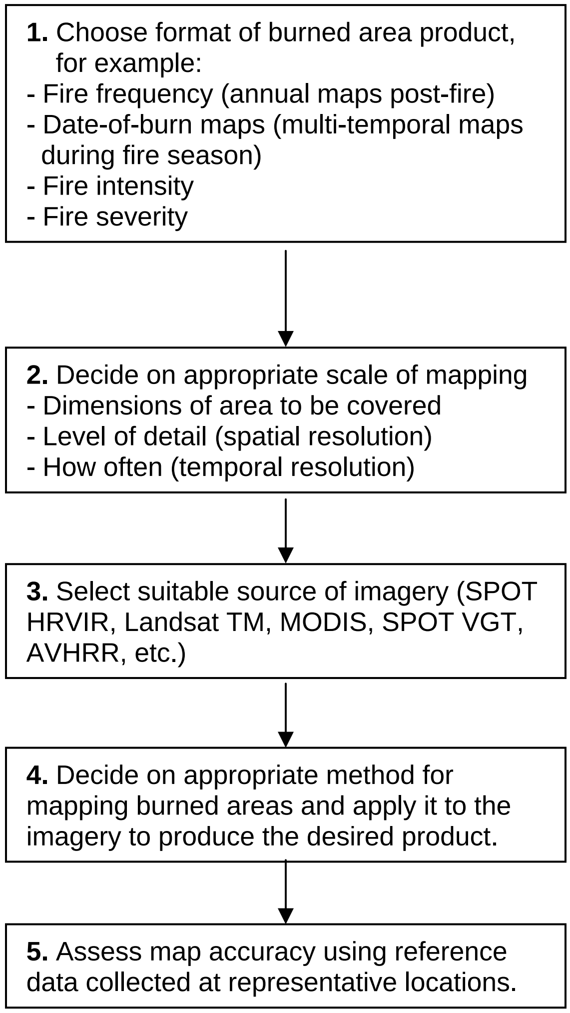

Figure 1. Flow diagram showing the main steps and considerations in the preparation of burned area products.

5.2.3 Rainfall Estimation

Derivation of Rainfall Estimates
Rainfall is normally measured using rain gauges. However, the network of rain gauges may be sparse in those areas affected by fire. Satellite observations are used in combination with, and to augment, rain gauge data. Satellite data provide a spatially complete, uniformly distributed coverage that allows better estimation of rainfall where rain gauges are infrequently and irregularly sited.

Rainfall Data in Fire Information Systems
Rainfall estimations can be produced for finely gridded areas, *e.g.* 5 x 5 km areas, but are often used as summaries over political or physical regions, for example, countries or catchments. Statistics can include total, mean and standard deviation of rainfall in millimetres, area of rainfall coverage within a region, etc. The rainfall data can be combined with other data to produce further information, for example, hydrological modelling or a fire information system.

Rainfall maps can be used to inform management, for example, a recent rainfall could to be taken into account when deciding on the timing of prescribed burns. Rainfall estimation can also be integrated with other data, for example, as an input to fire risk assessment. The rainfall information is incorporated in estimation of vegetation moisture content, which can then be combined with fuel data for assessing fire risk.

5.3 Implementing Remote Sensing in a Fire Management Context

Data produced by any remote sensing activities should be integrated into a Fire Management Information System so that, through the combination of data from various sources, more information can be extracted to better support management decision-making.

A range of situations could occur, and some fire management teams may have access to their own remote sensing group or government-run remote sensing resources. Many others may find some existing local expertise in remote sensing, *e.g.*, a local consultancy, scientific institute or university, who could assist in the setting up of a remote sensing group, provide training or even be contracted to do the work.

The following are some considerations for those who want to set up and run a remote sensing component for fire monitoring and management.

Skilled personnel
The person running the component should have a combination of remote sensing skills and field experience (perhaps in fire or vegetation ecology), or at least demonstrated aptitude and a willingness to learn new skills. He or she, should have some input to the design of a remote sensing strategy; should decide which imagery will be used to obtain the information, and how often, and choose and implement the methods to extract information. The person should make every effort to assure quality control at all stages, including assessing the accuracy of final products wherever possible.

Access to relevant information
Staff should ideally have access to publications on remote sensing, land mapping, fire ecology and other relevant information. Easy access to up-to-date literature is especially helpful in selecting appropriate methods to deliver particular information products and in avoiding common mistakes. Collaborative research with local and international scientific institutions can also help in product development.

Infrastructure
For in-house remote sensing clearly office space is required, and adequate remote sensing hardware and software must be acquired. Image processing and Geographic Information System (GIS) tools allow a fire information system to be built up with the objective of supporting operational fire management.

Adequate Budget to Maintain the Information System
As well as personnel and initial set up costs for hardware and software, the budget should include allocations for recurrent expenses, such as image data costs and additional data acquisition. Maintenance and upgrade costs for hardware and software, and replacement of consumables, must be considered too. Fieldwork is necessary to validate remote sensing outputs, so a budget for transport (and maybe equipment) should be available. Hence, budget constraints are very important in developing an operational remote sensing strategy.

6. Fire Protection Planning, Regional Integration and Fire Danger Rating

6.1 Fire Protection Planning

6.1.1 Systematic Fire Protection

Increasing frequency and intensity of fires are having a negative effect on ecosystems and are leading to a general degradation of the land in many areas. The search for a solution is difficult. Systematic Fire Protection (SFP) offers a framework for developing a fire protection program designed to address this problem. The framework of SFP consists of several integral steps that can be applied in a number of ways. These steps are:

Fire Prevention
Fire prevention’s goal is to prevent a fire from occurring and consists of two activities. The first is to reduce the production of firebrands from various sources and the second is to reduce the susceptibility of vegetation to ignition by some form of treatment.

Fire Pre-suppression
Actions taken in anticipation of a fire are referred to as pre-suppression. This can involve training and equipping resources, as well as modifying fuels or constructing fire belts.

Detection
In order to take quick action on a fire, it must be detected as closely as possible to its time of ignition. Detection triggers all suppression actions and is critical in minimizing fire size and

costs. Methods of detection include lookout towers, aircraft, infra-red scanners, patrols, and public reports.

Location
Once a fire has been detected, it must be located on a map or with other means in order to provide accurate information to personnel responding.

Dispatch
Once the location of the fire is determined, a decision must be made about strength of attack and specific forces to be sent.

Communication
The location and fire information is then transmitted to the forces being dispatched. Methods used may range from radio to bicycle messenger.

Travel
Once forces have received the dispatch order, they must travel to the fire using the fastest conveyance and routes possible.

Attack
Stopping the fire's spread as quickly as possible, using the personnel and equipment available, is the goal of fire attack.

Mop-up
Once the fire's spread has been halted, the next step is to secure the fire by extinguishing and cooling all hot spots.

6.1.2 Determining Fire Protection Objectives

The first step in applying Systematic Fire Protection is to determine the fire protection objectives for all the areas within the organization's jurisdiction. Not all land need to be protected at the same level. For example, the fire protection level for a commercial pine plantation will be quite different from semi-desert shrub land. Determining objectives can be accomplished by subjective means, or it can be done in a more logical manner, as described below.

A logical and rational approach to establishing fire protection objectives begins by delineating areas of similar vegetation, topography, climate, protection constraints, etc. This allows fire protection to be targeted and prioritised. Area evaluation of values at risk (commercial, environmental, and social), and potential for fire to damage of these values, is then performed. Values at risk comprise one or more of the following:

❖ Commercial Values (values with monetary values)

- Timber – value of trees for production of wood products;
- Forage – value of grasses and shrubs for animal feed (this would include potential losses in milk production, loss in weight, loss of animals due to feeding on poisonous plants);
- Thatch and reeds – value of roofing and fencing;
- Non-wood forest products – loss of berries, fruits, mushrooms, herbs, dyes, medicinal trees;
- Water – value of the land's capacity to capture and store water;
- Wildlife and fish – value in the utilization of wildlife including non-consumptive uses.

❖ Environmental Values (values that can not be quantified monetarily)

- Wildlife and fish habitat;
- Endangered plants and animals;
- Soils (erosion of top soils due to burning);
- Wind and shelter protection;
- Long-term ecological impacts (e.g. level of ground water table, silting of hydro-electric dams and reservoirs).

❖ Social and Political Values

- Public safety;
- Archaeological, historical, or other sites;
- Sustainability of resource base for local communities (fire damage to housing, infrastructure and crops).

Fire potential is evaluated considering:

❖ Fire Regime

- Historical role of fire and its impact on vegetation;
- Historical fire return interval;
- Recent Fire occurrence (5 to 10 years);
- Historical use of fire (including gender aggregated data);
- Fire cause(s) (gender aggregated data).

❖ Fire Fuel Conditions

- Present vegetation composition;
- Projected vegetation composition.

❖ Environmental Conditions

- Past and present climate and seasonal trends;
- Climatic change;
- Topography.

Once the protection objectives have been identified, they can be weighted, using the following Table (Table 1) as a guide:

Table 1. Guidance of Fire Protection Objectives

Protection Objectives Example	
Level	Description
Critical	Fire in any form is not desired at all. Fire has never played a role in the ecosystem or - because of human developments - can no longer be tolerated without significant economic loss. Virtually all fires would be actively suppressed.
Full Protection	Fire plays a natural role in the function of the ecosystem but - because of resource concerns and potentially high economic impacts from fire - considerable constraints exist. Fire suppression is usually aggressive.
Limited Protection	Fire is a desirable component of the ecosystem. Certain ecological/resource constraints may be applied. These constraints - along with health and safety, etc. - are used in determining the appropriate suppression tactic on a case-by-case basis.
Fire Use Area	Fire is desired to achieve the resource condition, sought for designated areas with no constraints. Prescribed fire is used to obtain the desired resource/ecological condition.

Once protection objectives for each area have been established and agreed to, the next step is to decide how to implement them.

6.1.3 Selecting Implementation Alternatives.

One of the primary means of evaluation is the measurement of the alternative's economic efficiency. This method balances costs with losses due to fire. The costs included in this method are:

- Budgeted. These include all the fixed annual costs of maintaining a fire organization, such as staffing, equipment, training, facilities, etc.
- Suppression. These include emergency costs, above the budgeted costs, used to pay for actual fire suppression.
- Net Value Change. This is cost of resources lost due to fire.
- Cost + Net Value Change(C+NVC). This is the sum of the above costs, which indicates the overall efficiency of the alternative.

6.2 Regional Integrated Fire Protection

6.2.1 Regional Phase

Evaluating Wildfire History
In order to understand the fire hazard problems of a region better, the wildfire history can be mapped, to determine where the most serious wildfires occur.

Regional Fire Protection Objectives
The regional fire protection strategy should be incorporated into the regional fire protection plan, and should be concisely compiled to cover important issues of fire protection at a regional level such as:

- Fire hazard evaluation and identification of hazardous areas
- External and internal fire protection strategy including regional bufferzoning
- Control over fire protection programmes
- Disaster management

Care should be taken that those issues such as ecological prescribed burning constrains, optimal water supply maintenance and urban interface problems/potential problems are carefully considered when the regional fire protection strategy is drawn up.

Regional Fire Hazard Mapping
Before fire hazard can be considered at regional level, it is necessary to classify fire hazard according to a specific fire hazard grading system. Regional fire hazard classifications used, vary according to the nature and percentage cover of natural fuels and land-use, and may be based mainly on natural vegetation cover features, man-made fire hazard features, or a combination of both. Region-specific classifications should be developed after careful evaluation of requirements.

Regional Bufferzoning
On-site studies, wildfire simulation, topographical terrain considerations and wind flow dynamic studies, together with wildfire history studies, should be used to consider where in the landscape major regional fire breaks (bufferzones) should be placed, what their specifications should be, and how they should be placed in the landscape, in relation to the most dangerous wind direction. These zones will disregard man-made property boundaries and provide continuous protection lines which can stop most (if not all) wildfires, or at least provide safe lines from where counter-fires can be applied against approaching wildfire fronts. The following main criteria have to be considered when bufferzones are placed:

- To incorporate natural protection features as much as possible, such as watersheds, constantly flowing rivers and indigenous forests.
- Include major roads, suitable prescribed burning areas/compartments (natural as well as plantations) and cultivated lands.
- Incorporate recent wildfire areas.

- Place the zones (as near as possible) at a 90 degrees angle with the most likely direction of maximum fire spread.
- Ensure that the buffers form continuous lines, from the safest possible starting to end points.
- Provide adequate width along favourable topography, from where a counter-firing line can be constructed, from where an approaching wildfire can effectively be attacked.

Bufferzones should also be mapped on the 1:50 000 regional fire protection maps, and must be described in detail in the strategic regional fire protection plan. All landowners and fire fighting organizations within the region should have full detail available about these regional bufferzones and fire fighting should (where possible) be concentrated along these lines.

The Strategic Fire Protection Plan

Certain realities are here to stay, which should be considered in developing an integrated fire protection plan:

- An increased population pressure, and subsequent increase in fire hazard as more and more people infringe on the natural and plantation environment.
- Global changes in weather patterns will have to be accepted as a fact, and planners will have to consider these issues in future seriously.
- Urban interface problems must be identified, and an action plan has to be developed by local authorities.
- Weed control programs on a regional level must be implemented, to address factors such as biomass accumulation (and subsequent fire hazard).
- Continuous attempts are necessary to come as close as possible to optimum ecological requirements.

Integration with conservation programmes

Priority areas, deserving special conservation status, such as unique floral communities, breeding areas for rare animals and special cultural sites, must be considered for incorporation as part of bufferzones. The creation of natural corridors throughout such areas will be facilitated in this way, by following main riparian zones and inter-connected internal bufferzones.

Multi-purpose strategic regional plan

A Strategic Fire Prevention Plan may form part of an Integrated Fire Management Plan, which includes the following aspects:

- Fire awareness raising (campaign) and fire prevention
- Fire pre-suppression
- Fire suppression
- Training and education
- Law enforcement and the use of incentives
- Prescribed burning for special purposes

Addressing urban interface problems

Much of the responsibility for implementing a good comprehensive and effective plantation/urban interface fire protection program is going to fall on local government and municipalities.

This situation of homes and other buildings located in, or adjacent to, fire-prone areas of vegetation can have the following effects:

- The risk of loss of life and property is greatly increased.
- Fire fighters are often put in exceptionally dangerous situations as they are forced to protect property.
- Fire commanders could shift tactics towards structure protection and away from controlling the main fire.
- Potential conflicting priorities in fire management policies where public and private land meet.

There is a need for close collaboration between the fire authorities and the people prescribing requirements for structural designs and materials to be used in building housing in urban interface areas.

There is also a need to connect the local population in the planning of prescribed burning at landscape levels. Previously people have reacted very negatively towards any fuel reduction activities due to the pollution it causes as well as to the incidents, when prescribed fire runs out of control.

6.2.2 Evaluation Phase

Fuel modelling, Fuel Classification and Fire Hazard Rating
To arrive at a suitable fuel classification base at a smaller scale (1:10 000 to 1:30 000) it is necessary that the fuels of all significant burnable areas in the region are considered for fuel modelling, to arrive at a representative fuel model file. This process can be regarded as the first step towards fire hazard assessment at a more detailed level, which can be used during the evaluation process. Fuel models should then be developed and tested, which can then be ranked according to standardized performance under the following parameters set for typical wildfire conditions:

- Flame Length (m)
- Rate of Spread (m/min)
- Fireline Intensity (kW/m)
- Heat per Unit Area (kJ/sq.m.)
- Maximum Spotting Distance (km)

Fire hazard ratings should then be calculated per area or compartment, to illustrate the existing as well as future predicted fire hazard status.

Mapping Fire Hazard over Time

A suitable base map (or maps) should be selected to act as fire hazard rating maps, which should be at the smallest possible scale without having to use more than one or two maps per rating year.

Two maps should be prepared (with GIS assistance if possible) to illustrate fire hazard. One to show the existing hazard situation, the other to show the future (predicted) hazard status. When comparing the two (sets) of maps - one for the present and one for the future fire hazard status - prominent high fire hazard areas and major shifts in hazard can easily be identified and then be considered in the following decision-making process (placement of fire protection systems such as fire breaks):

Evaluating Existing Fire Protection Measures
Based on the fire hazard-rating phase, long-, medium- and short-term programmes are put together. In this process some of the issues that must be addressed are:

- The placement of existing fire belts.
- Riparian zone requirements.
- Nature conservation requirements, such as special regimes for natural heritage sites, wetlands, etc.
- Financial constraints and the cost-effectiveness of the recommendations.
- Adjustments required in the working plan and changes to land-use policies.

6.2.3 Application Phase

Placing Bufferzone Systems
The finer detail of this programme can only be dealt with after completing the Evaluation Phase, and once the broader-scale routes of zones are considered at smaller scale maps. This will provide more detail regarding areas or compartments, grazing camps, the fuel mosaic pattern or wildfire history.

Where a lack of fuel management options or prescribed burning restrictions occur, alternative routes may (temporary) have to be considered, until such time that the fuel status of these areas are more favourable for fuel reduction/fire application. More exact (final) route placement may also give rise to minor deviations of bufferzone boundaries and routes.

Apart from the major regional bufferzones, other bufferzones - such as internal bufferzones – can now also be placed and described, with the emphasis on natural protection lines (such as wetlands) and artificial alternatives (such as public roads and areas with restricted fuel levels). The main aim here will be to reduce the area at risk within management units, and to fill gaps in the creation of continuous fire protection lines.

External Fire Protection Requirements
Once the bufferzone systems have been placed in the landscape, attention should be given to other external fire protection, on property boundaries and around management units.

Reducing the Area at Risk

This applies to the area within external boundaries, and can include industrial plantations with compartments/blocks or farms subdivided into different camps/cultivated lands. It can also be applicable to sub-divided nature reserves, hunting farms, rural areas, mountain catchment areas or other forms of natural grassland, bush or forest.

It is important that the area at risk, within a fire management unit, is reduced as much as possible to restrict free spread of wildfires, which either originated within the unit, or from outside its boundaries. Identifying effective, continuous, fire protection lines, which can be used as part of the internal fire protection system, can do this. Natural protection lines should be used for this purpose where possible, extending them with additional fire break sections where these lines are not continuous. In natural vegetation, existing wetland lines, rivers, mountain ridges and road systems should be used to advantage where possible to achieve this.

Prioritising Prescribed Burning Programmes
In many cases prescribed burning programmes can only be completed if long burning seasons are experienced, with a maximum number of suitable prescribed burning days. Unfortunately, during some years, only a restricted number of suitable burning days can be used. In some areas, particularly where dynamics fuels occur with significant seasonal fluctuations in dry fuel status (such as grasslands in Africa and Australia), the following burning priorities are normally used:

- Main (Regional) bufferzones (always top priority)
- External fire breaks on dangerous boundaries
- Fire protection along public roads
- Fire protection under powerlines
- Internal bufferzones
- Fuel management around internal settlements and houses
- External fire breaks along less dangerous boundaries
- Conservation burning programmes

6.3 Fire Danger Rating

It is important that fire managers can obtain some information about the level of fire danger for a given region for a specific day, in order to allocate manpower, equipment and applicable operational rules to face the situation. Daily weather patterns have a marked influence on fire danger even where human beings are mostly responsible for fires, but days since last rain (and quantity of precipitation), the status of vegetation and fuel moistures, and the soil dryness index can all be regarded as influencing factors, although their relative importance may vary between regions. To enable fire managers to evaluate fire danger daily, fire danger rating systems have been developed to assist them, some - such as the Canadian Forest Fire Danger Rating System (CFFDRS) and the National Forest Fire Danger Rating System (NFFDRS) - dating back from the early 1900s.

Because there exist major differences between regional requirements for fire danger rating systems because of climatic characteristics, geographic features and/or vegetation structure and drying pattern, it has been determined that region-specific FDR systems need to be used. Various continents, countries and regions have accordingly tested different FDR systems in use elsewhere, and developed system(s) suiting there own local conditions. However, it has been identified that certain basic elements should be incorporated in an FDR system, which are:

- Dry bulb air temperature
- Relative humidity
- Wind speed
- Days since rain and amount

Then there may be other region-specific parameters that should be included in certain countries/regions, some of which may be the following:

- Vegetation/fuel classification systems
- Fuel moisture
- Topographical factors
- Drought indexes
- Soil dryness indexes
- Grassland curing factor

In most developed countries suitable FDR systems have been tested and in use, some of which are even linked to information obtained from daily satellite images for improved accuracy, such as in the USA. In other countries basic FDR systems are in use, but improvement is being investigated (such as in some South American Countries and South Africa). However, in some developing countries, such as in most African and some central and south American countries, FDR systems still need to be introduced before daily fire danger ratings can be provided.

7. Fire Detection and Control

7.1 Fire Detection

7.1.1 Fire Lookout Systems

Lookouts are a well-proven method of fire detection and can be an important part of an overall fire protection system. They can be permanent or temporary, staffed or automated. Lookouts are typically located on high points such as hilltops, where visibility is good. Visibility is often improved by building lookout towers where natural elevated points do not provide adequate height.

Planning a Lookout Network
The purpose of a lookout is to provide early discovery of fires. Early discovery reduces the time it takes for fire attack, resulting in smaller fires and lower costs. Planning a lookout network or evaluating an existing network is important to ensure that it is effective and in harmony with overall fire protection goals and budgets.

Lookouts can range from sending a person with a radio to a hilltop during times of high fire danger, to a constructed tower that is staffed full-time, or to an infrared automated tower with communication links to headquarters. In any case, there are key items to consider when planning a lookout network.

Coverage Area: Determine the overall region that needs to be covered by lookouts. This is usually based on a fire management plan that identifies protection priorities and areas of high risk and value.

Visible Area: Natural features such as mountains, ridgelines, and vegetation can block what is seen from the lookout. Placement should maximize the total area seen among all the lookouts in the network and reduce the blind areas. This can be done by recording and overlaying seen areas from each lookout on a map. Most Geographical Information Systems (GIS) can perform this task.

Visibility Quality: Consider any impediments to visibility, such as haze from urban areas, mist, and smoke. In many areas of Africa, haze from fires during the dry season can severely reduce visibility during times when early detection is important. Normal range of visibility is from 30-40 km. Reduced visibility may require additional lookouts.

Communications: The ability to communicate smoke reports quickly is absolutely vital. A good lookout system depends on it. Radio and telephones provide the most effective means. If these are not available, use a messenger to convey the smoke report to headquarters.

Facilities and Technology: Determine the type of lookout to be used. Evaluate staffing, construction, maintenance, and technology costs. Minimum tool requirements for staffed lookouts include binoculars, maps, and communications.

Staffed Lookouts

Duties of a Lookout: Lookouts are the ground eyes of the fire protection organization. Reporting fires in a rapid and accurate manner is essential to quick suppression. In order to qualify as lookout, one must have good eyesight, be trustworthy, be able to read maps, and use the tools of the job (compass, radio, etc.).

Detecting smoke: Looking for smoke and a potential fire is the primary job of the lookout. A systematic approach should be used to scan the area for smoke.

Identifying Smoke: Once a smoke has been detected, the lookout must rapidly determine if it represents a fire, and take action to report it to headquarters.

Determining the fire’s location: In order to dispatch personnel, the fire’s location must be accurately determined. This can be done in a number of ways depending on the equipment available. First choice is to use a fire-finder, if available. A fire-finder is a sighting device mounted in the lookout building that combines a map and features of a compass. The fire-finder provides a very accurate way to determine the fire’s bearing, in degrees and distance from the lookout. A map and compass are a good alternative to a fire-finder.

Reporting of fire: The location of a fire should promptly be reported to headquarters ones its location has been determined.

Automated Lookouts
Automated lookouts have been in use in various countries around the world for decades. Technology has evolved to include various types of detection mechanisms, including high-resolution digital TV cameras and infrared sensors. These cameras can be controlled from a central location or they can be set to scan the visible area under computer control. Some systems use sophisticated image processing that can discern smoke without human involvement, trigger an alarm, and provide very accurate location information. In addition, this type of system has the ability to be integrated with other command and control information and GIS systems, increasing its effectiveness.

7.1.2 Air and Ground Patrolling

To deal effectively with a fire, a fire manager must firstly know the presence of fire. There are many methods of detecting fires rapidly, from light aircraft patrolling during high fire danger, to mountain top infrared scanners, cameras, lookout towers to people patrolling the forest. All detection methods are designed to determine a fire exists; as quickly as possible.

The primary advantage of the ground patrol method is its flexibility. Where terrain prevents lookout points, foot and bicycle patrols connected to fire fighting teams can be organized during the fire season. Patrol routes must be planned to cover hazard and danger areas, taking into consideration high-risk areas such as flammable vegetation, wild bees and beekeeping areas, and human activities. Patrols must be in constant communication with ground crews so as to dispatch support as quick as possible.

7.2 Fire Preparedness, Dispatching, and Co-operative Schemes

In order to be successful a fire protection organizations must maintain a state of readiness in the place where their forces are deployed as well as to be able respond to reported fires rapidly and once at the fire, organize and direct its forces in an effective manner.

7.2.1 Provisioning, and Preparing Fire-fighting Resources

Preparedness is the act of organizing resources, in order to respond to a fire. Fire organizations require an adequate supply of fire fighting resources that are available and ready to respond. It is very important to ensure that the supply of resources meets the fire fighting workload of the area of responsibility. Judging the appropriate level of resource availability requires that you review the history of previous fires, and analyse the types of resources used, and their effectiveness. A typical tiered approach is composed of the following:

Initial attack and other dedicated fire resources
These forces are the most capable and highly trained available. Their state of readiness is usually the highest and they are expected to respond quickly (usually in minutes) when dispatched. They are normally paid out of fire protection budgets.

Reserve Resources
These forces are drawn from within the organization or from other organizations as required, but are not normally assigned to fire duty. Personnel are usually identified before the fire season to fill specific roles based on their training and experience. Equipment used for non-fire tasks that could fill a fire role should be identified and provisions made for its call-up, if needed. Reserve forces may be put on a higher state of readiness due to high fire danger or ongoing fires.

Emergency Forces
Often countries have provisions to acquire people or equipment on the spot, or to use volunteers. These forces may not have training and are often not equipped for fire fighting, resulting in an unsafe situation if they are employed in actual fire line work. It is advisable to use these personnel in support jobs or for mop up, where they are not exposed to hazardous situations.

Potential sources of emergency resources are:

- Local and national governmental departments and branches.
- Military and civil defence.
- Private ranches and farms.
- Villages and towns.

Local Leader or Traditional Leader Program
Particularly in temperate Africa, another type of fire fighting force is highly desirable due to scarce resources and long travel times. Local or traditional leaders select people from villages, local communities or towns to organize and direct fire fighting operations in their area of jurisdiction. Each local leader should be able to organize and bring his people together to work on fires in their areas. There is however a need to educate and train these leaders in fire suppression techniques and safety measures.

7.2.2 Pre-Attack Planning

Determining what fires to suppress is very important. Not all fires are equal in terms of potential damage. In fact, many fires are beneficial to the ecosystem. Because fire-fighting resources are scarce, the decision to commit resources to a fire is a critical one. Placing limited resources on a low-threat fire might leave more valuable areas without adequate protection.

7.2.3 Dispatching

Dispatching is at the centre of fire fighting operations. Dispatch centres (also known as control, alarm, or communication centres) can be compared to the body's central nervous system. They receive a report of a fire and provide a response in the form of mobilized resources and other actions. Dispatch centres may be small, such as a field office staffed by a single person, or they may large and complex, providing services for many different public safety functions, including fire, police, and ambulance. They all perform the following functions:

- Keep track of the location and availability of resources
- Receive reports of fire
- Determine the appropriate response
- Dispatch resources to the fire
- Receive orders and fill orders for fire fighting resources

7.2.4 Co-operative Fire fighting Schemes

Many fire organizations have discovered the advantages of co-operating with each other and with organizations that have a compatible mission. The fact is that few organizations have the personnel or equipment, to handle every fire situation. The following schemes have been found to be effective in increasing co-operation:

Fire Co-operatives
Fire co-operatives (also known as Fire Co-ordination Groups or Fire Protection Associations) are an excellent way to facilitate co-operation. The co-operative is composed of representatives of organizations involved in fire fighting operations, landowners, and emergency services within a geographical area. This area could be local, regional, national, or even international. Co-operatives work to solve common problems and increase co-operation. In some countries, co-operatives are encouraged through enabling laws and policies. Fire co-operatives often form sub-groups to work on specific issues like fire prevention and training.

Co-operative Agreements
Co-operative agreements offer a mechanism for formalizing co-operation between organizations. These agreements may address specific elements of co-operation, such as sharing of personnel and equipment and how reimbursement will be handled, or they may form a broad framework under which other agreements may be developed.

Closest Forces Concept and Resource Sharing
The “closest forces concept” is used to dispatch fire-fighting resources nearest the fire, regardless of their organization and the jurisdiction where the fire is located

Reciprocal Protection
Often organizations have areas that can be better protected by another organization. This may be due to distance, access or other reasons. In this case, the protection of these areas can be swapped so that the total fire suppression workload can be optimised. This does not mean changing the administration of these lands, only the fire protection. This type of scheme requires a formal agreement between the participating organizations.

7.3 Incident Command System

The Incident Command System (ICS) is recognized as an effective system for managing fires and other emergencies. Since its inception, ICS has been recognized as the international model for managing emergency situations. It has been used in countries throughout the world.

ICS is based on the premise that no single agency or department can handle every fire situation alone. Everyone must work together to manage the emergency. To co-ordinate the effective use of all of the available resources, agencies need a formalized management structure that lends consistency, fosters efficiency, and provide direction during a response. The ICS organization is built around five major components (see Annex II):

- Command
- Planning
- Operations
- Logistics
- Finance/Administration

7.3.1 The Command Function

The command function is directed by the Incident Commander, who is the person in charge at the incident and who must be fully qualified to manage the response. Major responsibilities for the Incident Commander include:

- Establishing command and setting up the Command Post.
- Protecting life and property.
- Controlling personnel and equipment resources.
- Maintaining accountability for responder and public safety, as well as for task accomplishment.
- Establishing and maintaining an effective liaison with outside agencies and organizations.
- Ensuring personnel safety.
- Assessing incident priorities.
- Determining operational objectives.
- Developing and implementing the Incident Action Plan (IAP).
- Developing an appropriate organizational structure.
- Maintaining a manageable span of control.
- Co-ordinating overall emergency activities.
- Authorizing the release of information to the media.
- Keeping track of costs.

7.3.2 The Planning Section

On smaller incidents, the Incident Commander is responsible for planning, but when the incident is of larger scale, the Incident Commander establishes the Planning Section. The Planning

Section's function includes the collection, evaluation, dissemination, and use of information about the development of the incident and status of resources. This section's responsibilities can also include creation of the Incident Action Plan (IAP), which defines the response activities and resource utilization for a specified time period.

7.3.3 The Operations Section

The Operations Section is responsible for carrying out the activities described in the IAP. The Operations Section Chief co-ordinates Operations Section activities and has primary responsibility for receiving and implementing the IAP. The Operations Section Chief reports to the Incident Commander and determines the required resources and organizational structure within the Operations Section. The Operations Section Chief's main responsibilities are to:

- Direct and co-ordinate all operations, ensuring the safety of Operations Section personnel.
- Assist the Incident Commander in developing response goals and objectives for the incident.
- Request (or release) resources through the Incident Commander.
- Keep the Incident Commander informed of situation and resource status within operations.

7.3.4 The Logistics Section

The Logistics Section is responsible for providing facilities, services, and materials, including personnel to operate the requested equipment for the incident. This section takes on great importance in long-term operations. It is important to note that the Logistics Section functions are geared to support the incident responders.

7.3.5 The Finance/Administration Section

Though sometimes overlooked, the Finance/Administration Section is critical for tracking incident costs and reimbursement accounting. Unless costs and financial operations are carefully recorded and justified, reimbursement of costs is difficult, if not impossible. The Finance/Administration Section is especially important when the incident is of a magnitude that may result in a disaster declaration. Each of these functional areas can be expanded into additional organizational units with further delegation of authority. They also may be contracted as the incident de-escalates.

7.3.6 ICS Concepts and Principles

ICS is composed of major components to ensure quick and effective resource commitment and to minimize disruption to the normal operating policies and procedures of responding organizations. ICS concepts and principles have been tested and proven over time in business and industry and by response agencies at all governmental levels. ICS training is required to ensure that all who may become involved in an incident are familiar with ICS principles. An ICS structure should include:

- Common terminology
- A modular organization
- Integrated communications
- Unity of command
- A unified command structure
- Consolidated IAPs
- A manageable span of control
- Designated incident facilities
- Comprehensive resource management

8. Fire Insurance, Economics and Training

8.1 Fire Insurance

It is particularly in the agricultural and forestry sectors that land owners are faced with fire damage risk, and fire insurance can bring more stability to investments in these sectors. In the case of agricultural crops, short-term insurance against fire damage can be provided. However, in the case of forestry, longer-term insurance might have to be considered, as damage to plantations and forests can occur at any stage of the trees' life cycle. The cost of insurance will have to weigh up against the impact such costs will have on capital expenditure and the return on investment, and financial managers will have to determine a threshold of what insurance costs are viable, and which are unrealistic.

8.2 Fire Protection Economics

There are various aspects in Fire Management where economics will play an important role. Some of these are:

- Fire fighting equipment and manpower
- Aerial fire fighting facilities/organizations
- Fire prevention costs, such as maintaining lookout systems
- Fire protection costs, such as maintaining fire breaks

All these combined will form part of the economical environment, and will have to be incorporated in budgets and accounts, to be weighed up against the income derived from tourism, agricultural crops, forest products, urban expansion and social responsibilities in rural areas.

8.3 Training Issues

8.3.1 Training Strategy

Training in Fire Management should be co-ordinated at the highest possible level of government, and should always be highly prioritised. The execution of fire management training policies, however, should be delegated to lower levels of government institutions or to private enterprise, whichever is found to be more suitable. In a world of fast development technology and increased fire hazard as a result of *e.g.* global warming and climatic changes, it is also important that the fire-related training strategy must be adjusted from time to time to meet these new challenges.

8.3.2 Training Requirements

Formal training institutions will still form the basis of training provided in fire management and fire ecology, but where specific demands have developed in a changed fire-related environment, special "bridging courses" might have to be provided to fill knowledge gaps. Certain developing countries might have to consider sending key fire manager and ecologists to other countries for further specialized training.

It is important that regular attention is given to all levels of fire management training, such as training of ground fire fighting crews, fire bosses and fire managers.

9. International Wildland Fire Cooperation

Appendix I: Fire Management Options Tables

Appendix II: Examples of community participation in fire management

Appendix III: Incident Command System

Appendix IV: Glossary

Appendix V: Further Reading and Information Sources

APPENDIX I

Fire Management Options Tables

The following set of tables provides information on fire management options in temperate and boreal forest ecosystems of Africa, Australasia, South America, North America and Siberia.

Table 1a. Fire Management Options in Southern Temperate Forests: African continent

Fire Management Option	**Ecological, Economic and Management aspects**	**Lowland, Montane and Coastal Evergreen Forests**	**Thorn Woodland, Woodland mosaics and Broad-leaved tree Savannahs**
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Fire intensity depending on degree of disturbance. Forest transition zone and smaller forest patches destroyed. Pioneer species favoured, and sometimes exotic weeds invading	High intensity, fast moving surface fire, with spotty to complete damage to trees. Further opening of Woodlands and increased dominance of grasses
	Economic and Management Implications	High biodiversity losses and site degradation.	Repeated high intensity fires will result in overstorey reduction and possible long-term degradation.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Not applicable (only in adjoining fire-prone vegetation).	Low to medium intensity surface fire at 5-30 years fire interval, depending on yearly rainfall. Controlled promotion of desirable grass/herb and tree/bush generation.
	Economic and Management Implications	Not important.	Grazing provision, fuel reduction, and reduction of wildfire risk. Ecological balance and biodiversity maintained.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Transition zone must be protected from external fires. Extension of transition zone recommended. High stability.	Undesirable increase of species not suitable for grazing purposes. Replacement of grass stratum by succession.
	Economic and Management Implications	Exploitation and disturbance of forests must be avoided. Forest perimeters must be protected and encouraged to expand.	Only feasible if continuously, intensively, grazed, or mechanically cleared.

Table 1b. Fire Management Options in Southern Temperate Forests: African continent

Fire Management Option	Ecological, Economic and Management aspects	**Industrial Plantations** (e.g. even-aged *Acacia, Eucalyptus* and *Pinus* plantations)	Fynbos and Sub-Alpine Moorlands
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	High intensity surface, crown and ground fires, with serious site degradation and exotic weed invasion. Plantation stands reverted back to original (natural) vegetation. Weed problems may be increased.	Maintenance of biodiversity, but may favour alien vegetation in some areas.
	Economic and Management Implications	Management objectives jeopardized if no efficient fire prevention and control system is available.	In areas infested by exotics, increased weed control measures will be required to maintain natural vegetation biodiversity.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Application depending on age and species. Low intensity surface fires applied when and where required for fuel management and fire protection, at 2-5 year intervals, or after clearfelling of the trees. Maintenance of plantations. Ecological improvement and improved decomposition and nutrition.	Medium intensity surface fires, mainly applied during spring and autumn at a 12-25 year rotation depending on yearly rainfall and type. Biodiversity maintenance.
	Economic and Management Implications	Reduced wildfire risk, fuel/slash management, compromises ecological balance and maintains sustainable water supply.	Reduced wildfire risk. Ecological balance maintenance, while maintaining sustainable water supply without risk of site degradation.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Fuel accumulation, stand access problems and nutrient deficiencies. High risk of uncontrolled high-intensity wildfires.	High risk of uncontrolled, high-intensity fires and lack of biodiversity maintenance.
	Economic and Management Implications	Timber production feasible. Extreme risk of plantation production reduction and site degradation as a result of above-soil fuel and nutrient accumulation.	Only feasible on moist, steep aspects, e.g. when bordering a forest transition zone. Generally not feasible.

Table 1c. Fire Management Options in Southern Temperate Forests: African continent

Fire Management Option	Ecological, Economic and Management aspects	Dry Bushlands and Semi-Deserts	Savannahs and Grassland
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Irregular fire occurrence of varying intensities, depending on degree of biomass addition over time. Too frequent fire exposure may result in loss of biodiversity maintenance.	May occur at 2-3 yearly intervals in high altitude montane grassland, but in drier regions at up to 10-15 year intervals. Maintenance of a wildfire climax. Uncontrolled selection of fire adaptive plants.
	Economic and Management Implications	Site degradation and soil erosion possible.	Grazing potential will depend on grassland type, climatic region and presence of other degrading factors.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Only required when exceeding wildfire climax, which is rare.	Light to medium intensity surface fires, applied very 1-15 years depending on the climatic region and yearly rainfall. Controlled promotion of desirable grass/herb layer and tree/bush regeneration.
	Economic and Management Implications	Not important.	Reduction of wildfire risk and improved grazing provision.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Slow, but steady increase in wildfire risk, without serious loss of biodiversity maintenance.	Progressive successional development towards bush/tree savannah. Promotion of less fire tolerant species.
	Economic and Management Implications	Feasible for interval up to 20-50 years, but much longer in semi-deserts.	Not feasible for longer periods.

Table 2a. Fire Management Options in Southern Temperate Forests: South American continent

Fire Management Option	Ecological, Economic and Management aspects	Evergreen Mixed Forests (*Araucaria* dominated. Also *Northofagus* forests)	Thorn Forests (e.g. *Selva misionera*) and Thorn Tree-Desert Savannahs (e.g. Espinal)
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Fire intensity depending on degree of disturbance. Forest transition zone and smaller forest patches destroyed. Pioneer species favoured.	High intensity, fast moving surface fire, with spotty to complete damage to trees. Further opening of Forests and increased dominance of grasses
	Economic and Management Implications	High biodiversity losses and site degradation.	Repeated high intensity fires will result in overstorey reduction and possible long-term degradation.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Not applicable (only in adjoining fire-prone vegetation).	Application depending on age and species. Low to medium intensity surface fire at 5-30 years fire intervals, depending on yearly rainfall. Controlled promotion of desirable grass/herb and tree/bush generation.
	Economic and Management Implications	Not important.	Grazing provision, fuel reduction, and reduction of wildfire risk. Ecological balance and biodiversity maintained.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Transition zone must be protected from external fires. Extension of transition zone recommended. High stability.	Undesirable increase of species not suitable for grazing purposes. Replacement of grass stratum by succession.
	Economic and Management Implications	Exploitation and disturbance of forest must be avoided. Forest perimeters must be protected and encouraged to expand.	Only feasible if continuously, intensively, grazed, or mechanically cleared.

Table 2b. Fire Management Options in Southern Temperate Forests: South American continent

Fire Management Option	Ecological, Economic and Management aspects	**Industrial Plantations** (e.g. even-aged *Eucalyptus* and *Pinus* plantations)	**Sclerophyllous Scrub** (e.g. in Chile) **and other Alpine vegetation**
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	High intensity surface, crown and ground fires, with serious site degradation and exotic weed invasion. Plantation stands reverted back to original (natural) vegetation. Weed problems may be increased.	Maintenance of biodiversity, but may favour alien vegetation in some areas.
	Economic and Management Implications	Management objectives jeopardized if no efficient fire prevention and control system is available.	In areas infested by exotics, increased weed control measures will be required to maintain the natural vegetation biodiversity.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Low intensity surface fires applied when and where required for fuel management and fire protection, at 2-5 year intervals, or after clearfelling of the trees. *Pinus radiata* less suitable and susceptible to fire damage when young. Maintenance of plantations. Ecological improvement and improved decomposition and nutrition.	Variable intensity surface fires, applied at a rotation depending on yearly rainfall and type. Biodiversity maintenance.
	Economic and Management Implications	Reduced wildfire risk, fuel/slash management, compromises ecological balance and maintains sustainable water supply.	Ecological-balance maintenance, without site degradation risk.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Fuel accumulation, stand access problems and nutrient deficiencies. High risk of uncontrolled high-intensity wildfires.	Risk of uncontrolled fires depending on vegetation type and climatic region. Lack of biodiversity maintenance is possible in higher rainfall regions..
	Economic and Management Implications	Timber production feasible. Extreme risk of plantation production reduction and site degradation as a result of above-soil fuel and nutrient accumulation.	Only feasible on moist, steep aspects, e.g. when bordering a forest transition zone. Generally not feasible.

Table 2c. Fire Management Options in Southern Temperate Forests: South American continent

Fire Management Option	Ecological, Economic and Management aspects	Patagonian Semi-Desert Scrub and Cactus Scrub	Pampas and other intensively grazed grasslands
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Feasible under most circumstances. As a result of low biomass addition, wildfire intervals normally very long. Biodiversity maintenance normally not a problem.	May occur at variable intervals, depending on degree of grazing applied. Maintenance of a wildfire climax. Uncontrolled selection of fire adaptive plants.
	Economic and Management Implications	Only after many years of fire exclusion and above-normal rainfall, some fire hazard may rarely be created.	Grazing potential will depend on grassland type, climatic region and other degrading factors.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Only required when exceeding wildfire climax, which is rare.	Light to medium intensity surface fires, applied every 1-15 years depending on the degree of grazing applied, climatic region and yearly rainfall. Controlled promotion of desirable grass/herb layer and tree/bush regeneration.
	Economic and Management Implications	Not important.	Reduction of wildfire risk and improved grazing provision.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Slow, but steady increase in wildfire risk, without serious loss of biodiversity maintenance.	Progressive successional development towards bush/tree savannah. Promotion of less fire tolerant species.
	Economic and Management Implications	Seldom feasible.	Not feasible for longer periods.

Table 3a. Fire Management Options in Southern Temperate Forests: Australasia

Fire Management Option	Ecological, Economic and Management aspects	**Broad-leaved Evergreen and Evergreen Mixed Forests** (e.g. *Nothofagus* forests of Tasmania)	`**Sclerophyllous Forest** (Eucaly **Tree Savannah and Mic Woodland** (Mulga, Brigalow, et
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	May occur approx. every 300 years. Fire intensity depending on degree of disturbance by exploitation, fire or grazing. Forest transition zone and smaller forest patches destroyed. Pioneer species favoured.	Fires in Eucalyptus may occur approx. every 100 years. High intensity, fast moving surface fire, with serious to complete damage to trees. Further opening of Forests and Woodlands and increased dominance of grasses
	Economic and Management Implications	High biodiversity losses and site degradation.	Repeated high intensity fires will result in overstorey reduction and possible long-term site degradation.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Not applicable (only in adjoining fire-prone vegetation, such as grassland on forest edges).	Low to medium intensity surface fire at various fire intervals, depending on climatic characteristics, and grazing history.
	Economic and Management Implications	Not important.	Grazing provision, fuel reduction, and reduction of wildfire risk. Ecological balance and biodiversity maintained.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Transition zone must be protected from external fires and grazing. Extension of transition zone recommended. High stability.	Undesirable increase of species not suitable for grazing purposes. Replacement of grass stratum by succession.
	Economic and Management Implications	Exploitation and disturbance of forests must be avoided. Forest perimeters must be protected and encouraged to expand.	Seldom feasible.

Table 3b. Fire Management Options in Southern Temperate Forests: Australasia

Fire Management Option	**Ecological, Economic and Management aspects**	**Industrial Plantations** (e.g. even-aged *Pinus* plantations)	**Mallee Scrub and Alpine Vegetation**
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	High intensity surface, crown and ground fires, with serious site degradation and possible exotic weed invasion. Plantation stands reverted back to original (natural) vegetation.	Maintenance of biodiversity.
	Economic and Management Implications	Management objectives jeopardized if no efficient fire prevention and control system is available.	Not important, providing fire is not experienced too frequently. Then biodiversity will be maintained.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Application depending on age and species. Low to medium intensity surface fires applied when and where required for fuel management and fire protection, at 2-5 year intervals, or after clearfelling of the trees. Maintenance of plantations. Ecological improvement and improved decomposition and nutrition.	Selective application of fire of variable intensity surface fires, applied as and when required depending on yearly rainfall and type. Biodiversity maintenance.

Table 3c. Fire Management Options in Southern Temperate Forests: Australasia

Fire Management Option	Ecological, Economic and Management aspects	Semi-Desert Scrub and Hummock Grasslands	Tussock Grassland in various temperate climatic zones
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Irregular fire occurrence of varying intensities, depending on degree of biomass addition over time. Too frequent fire exposure may result in loss of biodiversity maintenance, but normally fires are rare occurrence. However, fire is more common in Hummock grassland, where it needs wind to spread .	May occur at various intervals depending on macro-climatic conditions and particularly yearly rainfall. Can develop intensively burning fires. Maintenance of a wildfire climax, depending on grazing intensity.
	Economic and Management Implications	Localized site degradation and soil erosion possible, but not common.	Grazing potential will depend on grassland type, climatic region and other degrading factors.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Only required when exceeding wildfire climax, which is rare.	Light to medium intensity surface fires can be applied at various intervals, depending on the climatic region and yearly rainfall. Controlled promotion of desirable grass/herb layer and tree/bush regeneration.
	Economic and Management Implications	Not important.	Reduction of wildfire risk and improved grazing provision.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Slow, but steady increase in wildfire risk, without serious loss of biodiversity maintenance.	Fuel can accumulate in excess of 14-15 tons/ha fuels loading. Grazing main influencing factor.
	Economic and Management Implications	Feasible for long intervals in semi-deserts.	Not feasible, and biodiversity maintenance will suffer.

Table 4a. Fire Management Options in Northern Temperate and Boreal Forests of Siberia

Fire management option	Ecological, Economic and Management Aspects	Dark coniferous forests (the mountain taiga and forest-steppe zones; the southern and central taiga subzones)	Pine, mixed pine/birch and larch stands (mountain taiga, the forest-steppe zone, and the southern and central taiga subzones)
Uncontrolled wildfires	**Fire characteristics, Fire interval and Ecological impacts Implications**	Not allowed to burn Wildfire suppression in dark coniferous, pine, and larch forests of southern and central taiga, mountain taiga, and forest-steppe contributes to sustainability of boreal forest resource and ecological potential. The socio-economic situation is improving. Need to decide on some optimal forest fire protection level.	
	Economic and Management Implications		
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire characteristics, fire interval, ecological impacts**	a) excluded; b) ecological functions maintained	a) surface low-intensity fires; fire interval of 5-30 years; b).pollution of the atmosphere, carbon losses
	Economic and Management Implications	a) resources are maintained; b) socio-economic situation gets more stable; c) need to increase forest protection effectiveness and costs	a) partial timber loss; b).regrowth killed; c) fuel loading and fire hazard reduced; d). reduction of forest protection costs
Fire Exclusion Suppression of all human-caused and natural wildfires	**Fire characteristics; fire interval; ecological impacts**	Suppression of all fires at early stages: a) protection of ecological functions; b) fire interval increases	All-fire suppression at the early or ending stage: a) maintenance of ecological functions
	Economic and management implications	a).increase in protection costs, saving of valuable timber; b).downed woody fuel loading and fire danger rate increase during dry seasons	a).High-value timber protection; b). Fuel loading increases, regrowth becomes over-dense, stand fire resistance decreases, forest protection costs increase

Table 4b. Fire Management Options in Northern Temperate and Boreal Forests of Siberia

Fire management option	Ecological, Economic and Management Aspects	Larch and pine forest on patchy permafrost (or w/o permafrost (the southern and central taiga subzones)	Larch forest on continuous permafrost (the northern taiga and open woodland subzone)
Uncontrolled wildfires	**Fire characteristics, Fire interval and Ecological impact**	**Not allowed to burn** Wildfire suppression in dark coniferous, pine, and larch forests of southern and central taiga, mountain taiga, and forest-steppe contributes to sustainability of boreal forest resource and ecological potential. The socio-economic situation is improving. Need to decide on some optimal forest fire protection level.	Wildfires of low to moderate intensity are allowed to burn freely; 100-150-year fire interval: a) forest cover mosaic becomes more diverse, ecological forest function strengthened, forest productivity increases
	Economic and Management Implications		Forest protection costs reduced
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire characteristics, fire interval, ecological impacts**	a) moderately intensive surface fires at an interval of 5-20 years, or prescribed burning every 5-15 years; b) atmosphere polluted, carbon lost	a).prescribed burning is allowed in mature and old growth; special burning is unreasonable from the economic, restoration, and ecological viewpoints; b). Degradation of protection and ecological functions of forests, pollution of the atmosphere, carbon losses
	Economic and Management Implications	a) Partial loss of timber; b) Regrowth killed; c) fuel loading and fire danger reduced; d) money-saving forest protection	a) Timber losses; b) post-fire forest development promoted; c) fire hazard and protection costs reduced
Fire Exclusion Suppression of all human-caused and natural wildfires	**Fire characteristics; fire interval, ecological impacts**	Suppression of all wildfires at the early stage: a) ecological functions are maintained; b) fire interval increases	Suppression of all wildfires: a) ecological functions are maintained; b) fire interval gets longer; c).forest cover gets less mosaic and biodiversity decreases
	Economic and management implications	a) high-value timber preservation; b) increase in fuel loading and fire hazard; c) high fire suppression resource costs; d) protection cost increase is inevitable	a) increase in fuel loading and fire danger rate; b) Occurrence of conditions favourable for high-intensity fires; c) huge expenses on aerial and ground fire protection resources; d) continuous increase in ineffective expenses on forest fire protection

Table 5. Fire Management Options in Pine Forests of East-European and Siberian forest and forest-steppe zones

Fire Management Option	Ecological, Economic and Management Aspects	Pine Forests of East-European and Siberian forest and forest-steppe zones
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	1. Surface fire, low intensity (early or late fire season), little damage to trees (density of vital stand >0.40), burn type - "stand burn", thickness of retained (unburned) duff >2 cm, elimination of undergrowth, weak natural regeneration of pine 2. Surface fire, medium to high-intensity (high fire season), spotty damage to trees (density of vital stand 0.05-0.40), burn type - "sparse stand burn". 2.1. Retained duff <2 cm, successful pine regeneration. 2.2. Retained duff >2 cm, weak pine regeneration. 3. Crown fire, high intensity, (high fire season), completely damage of stand. 3.1. Burn type "open burn with peripheral pine regeneration". 3.1.1. Retained duff <2 cm, successful pine regeneration. 3.1.2. Retained duff >2 cm, weak pine regeneration. 3.2. Burn type "open burn without pine seed sources, natural regeneration of deciduous (leafed) trees.
	Economic and Management Implications	1. Fuel and hazard reduction, maintenance or increase of tree growth, elimination of undergrowth, sanitary selective thinning, promotion for natural regeneration of pine. 2. Partial loss of timber, decrease of stand productivity, creation of uneven-aged stand, elimination of undergrowth, insect infestation; clean cut. 2.1 Natural renewal of pine. 2.2 Promotion for natural regeneration of pine. 3. Complete loss of timber. 3.1.1. Natural renewal of pine. 3.1.2. Promotion for natural regeneration of pine. 3.2. Stand replacement, artificial renewal of pine.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Surface burning, low to medium Intensity, 5-25 years interval, in the early or late fire season; little damage of trees, elimination of under phytocenose layer, improvement of environment for pine regeneration
	Economic and Management Implications	Reduction of fuel, fire danger and fire management costs; improvement of pine regeneration; decision-support system required.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Suppression of all natural and human-caused wildfires, low and medium intensity; prolongation of fire return interval, increase of fire hazard; deterioration of environment for pine regeneration
	Economic, Silvicultural and Management Consequences	High costs of suppression, saving of timber values; establishment of fire-sensitive tree species.

Table 6. Fire Management Options in Boreal and Northern Temperate Forests of Canada

Fire Management Option	Ecological, Economic and Management aspects	Boreal/TaigaConiferous Forests	Temperate Forests
Fire Monitoring Zone (no suppression of fires)	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Large high-intensity crown fires predominate. Pine and spruce forests adapted to fire and regenerate naturally. Fire return interval generally ~100 years. Primarily lightning-caused fires. Account for ~50% of Canadian area burned.	Not applicable – all temperate forests receive full suppression.
	Economic and Management Implications	Essentially natural fire regime. Fires actioned only when values threatened. Applies to roughly 50% of Canadian forest area, primarily in northern regions of boreal shield, taiga shield and taiga plains ecozones where trees are generally unmerchantable. No economic impacts	
Fire Exclusion Zone (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	~98% of fires controlled while small while 2% grow large, account for 98% of area burned in exclusion zone, primarily as large, high-intensity crown fires in pine and spruce forests. Fire return interval ~200-1000 years. Human-caused fires dominate but lightning fires account for most of area burned.	Fires generally smaller in less flammable mixed woods where pine and spruce are mixed with fir, aspen, maples and oaks – aggressive suppression more successful. Fire return interval >1000 years.
	Economic and Management Implications	Intensive protection of human and industrial values (particularly forest resource) Applies to southern regions of boreal shield and boreal plains ecozones. Major component of $500 million annual Canadian fire costs.	Similar to boreal exclusion zone. Located in southern regions of eastern and western Canada. Fire activity much less than in boreal.
Prescribed Fire (underburning in forest stands, and removal of logging residue)	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Prescribed fire generally not applied in boreal zone. Unnecessary for adequate regeneration.	Increasing prescribed fire use for ecosystem maintenance and forest health. Some burning of logging residue to promote artificial regeneration.
	Economic and Management Implications		Logging slash areas often present high fire hazard but burning is an economic means of site preparation

Table 7a. Fire management options in Western mixed coniferous (pine and fir) and high-elevation lodgepole pine forests in the lower 48 United States of America

Fire Management Option	**Ecological, Economic and Management aspects**	**Western mixed coniferous (pine and fir) forests**	**High elevation lodgepole pine (*Pinus contorta*) forests**
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Relatively short-return interval (5-20 years) surface fires were dominant in pre-colonial times. Intense crown killing fires at long intervals (>300 years) dependent on site moisture conditions and changes in climate. Ignition sources: Lightning and Native Americans.	Long return interval (200-400 year) crown killing fires. Typically ignited by lightning, with the return interval determined by successional changes in fuels and periodic drought.
	Economic and Management Implications	Intensive fire suppression in many areas has encouraged in-growth of shade tolerant species and accumulation of fuels. Today, wildfires in such areas quickly become of the crown-killing variety.	Fires in this type can be extensive in the northern Rockies, with suppression difficult in very dry years. Increase human development in such areas has resulted in increased liability.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Where fuels permit, light surface fires at 10-20 year intervals. Mechanical fuel reduction can be coupled with prescribed fire to restore conditions conducive to such fires	Naturally heavy fuels limit opportunities for use of artificial ignition prescribed fires. Natural ignition prescribed fire programs have presented difficulties (e.g., Yellowstone), but have been successful in areas of broken terrain.
	Economic and Management Implications	The cost of fuel restoration on 40 million ha of such forests is estimated at $1.5 billion each year for the next 30 years. Much controversy surrounds the specific restoration plans.	Limited
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Fires in these forests cannot be suppressed indefinitely… only delayed. The ecological impacts of suppression are described above.	Fire exclusion in these forests is effective only when weather conditions are favourable.
	Economic and Management Implications	Over the past 75 years, the majority of costs for fire suppression in the U.S. have been in this forest type.	Under dry conditions, suppression activities are directed at protection of life and property.

Table 7b. Fire management options in Eastern deciduous forests and Southeastern longleaf and loblolly pine savannahs and flatwoods of the United States of America

Fire Management Option	Ecological, Economic and Management aspects	Eastern deciduous forests	Southeastern longleaf (*Pinus palustris*) and loblolly pine (*P. taeda)* savannahs and flatwoods
Uncontrolled Wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Infrequent, associated with periodic drought and other disturbance such as hurricanes that provide woody debris. Short return interval surface fires may have been set in many areas by Native Americans in pre-colonial times.	Surface fires a 4-6 year intervals in savannahs, longer intervals in shrubby flatwoods.
	Economic and Management Implications	Very limited.	Very limited, and easily suppressed.
Prescribed Fire (natural and human-caused wildfires, prescribed burning	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Occasionally set to encourage oak and hickory regeneration (experimental) or to maintain savannah-like conditions at the forest margin with the prairie.	Surface fires are typically set at 1-4 year intervals to improve seedbed conditions, control hardwood ingrowth and minimize wildfire risk.
	Economic and Management Implications	Very limited.	Widespread and economically very important.
Fire Exclusion (suppression of all natural and human-caused wildfires	**Fire Characteristics, Fire Interval, and Ecological Impacts**	Not a significant issue	Fire exclusion in these types typically encourages in-growth of shrubs and shade-tolerant hardwoods and can lead to permanent type conversion.
	Economic and Management Implications		Costs and ease of suppression vary with climatic and soil conditions that affect fuel moisture. Because pines are commercially the most important species, fire exclusion can have significant long-term costs.

APPENDIX II

Examples of community participation in fire management are provided from Indonesia (Goldammer and Abberger 2001) and Côte d'Ivoire (Oura 1999).

Indonesia:

Community Based Forest Fire Management (CBFFM) implemented by the Integrated Forest Fire management (IFFM) project

Grass-root approaches are the backbone of fire prevention concepts in East Kalimantan. Many of the local people are upland farmers and use fire as a tool for land clearing. On the other hand, many of them also have experienced damages and losses due to the fires in 1997/98. Therefore, fire management at village level is first of all a self-help-oriented approach.

Extension work, which includes village awareness campaigns and the distribution of information materials, is the first essential step to plant “fire prevention seeds” at village level. This is followed by the provision of a basic fire management training and fire fighting hand tools. The next step is to form volunteer village fire crews and to institutionalise the approach in planning workshops together with village fire crews, formal and informal community leaders and involved government agencies.

Besides those activities, nature camps for children and “roadside campaigns” are further activities to support CBFFM, developed and carried out by IFFM.

For the success of the program, an incentive system has to be designed benefiting local people who participate in the CBFFM. This further enhances the sustainability of such a program in general. The following incentives should to be part of a CBFFM system along with training and the provision of equipment:

- Village fire crews should have regular access to fire relevant information (early warning aspect, communication, coordination and co-operation in the field, etc.).
- Career opportunities in fire management within the forestry department but also job opportunities (volunteer fire crews, village trainers, etc.) have to be created;
- Government support of community development (e.g. income generating programs like the rehabilitation of burnt forest areas, etc.; provision of seedlings in the framework of community forestry; technical support like water supply facilities, further equipment, etc.).
- Awards for out-standing fire prevention performance during high fire danger events given to successful villages.

Six Steps towards Community Based Forest Fire Management

Step 1: Orientation process/identification of villages

- Villages selected particularly in or near fire hazardous forest areas.
- Formal and informal meetings carried out with key resource persons from the local government and communities to discuss fire management approaches.
- Socio-economic studies carried out to identify and assess the motivation, potential and constraints (problems) of local communities in the project areas with respect to fire management.

Step 2: Fire prevention campaigns

- Extension meetings carried at strategic locations / villages with participants from up to 10 sub-villages/hamlets.
- Villagers are encouraged to form volunteer village fire crews.

Step 3: Fire prevention and suppression training for volunteer village fire crews

- Hand tools provided to each participating sub-village/hamlet.
- Crews provide for proper storage and maintenance of hand tools (small warehouse, standard operating procedures, etc.).

Step 4: Institutionalising fire prevention work at village level

- Participatory planning workshop at village level (with representatives of village fire crews, formal and informal leaders), which also considers gender issues.
- Workshop results proposed to local and provincial government.
- Province government should provide for legal framework as part of the overall fire management system.
- Village fire crews integrated in "village structure".

Step 5: **Training of Trainers**

- Up to five trained villagers per district appointed by village crews to participate.
- Village trainers to extend village fire prevention programs in close cooperation with crews of the provincial forestry service and concession crews.
- Job descriptions provided, also compensation for services by local government.

Step 6: **Networking**

- Regular meetings established between crew bosses of village fire crews, the forestry extension service and other involved government agencies, and concessions.
- Communication established. Early warning information reaches the local level in time, and vice versa.

Côte d'Ivoire:
Incentive system for successful fire prevention

The policy of Côte d'Ivoire involves an incentive system for successful fire prevention. In 1986 a National Committee on Forest Protection and Bush Fire Control has been established. Personnel of the Forest Service fill the positions of the General Secretariat and the Presidency of the National Committee. These bodies coordinate the participation of 14 ministries involved in national programs.

The task of this committee is to raise the awareness of the population of the damage caused by fires, the need for fire prevention and techniques for extinguishing fires. On the administrative level, 1500 Village Committees, 57 Local Committees and 32 Regional Committees were created to decentralize the task of fire control during the last ten years. The contracts with the committees are paid monthly (during the four months of the dry season). The remuneration is inversely proportional to the size of the area affected by fire. The basis of payment is:

- F CFA 500 000 (US$1000) per month per committee for 0 ha burned
- F CFA 400 000 (US$800) per month for less than 5 ha burned
- F CFA 200 000 (US$500) per month for less than 10 ha burned
- F CFA 50 000 (US$100) per month for less than 20 ha burned

APPENDIX III

The Incident Command System (ICS)

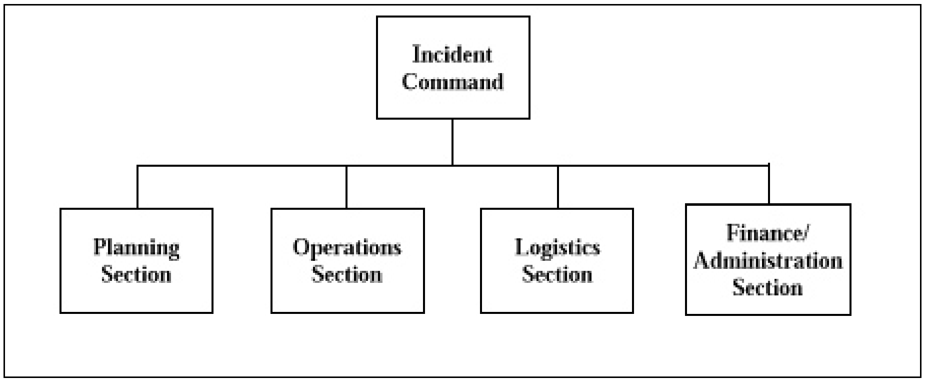

Figure 1. The main ICS Components

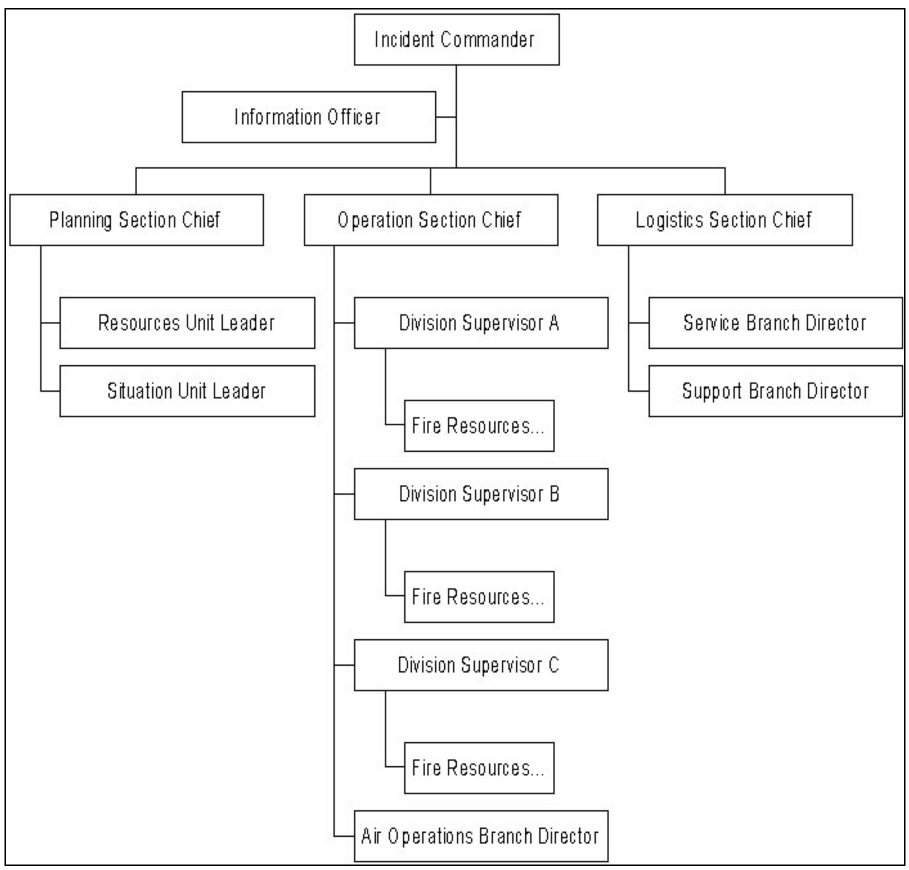

Figure 2. ICS Organization for a large multi-day fire

APPENDIX IV[1]

Terminology

The following terms have been selected from the updated FAO terminology (FAO 2003, in press.).

aerial fuel
The standing and supported live and dead fuels not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems, bark, lianas and other vines, moss and high brush. In general they easily dry out and may carry surface fires into the canopy.

agrosilvopastoral system
Land-use system in which woody perennials are used on the same land as agricultural crops and animals, in some form of spatial arrangement or temporal sequence. In fire management agrosilvopastoral systems are planned as fuelbreaks (particularly shaded fuelbreaks) to reduce fire risk by modifying understory vegetation and soil cover (cf. fuelbreak).

backfire
A fire spreading, or set to spread, into or against the wind: (1) As used in **fire suppression**: A fire set along the inner edge of a control line to consume the fuel in the path of a forest fire and/or change the direction of force of the fire's convection column (Note: doing this on a small scale and with closer control, in order to consume patches of unburned fuel and aid control-line construction (as in mopping-up) is distinguished as "burning out, firing out, clean burning"); (2) As used in **prescribed burning:** designation of fire movement in relation to wind.

backfiring
A form of indirect attack where extensive fire is set along the inner edge of a control line or natural barrier, usually some distance from the wildfire and taking advantage of indrafts, to consume fuels in the path of the fire, and thereby halt or retard the progress of the fire front.

biomass
(1) The amount of living matter in a given habitat, expressed either as the weight of organisms per unit area or as the volume of organisms per unit volume of habitat. (2) Organic matter that can be converted to fuel and is therefore regarded as a potential energy source. Note: Organisms include plant biomass (phytomass) and animal biomass (zoomass). (3) In fire science the term biomass is often used synonymously with the term "fuel" and includes both living and dead phytomass (necromass); the zoomass is usually excluded.

buffer strip / buffer zone
A fuel break on the form of a strip of land along or adjacent to roads, trails, watercourses and recreation sites, or between (separating) fuel complexes (cf. fuelbreak).

candle bark

[1/] For additional fire terms please refer to the revised FAO Wildland Fire Management Terminology. FAO Forestry Paper 70. FAO, Rome 2003. In press.

Long streamers of bark decorticated from some gum-barked *Eucalyptus* species forming a firebrand responsible for long-distance spotting.

combustion
Consumption of fuels by oxidation, evolving heat and generally flame (neither necessarily sensible) and/or incandescence. Combustion can be divided into four phases: pre-ignition (or preheating), flaming, smouldering, and glowing.

control line
Comprehensive term for all constructed or natural barriers and treated fire edges used to control a fire.

dead fuel
Fuels with no living tissue in which moisture content is governed almost entirely by atmospheric moisture (relative humidity and precipitation), dry-bulb temperature, and solar radiation (cf. Live Fuel).

dispatcher
A person employed to receive reports of discovery and status of fires, confirm their locations, take action promptly to provide the firefighters and equipment likely to be needed for control in first attack, send them to the proper place and provide support as needed.

draped fuels
Needles, leaves, and twigs that have fallen from tree branches and have lodged on lower branches or brush. Comprises a part of aerial fuels.

drip torch
A hand-held apparatus for igniting prescribed fires and backfires by dripping flaming fuel on the materials to be burned. The device consists of a fuel fount, burner arm, and ignition source. Fuel used is generally a mixture of 65-80% diesel and 20-35% gasoline.

early burning
Prescribed burning early in the dry season, before the leaves and undergrowth are completely dry or before the leaves are shed; carried out as a precaution against more severe fire damage later in the fire season.

escaped fire
Fire which has exceeded or is expected to exceed initial attack capabilities or planned prescription.

fine fuel
Fast-drying dead fuels, generally characterized by a comparatively high surface area-to-volume ratio, which are less than 0.5 cm in diameter and have a timelag of one hour or less. These fuels (grass, leaves, needles, etc.) ignite readily and are consumed rapidly by fire when dry. (cf. flash fuel, medium fuel, heavy fuel).

fire behaviour
The manner in which fuel ignites, flame develops, and fire spreads and exhibits other related phenomena as determined by the interaction of fuels, weather, and topography. Some common terms used to describe fire behaviour include the following:
smouldering - A fire burning without flame and barely spreading.
creeping - A fire spreading slowly over the ground, generally with a low flame.
***running* -** A fire rapidly spreading and with a well-defined head.
torching - Ignition and flare up of foliage of a single tree or a small clump of trees, usually from bottom to top (syn. candling).
spotting - A fire producing firebrands carried by the surface wind, a fire whirl, and/or convection column that fall beyond the main fire perimeter and result in spot fires. Note: Solid Mass or Ember Transport under Heat Transfer.
***crowning* -** A fire ascending into the crowns of trees and spreading from crown to crown. Note: Three classes of Crown Fire under Forest Fire (1).

fire belt
A strip, cleared or planted with trees, maintained as a firebreak or fuelbreak.

firebreak
Any natural or constructed discontinuity in a fuelbed utilized to segregate, stop, and control the spread of fire or to provide a control line from which to suppress a fire; characterized by complete lack of combustibles down to mineral soil (as distinguished from fuelbreak).

fire climax
A plant community at a stage of succession maintained by periodic fires.

fire control
All activities concerned with protection of vegetation from fire.

fire cycle
The number of years required to burn over an area equal to the entire area of interest.

fire danger
A general term used to express an assessment of both fixed and variable factors of the fire environment that determine the ease of ignition, rate of spread, difficulty of control, and fire impact; often expressed as an index.

fire danger rating
A component of a fire management system that integrates the effects of selected fire danger factors into one or more qualitative or numerical indices of current protection needs.

fire-dependent species
Plant and animal species which require regular fire influence which triggers or facilitates regeneration mechanisms, or regulates competition. Without the influence of fire these species would become extinct.

fire ecology

The study of the relationships and interactions between fire, living organisms, and the environment.

fire exclusion
Planned (systematic) protection of an ecosystem from any wildfire, including any prescribed fire, by all means of fire prevention and suppression in order to obtain management objectives (cf. fire control).

fire frequency
The average number of fires or regularly occurring fire events per unit time in a designated area.

fire hazard
(1) A fuel complex, defined by volume, type, condition, arrangement, and location, that determines the degree both of ease of ignition and of fire suppression difficulty; (2) a measure of that part of the fire danger contributed by the fuels available for burning. Note: Is worked out from their relative amount, type, and condition, particularly their moisture contents.

fire history
The reconstruction and interpretation of the chronological record, causes and impacts of fire occurrence in an ecosystem in relation to changes of past environmental, cultural and socio-economic conditions. Fire history evidence is based on analysis of charcoal deposits in soils, sediments, and ice, dendrochronology (fire scar analysis), historical documents, and fire reports.

fire information system
An information system designed to support fire management decisions. Advanced fire information systems integrate different sources of information required (e.g., vegetation conditions including fire history, topography, fire weather, fire behaviour models, real-or near-real time fire detection and monitoring data, fire management resources, infrastructures and pre-suppression information) on the base of a Geographic Information System (GIS) and allows real-time distribution or access via telecommunication.

fire interval or fire-return interval
The number of years between two successive fires documented in a designated area (i.e., the interval between two successive fire occurrences); the size of the area must be clearly specified.

fire management
All activities required for the protection of burnable forest and other vegetation values from fire and the use of fire to meet land management goals and objectives. It involves the strategic integration of such factors as a knowledge of fire regimes, probable fire effects, values-at-risk, level of forest protection required, cost of fire-related activities, and prescribed fire technology into multiple-use planning, decision making, and day-to-day activities to accomplish stated resource management objectives. Successful fire management depends on effective fire prevention, detection, and pre-suppression, having an adequate fire suppression capability, and consideration of fire ecology relationships.

fire management plan

(1) A statement, for a specific area, of fire policy and prescribed action; (2) The systematic, technological, and administrative management process of determining the organization, facilities, resources, and procedures required to protect people, property, and forest areas from fire and to use fire to accomplish forest management and other land use objectives (cf. fire prevention plan or fire Campaign, pre-suppression planning, pre-attack plan, fire suppression plan, end-of-season appraisal).

fire pre-suppression
Activities undertaken in advance of fire occurrence to help ensure more effective fire suppression; includes overall planning, recruitment and training of fire personnel, procurement and maintenance of fire fighting equipment and supplies, fuel treatment, and creating, maintaining, and improving a system of fuelbreaks, roads, water sources, and control lines.

fire prevention
All measures in fire management, fuel management, forest management, forest utilization and concerning the land users and the general public, including law enforcement, that may result in the prevention of outbreak of fires or the reduction of fire severity and spread.

fire protection
All actions taken to limit the adverse environmental, social, political, cultural and economical effects of wildland fire.

fire regime
The patterns of fire occurrence, size, and severity - and sometimes, vegetation and fire effects as well - in a given area or ecosystem. It integrates various fire characteristics. A natural fire regime is the total pattern of fires over time that is characteristic of a natural region or ecosystem. The classification of fire regimes includes variations in ignition, fire intensity and behaviour, typical fire size, fire return intervals, and ecological effects.

fire season
(1) Period(s) of the year during which wildland fires are likely to occur and affect resources sufficiently to warrant organized fire management activities; (2) a legally enacted time during which burning activities are regulated by State or local authority.

fire suppression
All activities concerned with controlling and extinguishing a fire following its detection**.** (Syn. Fire Control, Fire Fighting)**.**
Methods of suppression are:

***direct attack* -** A method whereby the fire is attacked immediately adjacent to the burning fuel.
parallel attack - A method whereby a fireguard is constructed as close to the fire as heat and flame permit, and burning out the fuel between the fire and the fireguard.
***indirect attack* -** A method whereby the control line is strategically located to take advantage of favourable terrain and natural breaks in advance of the fire perimeter and the intervening strip is usually burned out or backfired**.**
***hot spotting* -** A method to check the spread and intensity of a fire at those points that exhibit the most rapid spread or that otherwise pose some special threat to control of the situation. This is in

contrast to systematically working all parts of the fire at the same time, or progressively, in a step-by-step manner.
***cold trailing* -** A method of determining whether or not a fire is still burning, involving careful inspection and feeling with the hand, or by use of a hand-held infrared scanner**,** to detect any heat source.
***mop-up* -** The act of extinguishing a fire after it has been brought under control.

fire weather
Weather conditions which influence fire ignition, behaviour, and suppression. Weather parameters are dry-bulb temperature, relative humidity, wind speed and direction, precipitation, atmospheric stability, winds aloft**.**

flammability
Relative ease of igniting and burning of a given fuel under controlled conditions, with or without a pilot flame. Flammability of a fuel is characterised quantitatively by the ignition delay of a sample of fuel exposed to a normalised radiation source.

flash fuel
Fuels, e.g. grass, ferns, leaves, draped (i.e., intercepted when falling) needles, tree moss, and light slash, that ignite readily and are consumed rapidly by fire when dry; generally characterized by a comparatively high surface-to-volume ratio.

forest fire

I. Definition of forest fire
Any wildfire or prescribed fire that is burning in a forest, variously defined for legal purposes. The FAO Forest Resource Assessment 2000 aims towards global standardization of the terminology:
***forest*:** Land with tree crown cover of more than 10 percent and area of more than 0.5 hectares. The trees should be able to reach a minimum height of 5 meters at maturity.
***other wooded land*:** Land either with a crown cover of 5-10 percent of trees able to reach a height of 5 meters at maturity; or a crown cover of more than 10 percent of trees not able to reach a height of 5 meters at maturity; or with shrub or bush cover of more than 10 percent.
***other land*:** Land with less crown cover, tree height, or shrub cover as defined under "Other wooded land". Indication is desired if recurring wildfires affect "Other land" by inhibiting regeneration to the "Forest" and "Other wooded land" categories.

I. Typology
***ground fire*:** A fire that burns **in** the ground fuel layer (syn. Subsurface fire, below surface fire).
***surface fire*:** A fire that burns in the surface fuel layer, excluding the crowns of the trees, as either a head fire, flank fire, or backfire.
***crown fire*:** A fire that advances through the crown fuel layer, usually in conjunction with the surface fire. Crown fires can be classified according to the degree of dependence on the surface fire phase:
***intermittent crown fire*:** A fire in which trees discontinuously torch, but rate of spread is controlled by the surface fire phase (syn. Passive Crown Fire).

***active crown fire*:** A fire that advances with a well-defined wall of flame extending from the ground surface to above the crown fuel layer. Probably most crown fires are of this class. Development of an active crown fire requires a substantial surface fire, and thereafter the surface and crown phases spread as a linked unit (syn. Dependent Crown Fire).
***independent crown fire*:** A fire that advances in the crown fuel layer only (syn. Running Crown Fire).

forest protection
That section of forestry concerned with the management of biotic and non-biotic damage to forests, arising from the action of humans (particularly unauthorized use of fire, human-caused wildfires, grazing and browsing, felling), natural wildfires, pests, pathogens, and extreme climatic events (wind, frost, precipitation).

fragmentation
The process of transforming large continuous vegetation or landscape patterns into smaller patches by disturbance. Natural agents of fragmentation are fire, landslides, windthrow, insects, erosion. Human-induced fragmentations include land use (e.g., agriculture, grazing, forestry), construction of residential areas, roads and other infrastructures. Fragmentation involves change of fire regimes due to alteration and discontinuity of fuels.

fuel
All combustible organic material in forests and other vegetation types, including agricultural bio-mass such as grass, branches and wood, infrastructure in urban interface areas; which create heat during the combustion process.

fuel accumulation
Process or result of build-up of those elements of a vegetation complex which are not subject to biological decay, reduction by fire, animal grazing and browsing, or harvest by humans; used in characterizing fuel dynamics between two fires and implications on fire behaviour.

fuel arrangement
The horizontal and vertical distribution of all combustible materials within a particular fuel type.

fuelbreak
Generally wide (20 - 300 meters) strips of land on which either less flammable native vegetation is maintained and integrated into fire management planning, or vegetation has been permanently modified so that fires burning into them can be more readily controlled (as distinguished from firebreak). In some countries fuelbreaks are integrated elements of agro-silvopastoral systems in which the vegetative cover is intensively treated by crop cultivation or grazing. Some fuelbreaks contain narrow firebreaks which may be roads or narrower hand-constructed lines. During fires, these firebreaks can quickly be widened either with hand tools or by firing out. Fuelbreaks have the advantages of preventing erosion, offering a safe place for firefighters to work, low maintenance, and a pleasing appearance (cf. control line, agrosilvopastoral system, buffer strip/zone).

fuel consumption

The amount of a specified fuel type or strata that is removed through the fire process, often expressed as a percentage of the pre-burn fuel weight (or fuel load). It includes available fuel plus fuel consumed after the fire front passes.

fuel loading
The amount of fuel present expressed quantitatively in terms of weight of fuel per unit area. This may be available fuel (consumable fuel) or total fuel, usually expressed as ovendry weight.

fuel management
Act or practice of controlling flammability and reducing resistance to control of wildland fuels through mechanical, chemical, biological, or manual means, or by fire, in support of land management objectives.

fuel reduction
Manipulation, including combustion, or removal of fuels to reduce the likelihood of ignition, the potential fire intensity, and/or to lessen potential damage and resistance to control.

greenbelt
(1) A fuelbreak maintained by the cultivation of strips of less flammable plants within a zone of high fire hazard, e.g., an irrigated, landscaped, and regularly maintained fuelbreak put to some additional use (e.g., golf course, park, playground).

hazard reduction
Treatment of living and dead forest fuels to reduce the likelihood of a fire starting, and to lessen its damage potential and resistance to control (cf. Fuel Treatment). Activity gaining special importance in residential/wildland interface areas.

Incident Command System
A standardized on-scene emergency management concept specifically designed to allow its user(s) to adopt an integrated organizational structure equal to the complexity and demands of single or multiple incidents, without being hindered by jurisdictional boundaries. (element of the Incident Command System [ICS]).

Integrated Forest Fire Management (IFFM)
Designation of fire management systems which include one or both of the following concepts of integration: (1) Integration of prescribed natural or human-caused wildfires and/or planned application of fire in forestry and other land-use systems in accordance with the objectives of prescribed burning; (2) Integration of the activities and the use of the capabilities of the rural populations (communities, individual land users), government agencies, NGOs, POs to meet the overall objectives of land management, vegetation (forest) protection, and smoke management including “community-based fire management” or CBFiM. The term IFFM is common for fire management approaches in less developed regions including forest and non-forest ecosystems. Note: In case of absence of forests in the area concerned the term *Integrated Fire Management* (IFM) is used instead (cf. prescribed burning).

ladder fuel

Fuels which provide vertical continuity between strata and allow fire to carry from surface fuels into the crowns of trees or shrubs (torching, crowning) and support continuation of crown fires (cf. crown fuel, ground fuel, and surface fuel).

late burning
Prescribed burning activities towards the end of the dry season.

low intensity fire
Fire which burns with a relatively low intensity, e.g. a prescribed surface fire as opposed to a high-intensity crown fire.

pre-attack plan
A plan detailing predetermined fire suppression strategy and tactics to be deployed following fire occurrence in a given land management unit. A pre-attack plan contains data on fuel types and topographic conditions including fuelbreaks, access routes and travel times, water supply sources, lakes suitable for skimmer aircraft, and existing heliports. It also includes information on existing and/or proposed locations for control lines (including the types and number of fire suppression resources that may be required and probable rates of fireguard construction, and possible constraints), base and line camps, helispots, and the priorities for construction and/or improvement of pre-suppression facilities (syn. pre-attack planning, pre-attack, cf. fire management plan, fire suppression plan, pre-suppression planning).

prescribed burning
Controlled application of fire to vegetation in either their natural or modified state, under specified environmental conditions which allow the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to attain planned resource management objectives (cf. Prescribed Fire). Note: This term has replaced the earlier term "Controlled Burning".

prescribed fire
A management-ignited wildland fire or a wildfire that burns within prescription, i.e. the fire is confined to a predetermined area and produces the fire behavior and fire characteristics required to attain planned fire treatment and/or resource management objectives. The act or procedure of setting a prescribed fire is called prescribed burning (cf. Prescribed Burning). A wildfire burning within prescription may result from a human-caused fire or a natural fire (cf. prescribed natural fire, integrated forest fire management, wildfire).

prescribed natural fire
Naturally ignited fires , such as those started by lightning, which are further used to burn under specific management prescriptions without initial fire suppression and which are managed to achieve resource benefits under close supervision (cf. prescribed fire, wildfire).

prescription
Written statement defining the objectives to be attained as well as the conditions of temperature, humidity, wind direction and speed, fuel moisture, and soil moisture, under which a fire will be allowed to burn. A prescription is generally expressed as acceptable ranges of the prescription elements, and the limit of the geographic area to be covered.

rate of spread
The speed at which a fire extends its horizontal dimensions, expressed in terms of distance per unit of time (m/min or km/h) (syn. fire spread, cf. rate of area growth, rate of perimeter growth).

reclamation burning
Prescribed burning for restoration of ecosystem characteristics and functioning (cf. restoration).

rehabilitation
The activities necessary to repair damage or disturbance caused by wildfire or the wildfire suppression activity (cf. restoration).

residence time
(1) The time required for the flaming zone of a fire to pass a stationary point. (2) The time an emission component is in the air between emission and removal from the air or change into another chemical configuration.

residential / wildland interface
The transition zone between residential areas and wildlands or vegetated fuels (cf. Urban, Urban/Wildland Interface, Wildland, Wildland Fire, Rural Urban Interface).

restoration
Restoration of biophysical capacity of ecosystems to previous (desired) conditions. Restoration includes rehabilitation measures after fire, or prescribed burning where certain fire effects are desired (cf. rehabilitation, reclamation burning).

ring fire
A fire started by igniting the full perimeter of the intended burn area so that the ensuing fire fronts converge toward the centre of the burn.

risk
(1) The probability of fire initiation due to the presence and activity of a causative agent. (2) A causative agent.

rural fire protection
Fire protection and firefighting problems that are outside of areas covered by municipal Fire & Rescue Services and its Fire Ordinance; these areas are usually remote from public water supplies and require all terrain vehicles to reach.

serotiny
Storage of seeds in closed seed containers in the canopy of shrubs and trees. For instance, serotinous cones of Lodgepole Pine do not open until subjected to temperatures of 45 to 50°C, causing the melting of the resin bond that seals the cone scales.

slash
Debris (fuels) resulting from natural events (wind/ fire) or human activities like forest harvesting.

slash disposal
Treatment of slash to reduce fire hazard or for other purposes (cf. Fuel Management).

smoke haze
An aggregation (suspension) in the atmosphere of very fine, widely dispersed, solid or liquid particles generated by vegetation fires giving the air an opalescent appearance.

smoke management
The application of knowledge of fire behaviour and meteorological processes to minimize air quality degradation during prescribed fires.

spot fire
(1) Fire ignited outside the perimeter of the main fire by a firebrand (by flying sparks or embers transported by air currents, gravity, or fire whirls). (2) A very small fire which jumped over the fireline, that requires little time and resources to extinguish by air currents, gravity, and/or fire whirls (cf. Long-Range Spotting).

stand replacement fire
Fire which kills all or most living overstory trees in a forest and initiates secondary succession or regrowth.

underburning
Prescribed burning with a low intensity fire in activity-created or natural fuels under a timber canopy.

urban / wildland interface
The transition zone (1) between cities and wildland (cf. urban, wildland, wildland fire), (2) where structures and other human development meets undeveloped wildland or vegetative fuels (syn. residential/wildland interface, wildland/urban interface, rural urban interface).

values-at-risk
Natural resources, developments, or other values that may be jeopardized if a fire occurs.

wilderness
(1) A wild, uncultivated, uninhabited region, vegetated and non-vegetated. (2) Area of remarkable natural beauty and ecological diversity. (3) Area established to conserve its primeval character and influence for public enjoyment, under uncultivated conditions, in perpetuity.

wildfire
(1) Any unplanned and uncontrolled wildland fire which regardless of ignition source may require suppression response, or other action according to agency policy. (2) Any free burning wildland fire unaffected by fire suppression measures which meets management objectives (cf. wildland, wildland fire, prescribed natural fire, prescribed fire).

wildland

Vegetated and non-vegetated land in which development is essentially non-existent, except for roads, railroads, powerlines, and similar transportation facilities; structures, if any, are widely scattered. In fire management terminology this general term includes all burnable vegetation resources including managed forests and forest plantations (cf. residential/wildland interface, wildfire).

wildland fire
Any fire occurring on wildland regardless of ignition sources, damages or benefits (cf. wildland, wildfire, residential/wildland interface).

APPENDIX V

Further Reading and Information Sources

Note: This list of references includes the sources cited in the guidelines as well as a number of monographs and synthesis volumes. These books cover the most important aspects of wildland fire science, including fire ecology, cultural history, atmospheric chemistry, public health and safety, and fire management.

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Booysen, P. de V., and N. M. Tainton (eds.) 1984. Ecological effects of fire in south African Ecosystems. Ecological Studies 48, Springer, Berlin, 426 p.

Brown, A. A., and K. P. Davis 1973. Forest fire. Control and use. McGraw Hill, New York, 686 p.

Chandler, C, P. Cheney, P. Thomas, L. Trabaud and D. Williams 1983: Fire in forestry. Vol. I and II. John Wiley & Sons, New York, 450 + 298 p.

Clark, J. S., H. Cachier, J. G. Goldammer, and B. J. Stocks (eds.). 1997. Sediment records of biomass burning and global change. Springer-Verlag, Berlin-Heidelberg-New York, 489 p.

Crutzen, P. J., and J. G. Goldammer (eds.) 1993. Fire in the environment: The ecological, atmospheric, and climatic importance of vegetation fires. Dahlem Workshop Reports. Environmental Sciences Research Report 13. John Wiley & Sons, Chichester, 400 p.

ECE/FAO International Forest Fire News (IFFN) 1998-2001. UNECE, Geneva. IFFN contributions published after 1990 are available on the website of the Global Fire Monitoring Center (GFMC): <http://www.uni-freiburg.de/fireglobe/>.

FAO 1986. Wildland Fire Management Terminology. Food and Agriculture Organization of the United Nations, FAO Forestry Paper 70, 257 p. (revised edition in prep., ca. 2002).

FAO. 1999. Meeting on Public Policies Affecting Forest Fires, Rome, 28-30 October 1998, FAO Forestry Paper 138. Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy, 369 p.

FAO. 2001a. FAO/ITTO International Expert Meeting on Forest Fire Management, Rome, Italy, 7-9 March 2001. Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy, 27 p. (also published in Int. Forest Fire News No. 24, 78-98).

FAO. 2002a. Legal Frameworks for Forest Fire Management: International Agreements and National Legislation.

FAO. 2002b. FAO Guide technique international ; Protection des forêts contre l'incendie. Fiches techniques pour les pays du Bassin Méditerranée (Handbook on Forest Fire Protection as a Technical Guide for the Mediterranean Basin).

Gill, A. M., R. H. Groves and I. R. Noble (eds.) 1981. Fire and the Australian biota. Austr. Acad. Sci., Canberra,582 p.

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Goh, K. T., D. H. Schwela, J. G. Goldammer, and O. Simpson. (1999). Health Guidelines for Vegetation Fire Events. Background Papers. Published on behalf of UNEP, WHO, and WMO. Institute of Environmental Epidemiology, Ministry of the Environment, Singapore, 498 p.

Goldammer, J. G., and M. J. Jenkins (eds.) 1990. Fire and ecosystem dynamics. Mediterranean and northern perspectives. SPB Academic Publishers, The Hague. 199 p.

Goldammer, J. G., and V. V. Furyaev (eds.) 1996. Fire in ecosystems of boreal Eurasia. Kluwer Acad. Publ., The Hague. 528 p.

Goldammer, J. G., and C. de Ronde (eds.). 2001. Fire management handbook for Subsahara Africa. NN Publ.

Heikkilä, T. V., R. Grönqvist, and M. Jurvélius 1993. Handbook on forest fire control. A guide for trainers. Forestry Training Programme (FTP) Publication 21, Helsinki, Finland, 239 p.

International Tropical Timber Organization (ITTO) 1997. ITTO Guidelines on Fire Management in Tropical Forests. ITTO Policy Development Series No.6. ITTO, Yokohama, 40 p.

Kasischke, E. S., and B. J. Stocks (eds.). 2000. Fire, climate change, and carbon cycling in the boreal forest. Ecological Studies 138, Springer-Verlag, Berlin-Heidelberg-New York, 461 p.

Kozlowski, T. T. and C. E. Ahlgren (eds.) 1974. Fire and ecosystems. Academic Press, New York, 542 p.

Oura, B. 1999. Management and Prevention of Forest Fires in Côte d'Ivoire SODEFOR's Forest Fire Protection Programme. International Forest Fire News No. 20, 50-56.

Pyne, S. J. 1982. Fire in America. Princeton Univ. Press. 654 p.

Pyne, S. J. 1991. Burning bush. A fire history of Australia. Henry Holt and Company, New York, 520 p.

Pyne, S. J. 1995. World fire. Henry Holt, New York, 379 p.

Pyne, S. J. 1997. Vestal Fire. An environmental history, told through fire, of Europe and Europe's encounter with the World. University of Washington Press, 680 p.

Pyne, S. J., P. J. Andrews, and R. D. Laven. 1996. Introduction to Wildland Fire. Second edition, John Wiley and Sons, New York-Chichester, 769 p.

Schwela, D. H., J. G. Goldammer, L. H. Morawska, and O. Simpson. (1999). Health Guidelines for Vegetation Fire Events. Guideline document. Published on behalf of UNEP, WHO, and WMO. Institute of Environmental Epidemiology, Ministry of the Environment, Singapore, 291 p.

Trabaud, L. (ed.) 1987. The role of fire in ecological systems. SPB Academic Publishers, The Hague, 157 p.

Wein, R. W. and D. A. MacLean (eds.) 1983. The role of fire in northern circumpolar ecosystems. John Wiley & Sons, New York, 322 p.

Whelan, R. J. 1995. The ecology of fire. Cambridge Studies in Ecology. Cambridge University Press, Cambridge (UK), 346 p.

Wright, H. A. and A. W. Bailey 1982. Fire ecology. United States and Southern Canada. John Wiley and Sons, New York, 501 p.

Major International Wildland Fire Websites

Note: In the temperate and boreal countries a large number of wildland fire websites are available. This list of websites on the Internet provides the website of the Global Fire Monitoring Center (GFMC) as a Web Portal to worldwide wildland fire information access, and the wildland fire websites of the UN agencies.

Global Web Portal: The Global Fire Monitoring Center (GFMC):
http://www.fire.uni-freiburg.de

FAO Forest Fire Website
http://www.fao.org/forestry/foris/webview/forestry2/index.jsp?siteId=1520&langId=1&97038584

FAO Global Forest Fire Assessment 1990-2000:
http://www.fire.uni-freiburg.de/programmes/un/fao/Wp55_eng.pdf

UN-ISDR Inter-Agency Task Force For Disaster Reduction, Working Group on Wildland Fire:
http://www.unisdr.org/unisdr/WGroup4.htm

Global Wildland Fire Network:
http://www.fire.uni-freiburg.de/GlobalNetworks/globalNet.html

WHO Health Guidelines on Vegetation Fire Events:
http://www.who.int/peh/air/vegetation_fires.htm

Global Observation of Forest Cover/Global Observation of Landcover Dynamics (GOFC/GOLD), Fire Mapping and Monitoring:
http://gofc-fire.umd.edu/

International Tropical Timber Organization (ITTO) Wildland Fire Website at GFMC:
http://www.fire.uni-freiburg.de/programmes/itto/itto_start.htm