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Findings, Observations and Recommendations for Preparing ITTO Guidelines for the Protection of Tropical Forests Against Fire

by

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1. Introduction

The vast majority of today's global vegetation fires, i.e. uncontrolled wildfires, intentionally set fires in forests, savannas, grasslands and other wildlands, and agricultural burning, is human-caused and takes place in the tropics and subtropics.

Before natural fire regimes on Earth had been altered or replaced by anthropogenic fire regimes, fire was most common and exerted strong phylogenetic pressure on the development of terrestrial life, wherever natural bioclimatic conditions favored the occurrence of lightning fires. Lightning fires have significantly contributed to shape tropical and subtropical savannas and seasonal forests.

Today most of the human population pressure on Earth is building up in tropical and subtropical countries where fire is being used extensively as land treatment tool, e.g. for conversion of forested lands into agricultural lands, for maintaining grazing lands, and for facilitating the utilization of non-wood forest products of the seasonal forests and savannas. Fire influence through traditional burning practises over millenia has strongly favored and selected plant communities that are considered to be sustainable and long-term stable fire ecosystems. However, the contemporarily changing fire regimes and the alteration of sustainable time-space-fire relationships in the wake of changing land-use practises are often associated with severe vegetation degradation processes.

In the present equatorial climate short-term climate oscillations (interannual climate variability) are common. One of the most prominent and well investigated phenomena is the El Niño-Southern Oscillation (ENSO) event which is associated with extended droughts in the West Pacific region. As it has been observed during the recent ENSO events of 1982-83 and 1987, to a lesser extent in 1991 and 1994, rain forests may become extremely flammable during these droughts.

In the recent decade extended droughts, together with the rapidly increasing exploitation of tropical forests and the demand for converting these forests into other land-use systems, go along with increasing fire pressure on tropical wildlands. Wildfires of unprecedented size and environmental impacts have been observed in the last decade.

While it is recognized that certain burning techniques are integral and necessary management components of tropical land-use systems which need to be sustained, land managers and policy makers in many tropical countries are not adequately prepared to prevent uncontrolled wildfires and to cope with extreme wildfire situations.

The development of guidelines and plans of action to reduce the detrimental effects of tropical fires follows the recommendations of many international agreements and declarations of intent to protect tropical forests against destruction (see Annex I + II).

The materials presented in the following were compiled in order to provide the base for preparing the *ITTO Guidelines for the Managementof Tropical Forest Fires*.

2. Fire Regimes and the Use of Fire as a Land Management Tool

Fire regimes in tropical forests and derived vegetation are characterized and distinguished by return intervals of fire (fire frequency), fire intensity (e.g. surface fires vs. stand replacement fires) and the direct and indirect impacts on vegetation and soil.

Lightning is an important source of natural fires which have influenced savanna-type vegetation in pre-settlement periods. The role of natural fires in the "lightning-fire bioclimatic regions" of Africa was recognized early. Lightning fires have been observed and reported in the deciduous and semi-deciduous forest biomes as well as occasionally in the rain forest.

Today the contribution of natural fires to the overall tropical wildland fire scene is becoming less important as compared with human-caused fires. Most tropical fires are set intentionally by humans and are related to several main causative agents:

- deforestation activities (conversion of forest to other land-uses, e.g. agricultural lands, pastures, exploitation of other natural resources);
- traditional, but expanding slash-and-burn agriculture systems;
- grazing land management (fires set by graziers, mainly in savannas and open forests with distinct grass strata [silvopastoral systems]);
- use of non-wood forest products (use of fire to facilitate harvest or improve yield of plants, fruits, and other forest products, predominantly in deciduous and semi-deciduous forests);
- wildland/residential interface fires (fires from settlements, e.g. from cooking, torches, camp fires etc.);
- other traditional fire uses (in the wake of religious, ethnic and folk traditions; tribal warfare);
- socio-economic and political conflicts over questions of land property and land-use rights.

2.1 Fire in the Evergreen Equatorial Rain Forest

The main reason for fire occurrence in the equatorial rain forests is related to forest clearing for agricultural use and forest management. Three types of forest clearing by fire are distinguished:

(1) Shifting agriculture (slash-and-burn agriculture), where land is allowed to return to forest vegetation after a relatively short period of agricultural use;

(2) Temporary complete removal of forest cover for preparation of forest plantations (monocultures); and

(3) Permanent conversion of forest to grazing or crop land, as well as other non-forestry land uses.

In all cases, clearing and burning follows initially the same pattern: trees are felled at the end of the wet season, and the slash is left for some time to dry out in order to obtain best burning efficiency. The efficiency of the first burning is variable; it often does not exceed 10-30% of the aboveground biomass. This low burning efficiency is due to the large fraction of forest biomass residing in the tree trunks, only a small portion of which tends to be consumed during the first burn. The remainder is treated by a second fire or is left on the site to decompose.

Shifting agriculture systems in their early practises and extent were largely determined by low human population pressure on the forest resources. They provided a sustainable base of subsistence for indigenous forest inhabitants, and their patchy impacts had little effects on overall forest ecosystem stability. Today, shifting agriculture is practised by some 500 million people on a land area of c. 300 to 500 million ha, and is becoming increasingly destructive because of larger individual sizes of areas cleared and shorter fallow (forest recovery) periods.

In addition to shifting cultivation, large forest areas are converted for permanent crop and grazing lands. The burning of primary or secondary rain forest vegetation for conversion purposes has been accelerated in the recent years.

Forest clearing fires, however, often escape. Recent observations of the impact of drought and fires in 1982-83 on the rain forests of Borneo and on the Amazon rain forest have shown that undisturbed perhumid rain forest biomes may occasionally become flammable and that escaped forest clearings fires lead to large-scale wildfires.

It has been observed that wildfires in tropical rain forests lead to high mortality because the generally thin-barked rain forest species are very susceptible to the influence of high fire temperatures. Resprouting capabilities enable a few trees to recover after fire. Repeated fires lead to the invasion of pyrophytic grasses, e.g. *Imperata* spp. Large tracts of tropical lowlands formerly occupied by rain forest are now degraded *Imperata* grasslands that are maintained by short fire-return intervals.

2.2 Fire in Seasonal Forests

The occurrence of seasonal dry periods in the tropics increases with distance from the perhumid equatorial zone. The forests gradually develop to more open, semi-deciduous and deciduous formations (e.g. moist and dry deciduous forests, monsoon forests). Between a more or less closed deciduous forest (characterized by fuels from the tree layer) and a grass savanna (grasses as predominant fuels) a broad range of ecotones can be found.

The main fire-related characteristics of these formations are seasonally available flammable fuels (grass-herb layer, shed leaves). The most important adaptive traits are thick bark, ability to heal fire scars, resprouting capability (coppicing, epicormic sprouts, dormant buds, lignotubers, etc.) and seed characteristics (dispersal, serotiny, fire cracking, soil seed bank and other germination requirements). These features are characteristic elements of a fire ecosystem.

Fires are mainly set by forest users (herdspeople, collectors of non-wood-forest products). The forests are underburned in order to remove dead plant material, to stimulate grass growth, and to facilitate or improve the harvest of other forest products. The tree layer is generally not affected by the flames, although crowning may occur earlier in the dry season when the leaves are not yet shed. In some cases fires may affect the same area twice or three times per year, e.g. one early dry season fire consuming the grass layer and one subsequent fire burning in the litter layer consisting of shed leaves.

The ecological impact of the yearly fires on the deciduous and semi-deciduous forest formations is significant. The fire strongly favors the survival of fire tolerant trees (e.g. the economically important species Sal [*Shorea robusta*] and Teak [*Tectona grandis*]).

However, fire climax deciduous forests are not necessarily in an ecologically stable condition. Long-term effects of frequent fires are associated with considerable losses of topsoil due to the removal of the protective litter layer just before the return of the rains and the subsequent erosion.

2.3 Fire Climax Pine Forests in the Tropical Submontane and Montane Belts and in the Subtropical Lowlands

Approximately 105 species of the genus *Pinus* are recognized. From the main center of speciation in Central America and Southeast Asia some species extend into the tropics; there are no pines occurring naturally between the tropics of Africa and in the whole of the Southern Hemisphere except Sumatra. In the tropics the pines are largely confined to the zone of lower montane rain forest. They are usually found on dry sites and prefer a slight to distinct seasonal climate. Most tropical pines are pioneers and tend to occupy disturbed sites, such as landslides, abandoned cultivation lands and burned sites. In the subtropics pines are also found in the lowlands, e.g. in the south of the North American continent.

Besides the pioneer characteristics, most tropical pines show distinct adaptations to a fire environment (bark thickness, rooting depth, occasionally sprouting, high flammability of litter). The tropical pure pine forests of Central America and South Asia most often are the result of a long history of regular burning. As in the tropical deciduous forests, fires are mainly set by graziers, but also spread from escaping shifting cultivation fires and the general careless use of fire in rural lands. Fire return intervals have become shorter during the last decades, often not exceeding 1 to 5 years. These regularly occurring fires favor the fire-adapted pines which replace fire-sensitive broadleaved species. The increased frequency of human-caused fires has led to an overall increase of pines and pure pine stands outside the potential natural area of occurrence in a non-fire environment. In the mountainous zones of the tropics fire leads also to an increase of the altidudinal distribution of pines, e.g. by expanding the mid-elevation pine forest belt downslope into the lowland rain forest biome and upslope into the montane broadleaved forest associations. These tropical fire climax pine forests are occurring throughout Central America, the mid-elevations of the southern Himalayas, throughout submontane elevations in Burma, Thailand, Laos, Kampuchea, Vietnam, Philippines (Luzón) and Indonesia (Sumatra).

All over the tropical and subtropical world, fire climax pine forests may provide a high degree of habitability and carrying capacity for humans. If properly used in time and space, fires are an integral part of highly productive coniferous forest, granting landscape stability and sustained supply of timber, fuelwood, resin, and grazing land. However, together with the effects of overgrazing (including trampling effects) and extensive illegal (fuel-)wood cutting, the increasing occurrence of wildfires tend to destabilize the submontane pine forests and result in forest depletion, erosion and subsequent flooding of lowlands.

2.4 Savannas and Degraded Woodlands

The various types of natural savanna formations are potentially of edaphic, climatic, orographic or fire (lightning fire) origin and influenced by wildlife (grazing, browsing, trampling). Together with anthropogenic influences, e.g. livestock grazing, fuelwood cutting and other non-wood product uses, most tropical savannas are shaped by regularly occurring human-caused fires. The impact of these fires are so dominant that only complete exclusion of fire and the other human-made influences would allow the recognition the locally prevailing non-anthropogenic driver of savannization.

A tremendous variety in physiognomy of the savannas occurs throughout the tropics of Africa, America and Asia. A common feature, however, is the grass stratum, which is an important surface fuel of the open savanna woodlands (tree savannas) and the predominant or exclusive fuel in the grass savannas (grasslands), and in the transition types (ecotones) between these two.

The available fuel (aboveground biomass density of the grass stratum) per area unit varies with the different bioclimatic and phytogeographic savanna zones. In the arid zone of West Africa (Sahel) aboveground biomass ranges between 0.5 and 2.5 t ha^{-1}, in the mesic Sudan zone between 2 and 4 t ha^{-1}, and in the humid Guinea zone up to 8 t ha^{-1} and more. Fire frequency largely depends on fuel continuity and density. Thus, savannas with relatively high and continuous loads of flammable grasses, such as the Guinean savannas, are subjected to shorter fire-return intervals as compared to the arid savannas. The burning efficiency depends on the moisture content of dead and live organic matter. Fires occurring in the early dry season generally consume less of the aboveground biomass than at the end of the dry season.

2.5 Fires in Tropical Planted Forests

Planted forests in the tropics are established for three broad purposes. First, afforestations are planned to support the demands of local population (timber, fuelwood, non-wood forest products, silvopastoral and other agroforestry systems). Second, afforestations are part of landscape rehabilitation or environmental protection measures (e.g. planting of greenbelts and plantations to encounter the impacts of wind, erosion, and desertification). The third objective of afforestations is industrial plantations established for cash crops (mainly timber and pulpwood). Only a minor part of the industrial plantations is afforested with indigenous species. Most species planted are fast growing exotics among which *Pinus* spp. and *Eucalyptus* spp. are the genera most widely used.

Litter production in plantations of fast growing species is extremely high and not in equilibrium with decomposition. The monocultural structure of the plantations and the exclusion of other forest uses lead to accumulation of surface fuels (thick layers of needles/leaves, downed woody debris, shed bark strips) and aerial fuels (draped fuels).

Within their natural range both genera have developed forest formations highly influenced and shaped by natural and human-made fires. As a consequence of regularly occurring fires fire-sensitive vegetation was suppressed (eliminated) and the formation of pure stands tolerant to regularly occuring low- to medium-intensity fires was favoured.

Exclusion of fire from the fire climax ecosystems generally leads to build-up of fuels and extreme wildfire hazard (high-intensity stand replacement fires).

During the past decades almost all industrial exotic forest plantations in the tropics were established without considering and introducing recurrent fire as a basic element of stabilizing the biological disequilibrium in fuel dynamics. Consequently, many of these plantations are highly susceptible to high-intensity stand replacement fires. The introduction of prescribed fire into tropical plantations (or: the restoration of fire into fire ecosystems that were transferred from their native fire environment into a management system without fire) is a new and challenging field of fire research and fire management policies.

3. Other environmental impacts of tropical wildland fires

In recent years increasing attention has been given to the impact of tropical fires on regional and global-scale environmental processes, e.g. the role of tropical fires in biogeochemical cycles and especially in the chemistry of the atmosphere (Annex III, Fig.1). A recent estimate of the magnitude of tropical plant biomass burned in shifting agriculture, permanent deforestation, other forest fires and savanna fires revealed that the prompt (gross) release of carbon into the atmosphere from these fires may range between 1 and 4 billion tons. Though the amount of carbon remaining in the atmosphere (net release) is not known exactly, it is generally accepted that the annual net release of carbon into the atmosphere from plant biomass burned for permanent conversion of tropical forest into other land uses ("deforestation") amounts to ca. 1 billion tons.

There is still uncertainty on the amount of plant biomass combusted in savanna fires. Although it is is generally agreed that the great part of prompt carbon release is from savanna fires, no reliable figures are available on the land area affected by fire and the plant biomass burned annually. The amount of carbon released from recurrent savanna fires and remaining in the atmosphere is also not known. This gap of knowledge is due to the lack of reliable information on (1) fire-induced savanna degradation with consequently lowered capability of atmospheric carbon uptake by post-burn regrowth of vegetation (= increase of **net source**), and (2) formation and deposit of elemental carbon ("black carbon") which is not available anymore for sequestration by plants (= increase of a **net sink**).

Although the emissions from tropical vegetation fires are dominated by carbon dioxide (CO_2), many products of incomplete combustion that play important roles in atmospheric chemistry and climate are emitted as well. Much of the burning is concentrated in limited regions and occurs mainly during the dry season, and results in levels of atmospheric pollution that rival those in the industrialized regions of the developed world. Photochemical reactions, for instance, in the plumes of vegetation fires may be responsible for as much as one third of the global input of ozone into the troposphere. Recent observations of dramatically elevated levels of tropospheric ozone in some tropical regions, particularly over the southern tropical Atlantic Ocean between South America and Africa, led to the hypothesis that emissions from tropical wildland fires and subsequent photochemical processes may play an important role in atmospheric chemistry over that large region of the Earth. The investigation of this phenomenon through international fire research campaigns has veryfied this hypothesis.

The global climate is determined critically by tropical convective air movements, leading to the injection of air masses into high altitudes of the atmosphere and their long-range transport and re-distribution. These global circulation patterns originate at the continental and oceanic surfaces with elevated temperatures. The "warm pool" of the globe is in the maritime continent of the equatorial region of Asia.

In midst of the warmest centers of the world the highest amount of forest and savanna fires occurs, leading to the injection of trace gases and aerosols into the higher levels of the atmosphere from where they are transported over long distances and redistributed all over the globe. The whole global atmospheric system therefore is highly influenced by tropical fires.

4. Key Fire Management Principles

The description of the fire ecology of some selected tropical vegetation types and other ecological implications of tropical biomass burning demonstrate that a general and overall valid statement on the role of fire cannot be made. On the one side, it is clear that fire in the tropics has been used by humans since millenia in successfully cultivating and maintaining valuable forests and open savanna landscapes of high sustainability and carrying capacity. On the other side, in recent years fire has become the most destructive and omnipresent agent in tropical vegetation development.

The manager of tropical forest lands is challenged to carefully investigate the very specific real and potential role of fire in his area of responsibility, to determine the allowable extent of fire that is compatible with other management and conservation objectives, and to transfer this knowledge into an integrated fire management system.

4.1 Basic Fire Policy and Fire Management Options

In the following three basic possible fire policy (or fire management) options in tropical forestry will be highlighted, (1) fire exclusion, (2) no fire management measures at all, and (3) integrated fire management.[3] The ecological and economic implications of these options are summarized in a general scheme (Annex IV). The integrated fire management option embraces all possible treatments as listed in the table (fire exclusion, integration of uncontrolled but tolerable or desired wildfires, and prescribed fire).

Fire Exclusion

The option of fire exclusion is applicable in those forest types, in which any fire effect would be undesirable and counterproductive to the resource management and conservation objectives. Most of the perhumid equatorial rain forests require the strict exclusion of fire if conservation or management objectives are not to be jeopardized. This may also apply to plantation-type forests that are stocked by non-fire tolerant tree species. Fire conservancy requires a consequent fire

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[3] A short glossary of fire management terms is given in Annex VII

prevention and control approach and the availability of an efficient fire protection organization.

No Fire Management (Uncontrolled Wildfire Occurrence)

The second option (no fire management measures taken) is applicable in many of the savannas, the savanna-forest ecotones and in open deciduous forests throughout the tropics. Burning patterns (timing of burning, burning frequency) follow traditional land treatment practices or are subjected to chance, mainly being driven by weather patterns (dry spells, dry season). In many places there may be no alternatives because of the lack of active control capabilities in land management. As mentioned before, the uncontrolled fire regimes of many fire climax savanna and forest landscapes may be tolerable as long as no additional degradation factors interfere, e.g. excessive grazing. However, the introduction of integrated fire management in many places may increase productivity and sustainability of the vegetation, e.g. a progressive development from a savannized vegetation toward forest.

Integrated Fire Management

The third option, the integrated fire management system, is based on a thorough understanding of the impacts of fire in a specific forest type. It requires the capability to actively manage all fire situations, e.g. to prevent and suppress all undesirable fires, to use prescribed fire in order to obtain resource management goals, and to define and control the threshold between the desired and undesired effects of uncontrolled natural and human-caused fires.

Methods and technologies for implementing either the fire exclusion policy or an integrated fire management system are described in the following sections of fire prevention, fire suppression, prescribed burning, training requirements, fire management organization, and legislation.

4.2 Fire Prevention I: Measures in Planning and Implementing Forest Management

The prevention of forest fires and other wildland fires embraces a wide range of measures that either modify the fuels around or within the fire-threatened resources so that spread and intensity of fires are modified to such extent that fires can be controlled by the technical means available (fuel management), or reduce the human-caused ignition risks and sources.

Fuel Management

The most important fuels in forest and other wildland fires, which need to be treated, are the surface fuels and the aerial fuels between the surface and the canopy of overstory trees to be protected. The surface fuels (grass-herb stratum, shrubs) are the main carrier of fire, both for horizontal spread and and for build-up of vertical development of the fire. Aerial fuels are all combustibles not in direct contact with the ground, e.g. foliage, lianas, twigs, understory tree crowns, which carry the fire into the crowns ("fuel ladders").

The treatment of these fuels either concentrates on buffer zones (firebreaks or fuelbreaks between wildland vegetation and the forest stands to be protected or by breaking up large continuous forested areas) or is practised inside of the forest stands to be protected.

Firebreaks

The construction of firebreaks and fuelbreaks around and inside of a forest complex is a common method of separating fuels (interruption of continuity of fuels). A firebreak is a line of a width up to several meters on which all combustibles are removed and the mineral soil is exposed. The objective of firebreak construction is to segragate, stop, and control the spread of a wildfire. The width of the firebreak varies with fuel loads and expected spotting behaviour (fires jumping over the firebreak). Since fires may easily cross firebreaks of up to several dozen meters, it is often extremely uneconomical to establish and to maintain such large and unproductive strips of land. Furthermore firebreaks in steep terrain tend to erode during the rainy season.

Fuelbreaks with Agricultural Crops

The concept of fuelbreaks is entirely different. Fuelbreaks are generally wide (20-300 m) strips of land on which the native flammable vegetation has been permanently modified or replaced by introduced vegetation so that fires burning into them can be more readily controlled. In the tropics it has been demonstrated successfully that fuelbreaks can be maintained economically by agricultural or agro-silvopastoral land uses.

Agricultural and pastoral land uses usually involve intensive soil treatment and removal of aboveground biomass so that less flammable ground cover is available. A general recommendation for species to be planted on agricultural fuelbreaks cannot be given because of the specific site and climate conditions required. However, some basic principles should be observed. The design of agricultural fuelbreaks should be according to suitability of sites for growing agricultural crops. The selection, treatment and harvest of crops should observe the seasonality of fire danger, e.g. the removal of flammable plant debris at the begin of the period of high fire danger. The integration of millet cultivation (e.g. *Pennisetum glaucum*, a millet species largely planted as staple food throughout Africa and Asia) on fuelbreak strips may serve as an example for specific harvest planning. The edible parts of millet are usually harvested at the beginning of the dry season, and the remaining biomass (highly flammable stem with leaves) is left on the site until the end of the dry season. In this case it would be required, through contract with the farmer, that the removal of all aboveground biomass has to be finalized before the beginning of the fire season.

If sites are suitable it is preferable to grow creeping plants such as various legumes or groundnuts which will not carry any surface fire due to intensive soil treatment and low and spacy growth.

Pastoral and Silvopastoral Fuelbreaks

The integration of grazing is another method of reducing the flammability of the surface fuels on treeless strips and on "shaded fuelbrakes" (grazing under wide-spaced tree overstory). The grazing resource on the treeless fuelbreaks may occur naturally or may need to be seeded if suitable grass species are not growing *in situ*. The impact of "prescribed grazing" and the browsing of brush and tree succession keeps the total fuel loads down. If grazing and/or browsing is selective, e.g. by leaving certain grass and brush species unaffected, additional mechanical treatment or the use of prescribed burning is necessary in order to further reduce the surface fuel loads. Pastoral fuelbreaks may include firebreaks, e.g. small strips along each side of the fuelbreak; these firebreaks are mandatory if prescribed fire is applied for fuelbreak maintenance (see below).

Shaded fuelbreaks follow a principle similar to the concept of silvopastoral systems. The basic idea of shaded fuelbreaks is to avoid the complete opening of a forest either by firebreaks or by treeless fuelbreaks. It involves the combination of timber production and animal husbandry management. Timber production is restricted to a relatively low amount of trees, which depends on the species used and particularly on the topography of the terrain. The wide distance of spacing produces solitary-type trees. Depending of species involved and timber production goals these solitary trees may need to be pruned regularly (e.g. *Pinus* sp.). This spatial concept results in breaking the continuity of surface and aerial fuels, both vertically and horizontally.

Shaded fuelbreaks offer a variety of benefits both for pasture and forest management, e.g. reducing the heat stress of grazing animals or reducing plant water stress due to wide spacing and reduced competition. The selection of tree and animal species to be used in an integrated silvopastoral system must be investigated carefully in order to avoid incompatibility of both uses, e.g. possible tree damages caused by animals, etc.

Fuelbreaks Without any Other Land Use

Fuelbreaks that are not utilized for agricultural land uses need to be structured in the same way as the silvopastoral fuelbreaks. The removal of slash (thinning and pruning slash) requires mechanical treatment, e.g. by hand or by using shredding devices to cut the slash to small particles (chipping). These particles remain on the site for improvement of humus layer formation. A compact layer of chipped fuels is generally less flammable. Surface fires creeping on such compact layers are generally easy to control.

The thinning slash can also be removed from the fuelbreaks and burned in piles. The use of prescribed fire on fuelbreaks follows the general concepts as described in paragraph 4.6 (see also Annex V).

Fuel Management Inside of the Standing Forest to be Protected

The treatment of surface and aerial fuels inside of the whole area of standing forest to be protected from damages by undesired fires requires careful economic planning. Fuel reduction by mechanical means (e.g. pruning, thinning, removal of understory vegetation, other surface fuels and thinnning slash) requires high investment of labor which may turn out to be very costly. The costs can be reduced if the biomass, which should be removed, is utilized by local population, e.g. for fuelwood.

Fuels inside of those forest and sub-forest types, which are adapted to low-intensity surface fires, can be treated by prescribed fire. Extensive information on techniques is available for conducting safe underburning of plantations in order to reduce the accumulation of fuels (Annex V).

4.3 Fire Prevention II: Alternative Treatment of Harvest Residues

In order to reduce the overall environmental impacts of burning it is adivsable to promote methods of vegetation treatment that would allow to reduce the free burning of biomass. Two basic considerations point into the direction of possible alternatives:

- In most tropical countries agricultural residues are burned because of the desired, but often short-term effects of ash fertilization. There are only few places in the wet tropics where residues are being composted and returned to the production system in the form of organic fertilizer, thus improving the humus regime.

  The systematic use of agricultural residues for providing energy for households is common in those places of the dry tropics where other energy sources are scarce. However, all over the tropics fossil fuels (gas, oil, electricity) increasingly replace the use of biofuels.

Appropriate methods and strategies that would allow to better utilize the nutrients and energy of plant biomass must be investigated.

- In most tropical forestry systems which are based on clearcutting only a fraction of the tree biomass is harvested and utilized. The remainder is usually cut and burned (slash burning). This method of slash burning, especially in the context of conversion of natural vegetation into plantations, is causing most of the contemporary smoke emissions from tropical forestry systems.

  Alternative strategies must envisage forest management systems (silviculture, forest utilization) in which the wasteful free burning of biomass is reduced:

  Silvicultural methods based on selective cutting avoid the problem of disposing large amounts of slash.

  The non-timber biomass which is traditionally not harvested could be used for non-timber products, e.g. particleboards and paper, or for energy supply (dendrothermal plants).

4.4 Fire Prevention III: The Role of Communites in Fire Management in Rural Areas and Adjacent Forest Lands

The majority of tropical forest fires and other wildland fires is caused by the rural population. An efficient fire prevention strategy therefore requires an initial understanding of the cultural, socio-economic and psychological background of the tropical fire scene.

It is not surprising that socio-economic and cultural surveys on fire causes often reveal that the most important reason for the careless use of fire is related to the fact that the rural population does not realize the economic and ecological benefits from forests and forest protection. Additionally it is often recognized that rivalries and conflicts between forestry and agricultural land users provoke the intentional and careless setting of forest fires.

The tropical forest fire manager relies extremely on a positive relationship between the people in the rural space and his forest. Mutual confidence and public support can be created by participatory approaches, e.g. by employing people in the forestry sector, especially in fire prevention work (establishing and maintaining firebreaks and fuelbreaks, other fuel treatment). The integration of agricultural and grazing land use into the fuelbreak system, as described before, will also create a high degree of confidence and even dependance (e.g. through a cost-free leasing of fuelbrak land).

Other measures that may stimulate cooperation in fire prevention are "non-fire bonus incentives". Such incentives provide funding for villages (or other types of communities) if no fire occurs on specific lands and during specific times or time periods, e.g. the dry season.

Since the use of fire remains to be a vital factor in tropical land use it is recommended that fire management extension services be offered. The extension service should provide information and training in safe and controllable burning techniques. With these techniques it would be possible to contain the fire within the target area of application and to reduce the risk of human fatalities.

Such programs need to go along with public educational campaigns (e.g. through mass media, schools, churches). The campaigns rely on the selection of appropriate symbols and slogans which stimulate the general public to identify themselves with the message.

4.5 Appropriate Technologies for Combating Wildfires

Most of the modern technologies for forest and other wildland fire fighting have been developed in the temperate and boreal zone of industrialized countries. In tropical countries the lack of infrastructure and trained personnel and the high costs involved are the major impediments that prohibit the introduction of technologies such as aerial fire fighting (use of fixed-wing aircraft and helicopters for delivering extinguishants [water, retardants, foam] and personnel [parachute "smoke jumpers", helitack crews]) and the use of advanced but rather expensive extinguishants (chemical fire retardants, foam). However, modern ground tankers (4-wheel drive multiple-purpose vehicles for rapid fire attack) and personnel safety devices (fireproof clothing) have been succcessfully introduced in various parts of the tropical forest environment.

It has been recognized, however, that most of the average fire situations in many tropical vegetation types can be managed successfully by experienced ground crews of fire fighters. The success of ground crews depends on the availability of adequately designed hand tools and the provision of basic training in fire suppression and fire fighter's safety.

Appropriate Fire Suppression Tools and Methods

The most important fire suppression hand tools are those for creating fire lines (principally the same concept as firebreaks) and for extinguishing a surface fire front or fires jumping (spotting) over the control lines with fire swatters or small amounts of water (e.g. by using backpack pumps). Tools designed for cutting (removal of grass, brushes, small trees), hacking (removal of grass swards and brushes) and scraping/digging/raking (removal of litter layer and other debris for creating a mineral soil strip) are the main hand tools for fire line construction. Principally such tools are found in all rural societies of the tropics. However, in most places these tools do not have the stability specifically required for use in fire fighting or are not available in the mix necessary for constructing a fire line in a non-homogenous fuel bed.

Methods for fire line construction in homogenous and non-homogenous fuels as developed in North America and Australia can be applied in tropical fuel conditions and and safely conducted by local forest labourers. For instance, the step-up method is an appropriate technique for homogenous fuels in which each fire crew member works with the same hand tool. More complex fuels, e.g. consisting of of duff layer, grass layer, shrubs and trees of various sized, require the use of a variety of specific tools and a well trained fire crew.

The simplest and most portable water pumping outfit - for its size - is the backpack pump. It consists of a collapsible bag (plastic, rubber) or a tank (metal, plastic) that contains up to 20 l of extinguishant (usually water, but also chemical retardants or foaming agent, if available). A hand-operated pumping device with nozzle (adjustable for straight stream or spray) allows an extremely economic use of the liquid. Backpack pumps, operated by a skilled firefighter, are the most efficient, flexible and economical of all water pumping equipment, especially suitable for extinguishing fires spotting over fire lines and low-intensity surface fires.

Among the many other types of fire suppression equipment and techniques, the backfiring technique must be mentioned briefly. The use of fire to backfire ("counterfire") an approaching wildfire is a technique successfully applied by experienced fire teams throughout the world, but extremely dangerous and detrimental when used by unexperienced people. In the rural societies of the tropics many agriculturists have considerable empirical knowledge in backfire application. Fire safety training, however, in use of backfire and prescribed burning techniques (cf. following paragraph) is a mandatory part of extension programs for the rural population involved in any fire use and fire management activities.

The fire-fighting tools produced in the industrialized countries are usually of very high quality and well constructed to be used in extreme fire situations. However, since these tools often are quite expensive a local production should be considered. Examples from various tropical countries (e.g. India, the Philippines, Indonesia) show that the high-quality standards can be met and that considerable savings can be achieved using the skills of local producers.

4.6 Prescribed Burning

The characteristics of some tropical fire climax forests and sub-forest formations on the one side, and the presence of uncontrolled fire pressure on most tropical vegetation types on the other side require a careful approach in integrated fire management. The introduction of prescribed fire in many cases is mandatory if the productivity of these ecosystems would be endangered by fire exclusion or by fire occurring uncontrolled in time and space.

Prescribed burning is the controlled application of fire to wildland fuels in either their natural or modified state, under specific environmental conditions which allow the fire to produce the fireline intensity and rate of spread required to attain planned resource management objectives. In some tropical countries the method of prescribed burning is refered to as "early burning". This term somewhat expresses the fact that a fire is intentionally set by the forest manager in the early dry season because one of the expected effects is to prevent the comparatively more serious effects of a fire occuring uncontrolled during the peak of the dry season.

The principles of integrated fire management and the ecological, economic and management aspects of fire management options in tropical vegetation types show the broad variety of management objectives to be attained by prescribed burning (Annex V).

Prescribed fire in the context of tropical forest fire management should also embrace the beneficial use of fire in the agricultural sector. Many of the tropical forest fires are started by regular use of fire for disposing biomass on agricultural fields, pastures or in shifting agriculture systems.

One of the most important goals of Integrated Fire Management in the interface of tropical rural lands and forests is to develop and teach safe burning techniques that allow the farmer to contain the fire on his agricultural plot and to prevent escaping of the fire into the surrounding forests or wildlands. Fire Management extension services must be provided which help the farmers to better understand the beneficial and detrimental use of fire.

4.7 Training Requirements

Well trained forest managers and forest fire management specialists are needed to successfully cope with the multitude of problems arising from the ecological, socio-cultural and technical particularities and aspects of fire management in the tropics.

Most tropical countries cannot meet the training requirements for the different target groups, forestry personnel, farmers, and others (e.g. fire brigades, disaster management organizations, military, etc.).

Forestry Personnel

Traing of forestry personnel must be addressed on the academic, technical and forest worker level, including concessionaires. University-level curricula in fire management need to be developed, or at least special training courses must be offered to prepare the forest engineers for their task by providing basic knowledge in fire ecology and fire management.

Technical forest colleges must provide curricula oriented towards the use of methods and technologies to safely conduct prescribed burning and wildfire suppression.

Vocational training of forest workers must contain basic training and exercises in using equipment and basics in fire behaviour and fire safety.

Farmers

The farmers are an important target group of training or extension because they are the predominant source of uncontrolled wildfires. Primary targets of rural education campaigns must encompass

- alternatives of disposing harvest residues

- fire prevention measures

- safe prescribed burning methods

- safe fire suppression methods

Others

Other target groups are those authorities involved in fire fighting and general disaster management. These are primarily the urban and rural fire brigades which in general are well trained in structural and industrial fire fighting but not in the particularities of wildland fire behaviour and suppression. The fire control equipment of city and village fire brigades often cannot be used in wildland fire situations.

The same refers to the disaster management organizations (e.g. civil protection) and the military which are generally called for support if a wildland fire is getting large and out of control.

These other target groups, eventually cooperating through an Interagency Fire Management Board, must receive adequate information on wildland fire basics and management in order to improve the overall efficiency of local, regional or national fire management resources.

4.8 Fire Management Organization

The efficiency of a fire management organization depends on technical prerequisites (availability of fire intelligence, trained personnel, infrastructure and equipment) and on the legal base (definition of responsibilities, formulation of fire policies, legislative aspects, law enforcement, etc.). In some tropical countries technical fire management capabilities are available in industrial plantation areas or in national parks and game reserves. Outside of these intensively managed forests only a few tropical countries provide adequate technical and infrastructural prerequisites for an efficient fire management organization.

Conceptions of fire management options, equipment and training of personnel have been summarized above, and the policy part will be covered further down. In this section (including Annex VI) a brief outline of components of fire intelligence will be given, the most essential component of fire management.

In general, the term **fire intelligence** comprises all infrastructures, communication, base data and other hard- and software that provide the inputs to an information and decision-support system in fire management. A simplified, idealized scheme of the elements required for a complete fire intelligence and fire management decision support system is given in Annex VI.

No tropical country has available a more or less complete system of fire intelligence. One of the main problems is the large size of forest and other vegetation that need to be systematically monitored for fire detection. Only a few countries are able to carry out systematic surveys of fires by using remote sensing technologies, e.g. Brazil (observation/control of rain forest conversion fires) or Senegal (mainly research on savanna fires).

The integration of meteorological data into fire danger rating indices, and the further integration of these data into an information system (e.g. a Geographic Information System [GIS]) is almost impossible because of the lack of input parameters.

The overall lack of real-time, historic or average information on fire occurrence, area affected by fire and ecological and economic impacts of fires is obvious and leads to the conclusion that high priority must be given to develop national and international programmes which would fill the gap (see Annex II and paragraph 6).

4.9 Rehabilitation of Burned Tropical Forests

The consequences of fire in tropical forested systems are varying and depend on their adaptation to fire and droughts. Tropical rain forests are extremely susceptible to fire damages and many valuable species disappear after fire. The rehabilitation of burned tropical rainforests is most challenging, and the expertise available is still restricted. However, a recent ITTO project on rehabilitation of burned tropical dipterocarp rain forest in Indonesia has demonstrated a successful approach to use natural regeneration and enrichment planting of local tree species for the restoration of fire-damaged forest.

The area of tropical forests which is damaged by all kinds of natural and anthropogenic disturbances, including non-sustainable forest management practices, is increasing dramatically worldwide. Forest management strategies must take this into account, and adequater rehabilitation programs must be fostered.

5. Integration of Fire Management Planning with Overall National Strategies Promoting the Conservation and Sustainable Management of Tropical Forests

Following one of the objectives of the ITTA of 1983

> ***"To encourage the development of naional policies aimed at sustainable utilization and conservation of tropical forests and their genetic resources, at at maintaining the ecological balance in the regions concerned"***

and the recommendations of **ITTO *Guidelines for the Sustainable Management of Natural Tropical Forests*** and ***Guidelines for the Establishment and Sustainable Management of Planted Tropical Forests*** the development of fire management policies at the national, management unit and local levels must developed, containing following statements:

- A general statement on the impact of fire on the sustainability of the most important forests and other vegetation of the country (or management unit), on the environment in general, and the economic implications.
- A general statement regarding how to encounter the negative impacts of fire.
- Definition of a long-term fire management strategy. Definition of fire management policy in the various geographic regions in accordance with vegetation type, demographics and land uses in order to protect natural, socio-economic and human resources from the detrimental effects of fires.
- Definition of the role of the population in participating in fire management activities, especially in fire prevention.

A variety of legal aspects needs to be considered for the implementation of a fire policy and for coherent fire management planning, in general e.g.:

- Definition of landownership and availability of a landownership register.

- Development of a landscape plan in which definitions are given of the land uses permitted or practiced on a defined area of land.

- Regulations concerning land-use changes, in particular the establishment of residential constructions on burned areas.

- Definition of fire management responsibilities and provision of the necessary legal and organizational base within the existing structures (government administration, private sector) in order to strengthen or to create (where not yet available) the fire management capabilities.

- Rehabilitation of burned lands.

- Law enforcement.

International contributions are essential to (1) secure the introduction of fire management methods and technologies as developed in other countries and adapted to the requirements of the tropical countries, and (2) provide the funding necessary to build up expertise and infrastructures that will secure the most time-efficient build-up of fire management capabilities in the most critical areas.

Both the national and international activities require a high degree of coordination because of the multi-sectoral approach (and eventually of more than one international partner being involved). In order to ensure the efficient realization of the required activities an interagency body, e.g. a National Fire Management Coordinating Committee, needs to be established. Objectives and tasks of such a committee will be:

- To establish a national platform for the development of a Long-Term Integrated Forest Fire Management System;

- To ensure an intersectoral approach in which all Government authorities, other organizations and the private sector will participate;

- To coordinate international support to the establishment of the fire management system in order to avoid duplications of activities and investments and to optimize the efficiency of contributions; international partners shall be consulted for coordinating activities.

6. International Agreements and Development Programs

The objectives of ITTA to promote conservation of tropical forests and sustainable forestry systems, and the initiative of ITTO for the development of tropical fire management guidelines go parallel and are in agreement with other international programmes: The processes initiated by the United Nations Conference on Environment and Development (UNCED), the tasks of the Commission for Sustainable Develoment (CSD), and the activities of UNESCO and the International Decade for Natural Hazard Reduction (IDNDR), see Annex II).

The industrial countries should bear in mind that the tropical countries are dependent on knowledge and technologies for fire management developed in the industrial countries. A series of technical and financial cooperation projects in fire management have been implemented or are underway at present through international organizations or bilateral programmes.

ITTO producer and consumer countries are requested to actively support the international political and technical programmes by underscoring that fire and its detrimental effects are a unifying element in the international endeavours to protect the sustainability and productivity of the global forests.

The establishment of international mechanisms or facilities to develop international fire management strategies and programmes therefore must receive high priority.

7. Concluding Remarks

In this report the complexity and ambiguity of phenomena and problems related to fire in tropical forests and other land-use systems have been described. The socio-economic and cultural conditions in the tropical forest environment create enormous difficulties in managing the fire problems. Forest resource managers all over the tropics are facing a tremendous pressure exerted by humans and fire.

Adequate strategies must be devloped reduce the detrimental impacts of fire, at the same time acknowledging the beneficial and sustainable effects of fire in land use systems. This report has highlighted basic processes, problems and possible solutions, leaving a challenging task to the ITTO panel to jointly develop the ITTO Guidelines for the Management of Tropical Forest Fires.

Annex I: The Freiburg Declaration on Tropical Fires

In May 1989 an international group of scientists specialized in tropical fire ecology, atmospheric chemistry and climatology met at Freiburg University (Germany) and prepared the monograph "Fire in the Tropical Biota. Ecosystem Processes and Global Challenges" (Goldammer 1990; see Annex VIII). The *Freiburg Declaration on Tropical Fires* was released at the end of the meeting:

The Role of Fires in Tropical Forest Ecosystems

Fires in the forest and other vegetation of the tropics and subtropics and the changing tropical land use have increasing regional and global impact on the environment. The smoke plumes from tropical biomass fires carry vast amounts of atmospheric pollutants, including CO_2, CO, NO_x, N_2O, CH_4, nonmethane hydrocarbons, and aerosols. Smog-like photochemistry produces ozone concentrations comparable to those found in the industrialized regions. These perturbations of the tropical atmosphere are on such a scale that they can be easily detected by remote sensing from space. Alterations of the hydrological regimes can have severe environmental and human consequences for the regions being burned and in neighboring regions. The consequences of biomass burning, such as the aggravation of the greenhouse effect, affect nontropical regions most strongly. The catastrophic fires on the island of Borneo in 1982/83 indicate the danger that possible climatic changes pose to the survival of the tropical forests themselves.

On the other hand, fires play a central role in the maintenance of many natural ecosystems and in the practice of agriculture and pastoralism. The various types of savannas are burned frequently both by human-and non-human-caused fires. Burning is used as a tool in maintaining tree plantations and natural forests, especially in the subtropics. Forest in the moist tropics have long been used in shifting cultivation to support low population densities of traditional agriculturalist without degrading either the forest or the productive potential of the soil. This situation has changed radically by accelerating shifting cultivation cycles under the influence of market economies and because of increasing population pressure, both from demographic growth and from reduced access to land. Nonsustainable slash-and-burn pioneer agriculture, without the long fallows of traditional systems, is practised by populations that are either attracted to or forced to migrate to tropical forest areas, or that are transported to these regions under government colonization or transmigration programs. Both shifting cultivation and pioneer farmers depend on burning to produce crops at acceptable labor input intensities. Burning is also the key process in maintaining the cattle pastures that are replacing tropical forest in vast areas of tropical Latin America.

In the enormous areas of savannas - especially in Africa - where burning is a part of the natural cycle, the frequency of fires has greatly increased, and with this impact of uncontrolled fires is more and more detrimental. The dual role of fire must be recognized, being both a natural agent of ecosystem maintenance and a potentially disastrous cause of ecosystem destruction.

Where Do We Stand?

Fire control has been the traditional fire policy in many parts of the world. An increasing number of countries have adopted fire management policies instead, in order to maintain the function of fire in removing the accumulation of fuel loads that would otherwise lead to damaging wildfires, and in order to arrest succession at stages that are more productive to humans than are forests that would predominate in the absence of fire. Frequently, inappropriate choices are made - often because decisions are influenced by other regions where conditions differ. Such influence may come through misguided international aid programs, through visiting consultants and researchers, or through the temperate-zone bias of local technical stuff trained abroad. Researchers and policy-makers must be sensitve to the different functions of fire in each ecosystem and to the needs of the people who depend on it.

When current burning practices are correctly identified as damaging, as in the case of the recent explosion of deforestation and burning in lowland Amazonia, the measures taken are often ineffective. Prohibiting burning, and attempting to enforce this through inspection and punishment, is bound to fail. The motives for burning must be removed, such as land speculation, tax or other incentives, and land documentation criteria that reward deforestation. Migration of farmers to infertile rain forest areas must not be facilitated by highway construction and must not be augmented by policies that expel populations from other regions through land tenure concentration and through lack of employment alternatives. Sound policies to bring the use of fire under rational control must be based on an accurate understanding of why burning is done, what its costs and benefits are, and who enjoys the benefits and suffers the impact of present and alternative practices.

An Action Plan

Both more research and immediate action are needed. Education must begin now to bring about long-term changes in attitudes towards fire and nature. Global monitoring systems must be expanded and coordinated. For example, the rain forests of the Congo Basin have so far been almost untouched by fire, but must be watched because the situation could change rapidly, as it has in other tropical areas. Temperate zone countries can contribute greatly to research efforts through financial contributions and by participating in intellctual exchange with tropical countries. The International Geosphere-Biosphere Programme (IGBP) offers a promising channel for international cooperation in fire research and in the Intergovernmental Panel on Climate Change (IPCC), under the auspices of the United Nations Environmental Program (UNEP), will provide response strategies to these environmental threats. It is essential, however, that the IGBP focus its resources on the large ecosystems that play major roles in global geochemical processes. Tropical rain forest, for example, must be understood in the Brazilian Amazon and in Equatorial Africa rather than being studied primarily in isolated remnants of forests in Puerto Rico, Panama, Costa Rica, or Hawaii.

Without waiting for further results, much could be done to translate what we already know into action. These action include reforming the policies of international lending institutions and development assistance programs to give greater considerations to the environmental impacts of policies that either provoke or eliminate fires. Recent increase in the environmental review capabilities of the World Bank is a hopeful sign, but it is only a tiny beginning.

Institutional mechanisms must be developed to distribute fairly - both within and between nations - the costs and benefits of changes in fire policy. The questions of "fire for whom?" and "fire control for whom?" must be answered clearly if sound and fair policies are to be formulated. Policy must be respect national sovereignties. Fortunately, the interests of different nations almost always point in the same direction: limiting deforestation is not only in the long-term interest of the people of the tropical countries where forests are being cleared, but is also beneficial to other nations concerned by the loss of biodiversity and by the danger of atmospheric impacts in the temperate latitudes.

Freiburg (Germany), May 1989

Annex II (1): Basic Information on the International Decade for Natural Disaster Reduction (IDNDR)

On 11 December 1987 at its 42nd session, the General Assembly of the United Nations designated the 1990's as the International Decade for Natural Disaster Reduction (IDNDR)(Resolution 44/236 of 22 December 1989). The concept of this international programme was an initiative of the US Academy of Sciences in 1984. The basic idea behind this proclamation of the Decade was and still remains to be the unacceptable and rising levels of losses which disasters continue to incur on the one hand, and the existence, on the other hand, of a wealth of scientific and engineering know-how which could be effectively used to reduce losses resulting from disasters.

Objectives of the Decade

The general objective of the Decade is

> *to reduce through concerted international actions, especially in developing countries, loss of life, property damage and economic disruption caused by natural disasters such as earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruptions,* ***wildfires*** *and other calamities of natural origin such as grasshopper and locust infestations.*

The following four goals represent the **desired** destinations which Decade efforts should lead to:

> *(1) improve the capacity of each country to mitigate the effects of natural disasters expeditiously and effectively, paying special attention to assisting developing countries in the assessment of disaster damage potential and in the establishment of early warning systems and disaster-resistant structures when and where needed;*
>
> *(2) devise appropriate guidelines and strategies for applying existing scientific and technical knowledge, taking into account the cultural and economic diversity among nations;*
>
> *(3) foster scientific and engineering endeavours aimed at closing critical gaps in knowledge in order to reduce loss of life and property;*
>
> *(4) develop measures for the assessment, prediction, prevention and mitigation of natural disasters through programmes of technical assistance and technology transfer, demonstration projects, and education and training, tailored to specific disasters and locations, and to evaluate the effectiveness of those programmes.*

Based on the above broadly defined goals, it was found necessary to focus on a number of specific areas of activities which would mark progress to be achieved at the end of the Decade period.

By the year 2000, all countries, as part of their plan to achieve sustainable development, should have in place:

(1) comprehensive national assessments of risks from natural hazards, with these assessments taken into account in development plans;

(2) mitigation plans at national and/or local levels, involving long-term prevention and preparedness and community awareness, and

(3) ready access to global, regional, national and local warning systems and broad dissemination of warnings.

To date, 120 national IDNDR Commitees and focal points have been established around the world in order to realize the Decade's objectives. In addition a group of 25 scientific and technical experts selected on the basis of their personal capacities and qualifications and with due to regard to the diversity of disaster mitigation issues and geographical representation constitute the membership of the Scientific and Technical Committee of the IDNDR. Their functions include to develop programmes to be taken into account in bilateral and multilateral cooperation and to assess and evaluate the activities carried out in the Decade and to make recommendations on the overall programmmes in an annual report to the Secretary General.

Wildfires - "Natural Disasters" ?

In the past years there have been various successful examples of how national governments were prepared and the international community responded to disaster management support, e.g. after earthquakes, hurricanes, and floods.

What about wildfires? Are there or have there been any "wildfire disasters"? If so, has any of the goals indicated above been achieved in the sector of wildfire-caused disasters?

In the context of IDNDR, wildfires clearly have been defined as potential natural disasters. However, a global survey carried out by IDNDR shows an interesting picture. Among the 93 nations which responded to an enquiry by IDNDR a total of 49 nations considered wildfires to be an important "Prevailing Hazard" in their country. The remainder of 44 countries did not mention wildfires to be an important natural disaster threat (Tab.1).

Tab.1. Extracts from the information provided in national reports to the IDNDR. One of the questions directed to the countries was on "Prevailing Hazards". In the questionnaire the countries had to state whether wildfires were considered to be a prevailing hazard or not. The total number of responses was 93. Extracted from: WCNDR Information Paper No.2 (April-94)

Countries considering wildfires to be a prevailing natural hazard	**Countries considering wildfires not to be a prevailing natural hazard**
Algeria	Austria
Armenia	Bolivia
Australia	Botswana
Azerbaijan	British Virgin Islands
Bangladesh	Cameroun
Bermuda	Chad
Bhutan	Columbia
Bulgaria	Cook Island
Burkina Faso	Costa Rica
Canada	Cuba
China, People's Republic of	Denmark
Dominican Republic	Ecudaor
Egypt	Ethiopia
Finland	Fiji
Germany	Guatemala
Greece	Honduras
Guinée, Republic of	Iran
Haiti	Ireland
Hungary	Italy
Kazakhstan	Japan
Kenya	Korea, Republic of
Latvia	Kyrghyzstan
Malaysia	Mozambique
Maldives	Netherlands
Mauritius	New Zealand
Mexico	Nicaragua
Micronesia	Panama
Mongolia	Paraguay
Namibia	Solomon Islands
Nepal	South Africa
Nigeria	Spain
Norway	Sri Lanka
Oman	Sudan
Palau	Sweden
Papua New Guinea	Tajikistan
Peru	Tanzania
Philippines	Trinidad und Tobago
Poland	Turkmenistan
Portugal	Tuvalu
Romania	Ukraine
Russian Federation	United Kingdom
Switzerland	Vanuatu
Tunisia	Zaire
Turkey	
Union of Myanmar	
United States of America	
Uzbekistan	
Vietnam	
Western Samoa	

From another survey on damages caused by significant natural disasters the evaluation of wildfire-related economic and human losses were not clearly to be identified. In the preface to that survey it was defined that a "significant disaster" must meet one of the following criteria:

Damage: $\geq$ 1% of total annual GNP
Number of affected people: $\geq$ 1% of the total population
Number of deaths: $\geq$ 100

It is clear that only a few wildfire disasters meet these criteria in order to be put into the category of "significant" disaster. However, a look to the forest fire statistics from the People's Republic of China show that throughout the last 40 years more than 100 people annually died in forest fires on an area affected by fire of nearly one million ha per year.

Wildfires at the UN World Conference on Natural Disaster Reduction

A World Conference on Natural Disaster Reduction (WCNDR), which forms a part of a mid-term review of Decade activities, was held in Yokohama (Japan) between 23-27 May 1994. The conference was the first of its kind to be held on a global level it was expected to provide a platform for the exchange of experiences between Decade partners at national, regional, and international levels.

The ECE/FAO Team of Specialists on Forest Fire brought the fire issue onto the table of policy makers by presenting a poster and discussing the fire issue in the Technical Committees. A proposal was attached to the Yokohama Strategy on the ***"Possible Role of the UN System in Fire Research and Wildfire Disaster Management"*** (Annex II (2).

Annex II (2): Proposal to the Annex of the Yokohama Strategy of the International Decade for Natural Hazard Reduction (IDNDR), May 1994

A Possible Role of the UN System in Fire Research and Wildfire Disaster Management: A Proposal

Uncontrolled wildfires and prescribed fires occur in all vegetation zones of the world. It is estimated that fires annually affect up to

- 10-15 million hectares of boreal and temperate forest and other lands
- 20-40 million hectares of tropical rain forests due to forest conversion activities an escaped agricultural burnings
- 500-1000 million hectares of tropical and subtropical savannas, woodlands, and open forests

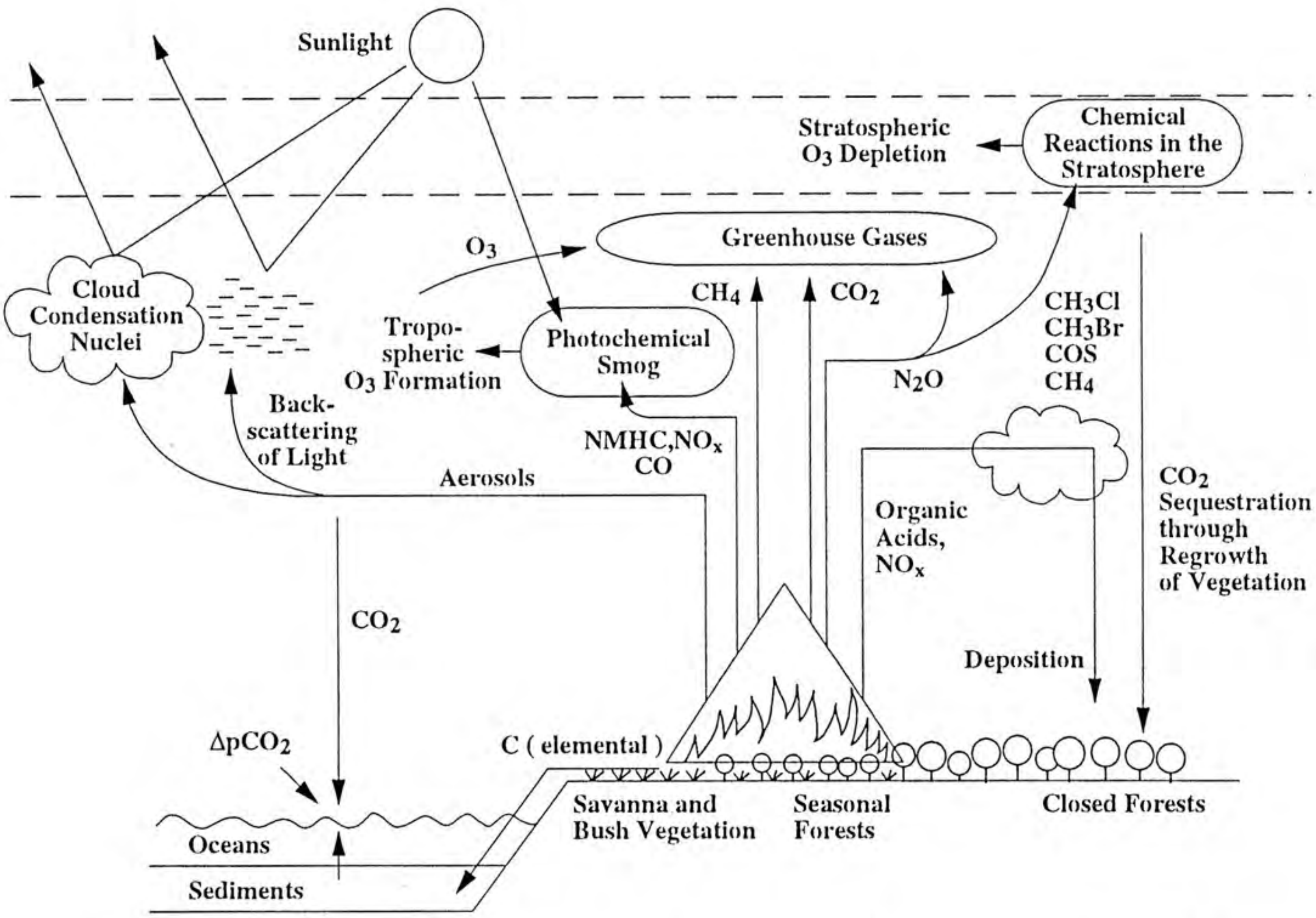
Only a minor part of these fires is caused by nature (lightning). Most of today's fires are caused by human activities. Some burning practices still follow the traditional rules of rural populations, and many ecosystems are well adapted to fire. The majority of fires, however, is in conflict with land-use priorities and other considerations, leading to

- Ecological problems (vegetation degradation, erosion, loss of biodiversity)
- Socio-economic problems (loss of human lives, loss of values-at-risk, especially in the wildland/residential interface, economic losses)
- Environmental phenomena (affecting air quality and the global carbon cycle, contribution to elevated concentration of trace gases and aerosols, with consequences on the regional and global climate)

Wildfire disasters sometimes occur as a consequence of other natural disasters (e.g. after earthquakes, volcano eruptions), and fires may lead to subsequent natural disasters (e.g. landslides, flooding after soil exposure). On an international base no system is available to monitor the extent and the consequences of vegetation fires on a global scale. Most countries in the developing world do not have adequate infrastructures, experience and hardware to manage wildfire disasters. Although bilateral assistance agreements exist and a number of field projects in fire management are carried out through national and international organizations, there are no facilities and/or mechanisms available to provide the necessary disaster management assistance on an international level on a permanent and quick-response base. Besides the ECE/FAO Team of Specialists on Forest Fire which has a restricted mandate and a regionally restricted area of influence, or some ongoing and planned regional fire research campaigns under the IGBP scheme, neither the UN system nor any other organization is providing adequate structures and mechanisms with international (global) responsibilities in fire management.

In order to take the first necessary steps for clarifying the global importance of wildfires and for building international structures and mechanisms for mutual fire management support, it is recommended to entrust the ECE/FAO Team of Specialists on Forest Fire, in close cooperation with FAO, UNESCO, IDNDR, and UNDRO, to develop a plan for the establishment of a UN-sponsored Global Fire Research and Management Facility which includes a Global Vegetation Fire Information System and the capabilities to provide support on request to any nation in fire management and prevention and management of wildfire disasters.

Annex III (1): Fig.1. The impact of gaseous and aerosol emissions from vegetation fires on atmosphere and climate (Goldammer 1993c)



The impact of gaseous and aerosol emissions from vegetation fires on atmosphere and climate

Annex III (2). Tab.1. Global estimates of annual amounts of biomass burning and of the resulting release of carbon to the atmosphere

Burning Source	Biomass burned			Carbon released
	Tropical	Extratropical	Total	
		Tg dm yr^{-1}		Tg yr^{-1} *
Forest	1260	1150	2410	1080
Savanna	3690	-	3690	1660
Biomass Fuel	1720	220	1940	880
Charcoal	20	1	21	82
Agricultural Waste	420	420	850	380
World Total	7120	1800	8910	4080

* Based on a carbon content of 45% in dry biomass. In the case of charcoal, the rate of burning (based on FAO production statistics) has been multiplied by 4 to account for losses in the production process (Source: Andreae and Goldammer, 1992).

Annex IV: Tab.1 Ecological, economic and management aspects of integrated fire management options in various tropical and subtropical forest and sub-forest types (from Goldammer 1993a)

	Ecological and Economic Aspects of Fire	Deciduous Broadleaved Forests (e.g. *Tectona grandis, Shorea robusta*)	Coniferous Forests (e.g. *Pinus* spp.)	Industrial Plantations (e.g. *Pinus* and *Eucalyptus* spp.)	Silvopastoral Systems (e.g. open pine forests with grazing)	Grass Savannas (e.g. extensively grazed wildlands)
Fire Exclusion	Ecological Impacts	High diversity of species, habitats and niches. High water retaining and soil protection capability.	Replacement of coniferous species by less fire tolerant broadleaved spezies. Pines only on dry shallow and disturbed sites. Overall increase of species diversity. High water retaining and soil protection capability.	High risk of uncontrolled high-intensity stand replacement fires.	Undesirable increase of species not suitable for grazing purposes. Replacement of grass stratum by succession.	Progressive successional development toward brush/tree savannas or forest. Promotion of less fire tolerant species.
	Economic and management Implications	Economic wood production difficult because of high diversity of species. Increase of non-wood forest products.	Economic wood production difficult because of high species diversity.	Wood production feasible. Extreme high risk of destruction of plantation by wildfire.	Only possible if intensively grazed and mechanically cleared.	Not feasible.
Uncontrolled Wildfires	Ecological Impacts	Selection of fire resistant/tolerant tree species.Opening of forest formation.	Retreat of fire sensitive species and favouring of fire resistant pines. Opening of forests. Stand replacement fires. Forest degradation.	Stand replacement fires.	Uncontrolled selective fire pressure. Maintenance of openness.	Maintenance of a wildfire climax. Uncontrolled selection of fire adapted plants.
	Economic and Management Implications	Species composition and relevant management and marketing opportunities out of control.	Tendency of degradation and loss of productivity.	Management objectives jeopardized if no efficient fire prevention and control system available.	Possible long-term degradation and loss of productivity.	Productivity depends on savanna type and other degradation factors involved.
Prescribed Fire	Ecological Impacts	Controlled selection of tree species. Advantageous for stimulation and harvest of selected non-wood forest products.	Controlled favouring of desired fire-tolerant species. Reduction of stand-replacement fire risk.	Maintenance of desired monostructure of plantations. Reduction of stand-replacement fire risk. Increase of vitality and water supply.	Controlled promotion (stimulation) of desired tree and fodder plant species.	Controlled promotion of desirable grass/herb layer and tree/brush regeneration.
	Economic and Management Implications	Integrated Fire Management System requires availability of relevant ecological background knowledge, trained personnel, and infrastructural facilities to prevent and control undesired wildfires and conducting safe prescribed burning operations				

Annex V: Prescribed Burning: Management Options and Techniques

It is impossible to cover in detail the possible prescribed burning principles, the objectives and the relevant techniques for all tropical sub-forest and forest types.[4]

Extensive experience is available on prescribed burning in forest management industrial pine plantations. The objectives of prescribed burning in pine plantations are summarized in Table 3. In the context of this report most important is the use of prescribed fire in underburning forests for temporarily reducing the hazardous build-up of dead fuels on the forest floor. This, in turn, reduces the risk of damaging high-intensity wildfires. Low-intensity prescribed fires do not only reduce the surface fuels but also speed up the recycling of nutrients into a form usable by the trees. The interval between fuel reduction burns depends on several factors including species, the rate of fuel accumulation, values at risk, and the risk of wildfire.

The safest technique for underburning plantations is the backing fire.[5] A backing fire must be started along a downwind baseline such as a road or a plowline and allowed to back into the wind. The wind keeps the flames bent over and cools the air on top of the flaming front, thus reducing the danger of crown scorch or the development of a crowning fire. The preferred prescribed burning windspeeds range between 2 and 5 $km \cdot h^{-1}$. The preferred relative humidity for prescribed burning varies from 30 to 50%. It strongly influences the fine fuel moisture content, which is the most important parameter affecting prescribed fire behaviour. For a successful burn the fuel moisture content of the litter layer should not be below 7% and above ca. 30-35% (de Ronde et al., 1990).

Most experience in prescribed underburning is available for the natural and man-made pine and eucalypt forests. Much of this expertise, however, can be transfered to the conditions of the tropcial deciduous and semi-deciduous forest formations.

Logging Debris Burning and Smoke Management

Another field of application of prescribed fire in the tropics is the burning of logging debris on clearcuts of degraded natural vegetation which are to be prepared for planting or converted to other land uses. Basically the burning of logging slash on open clearcuts requires less experience because of the lacking overstory to be protected. On the other hand the amount of aboveground biomass burned in forest conversion or clearcut fires is considerably higher than the amount

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[4] Detailed information on prescribed burning in grasslands and savannas is given in the literature (Annex VIII)

[5] Only the backing fire and the ring fire technique are described. Detailed information and description of other burning techniques are contained in the literature (Annex VIII).

of biomass combusted by underburning.[6] Precautions need to be taken in order to avoid (1) uncontrolled spread of fire (escaping fires) into areas not intended to be burned and (2) formation of hazardous smoke emissions.

Both safety hazards can be controlled by burning techniques (ignition and burning patterns) and by observation of other factors that influence fire behaviour, e.g. the spatial arrangement of fuels, fuel moisture, fire weather, etc. Two basic burning patterns are available for logging debris disposal by fire, broadcast burning (use of of backing or heading fire, point source or ring ignition) and pile and windrow burning.

The problem of escaping fires can be solved largely by constructing fire breaks around the area to be burned, or by observing ignition patterns that would drive the fire into the center of the area. The ring fire technique (also referd to as center or circular firing) is useful on clearcut areas where a hot fire is desired to reduce the logging debris as complete as possible and to kill any unwanted vegetation prior to planting. As with the backing fire technique the downwind control line is the first line to be ignited. Once the baseline is secured, the entire perimeter of the area is ignited so the flame fronts will all converge toward the center of the plot. One or more spot fires are often lighted in the center of the area and allowed to develop before the perimeter of the burning block is ignited. The convection generated by these interior fires create indrafts that help pull the outer circle of fire toward the center, thereby reducing the threat of slop-overs and heat damage to adjacent stands.

This technique is very important from the smoke management point of view. In the past years forest conversion fires have created considerable problems in near-surface air pollution. This was mainly due to stable atmospheric conditions [7] and poor burning techniques, e.g. pile and windrow burning.[8] The objective of piling logging debris before burning is to prolong fire residence time thereby increasing the consumption of large materials. In practice, however, the piling of heavy fuels ends up with mixing large amounts of topsoil and creating a moist pile/windrow interior in which the fuels hardly dry at all and oxygen for complete combustion is

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[6] Total fuel loads after clearcut of tropical rain forests may amount as much as 150 t ha^{-1} and needs to be burned as complete as possible by high-intensity fires, whereas the surface fuels inside of standing forests range between 2 and 10 t ha^{-1} and need to be burned with low-intensity fires in order to avoid damages of the standing crop.

[7] The extended burning activities in the Amazon Basin during the second half of the 1980's and in Indonesia during the ENSO-related fires of 1982-83, 1987 and again in 1991 created considerable problems in reduction of visibility. Airport facilities and marine navigation had to be closed or reduced during these years. A large inversion layer over Southeast Asia in September-October 1991 and 1994 trapped the smoke from wildfires and forest conversion fires and caused considerable problems not only in traffic safety but also in human health (respiratory diseases).

[8] Logging slash in many cases is piled and windrowed before burning because of problems in igniting and completely burning large fuels (heavy logs) in discontinuous fuel beds. This technique also offers safety for conducting the burn.

lacking. The result is a fire that continues to smolder for days and weeks and creates considerable problems in near-ground air quality.

Prescribed Burning Plans

Although detailed burning prescriptions for tropical forests are not yet available many of the principles and considerations of prescribed burning in industrial pine and eucalypt plantations can be used for planning. A successful prescribed fire is one that is executed safely and is confined to the planned area, burns with the desired intensity, accomplishes the prescribed treatment, and is compatible with resource management objectives. Such planning should be based on the following factors:

(1) Physical and biological characteristics of the site to be treated.

(2) Land and resource management objectives for the site to be treated.

(3) Known relationships between preburn environmental factors, expected fire behavior, and probable fire effects.

(4) The existing art and science of applying fire to a site.

(5) Previous experience from similar treatments on similar sites.

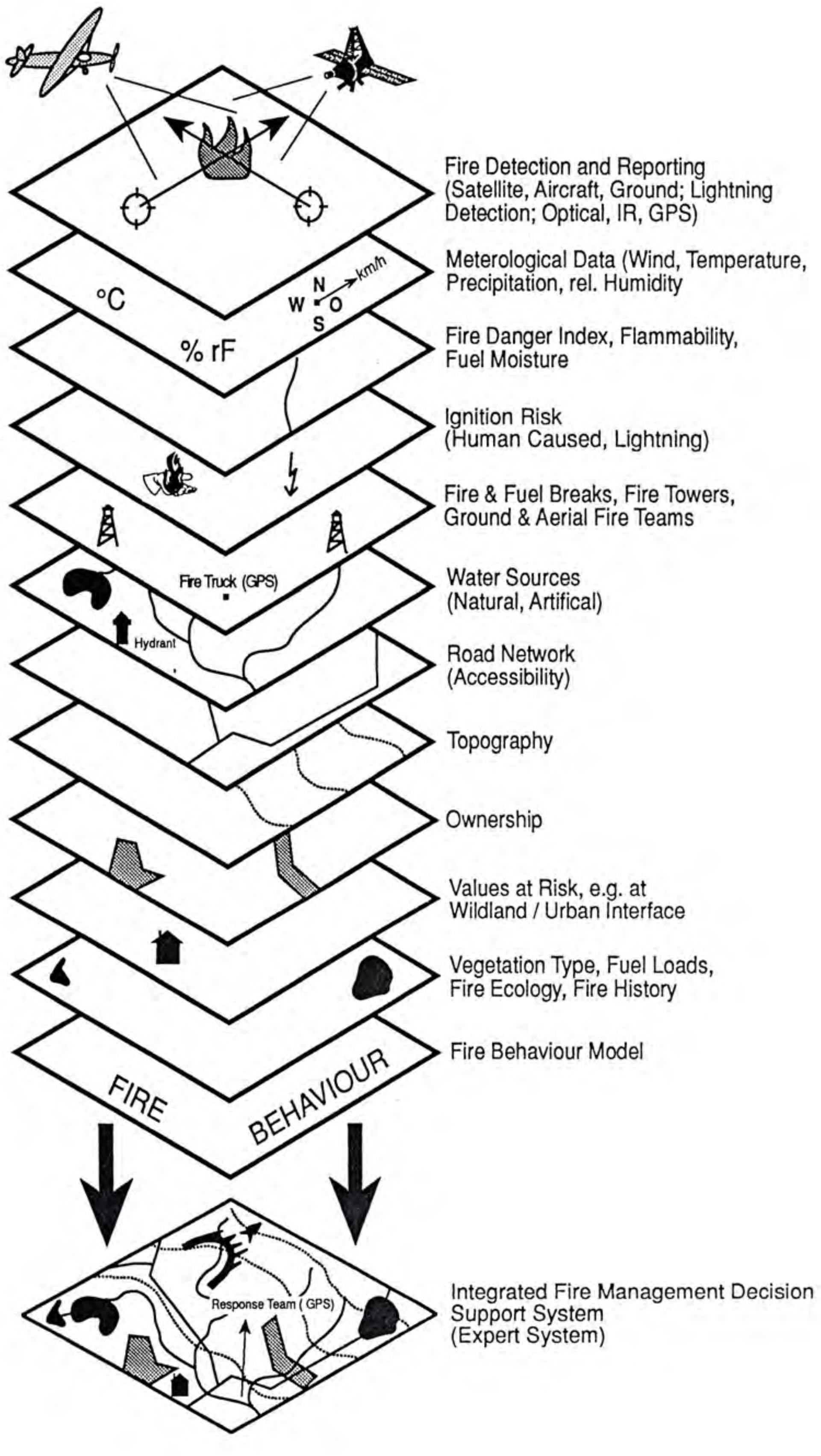
(6) Smoke impact from health and saftey standpoint.

Annex V. Tab.1. Potential objectives for the use of prescribed fire in management of industrial pine plantations in the tropics and subtropics

Objectives	Target	Desired effects	Undesired effects or potential hazards	Possible Substitution
Wildfire hazard reduction	Thinning or post-harvest slash, forest floor (raw humus), aerial fuels, rank understory	Reduce potential wildfire intensity, remove surface and ladder fuels, Reduce understory stature	Stand/tree damage (crown, bole, or root)	Partial (mechanical treatment/removal by hand, shredding, piling and burning outside of stand, pruning)
Site preparation for natural regeneration or planting	Forest floor, post harvest slash, undesired vegetation	Expose mineral soil (improve germination), increase seedfall	Encroachment, sprouting, or germination of undesired plants	Partial (herbicides to kill undesired vegetation)
Improve accessibility	Thinning of post harvest slash, rank understory	Improve access for silvicultural operations, esthetics (recreation)	Reduction of understory stature	Partial (herbicides to kill understory)
Increase growth/yield	Raw humus layer (forest floor), understory plants	Enhance nutrient availability; reduce competition for moisture, sun and nutrients	Loss of nutrients (leaching), erosion	Fertilization and herbicides
Alter plant species composition	Weeds and other undesirable vegetation	Promote desired species	Increase in weed germination/production of undesirable seeds	Herbicides
Pest management	Pests and diseases and their habitats	Eliminate spores, eggs, individuals, and breeding material	Fire-induced tree stress, increased susceptibility to secondary pests	Pesticides
Silvopastoral land use	Slash; forest floor; mature, unpalatable growth; competing vegetation	Create/improve conditions for desired ground cover		Mechanical removal of dead fuels and vegetation
Improve fire protection	Surrounding buffer zone, fuel breaks and fire breaks	Reduce spread and intensity of wildfires (outside of stands)		

Annex VI: Schematic Model of a Fire Intelligence System

(Unpublished Model of the Fire Ecology Research Group, Germany)



Annex VII: Wildland Fire Management Terminology

Selected important wildland fire management terms are given in the following. Some of them are taken from the United Nations Wildland Fire Management Terminology (FAO 1986).

Aerial Fuels - The standing and supported forest combustibles not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems, bark, and vines.

Backfire - 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.

Broadcast Burning - Allowing a prescribed fire to burn over a designated area within well-defined boundaries for reduction of fuel hazard, as a sivicultural treatment, or both.

Center Firing - A method of broadcast burning in which fires are set in the center of the area to create a strong draft; additional fires are then set progressively nearer the outer control lines as indraft builds up so as to draw them in toward the center.

Control a Fire - To complete a control line around a fire, any spot fires therefrom, and any interior islands to be saved; the control lines; and cool down all hot spots that are immediate threats to the control line, until the line can reasonably be expected to hold under foreseeable conditions.

Counter Fire Fire set between main fire and backfire to hasten spread of backfire. Also called draft fire. The act of setting counter fires is sometimes called front firing or strip firing. In European forestry synonomous with backfire.

Crown Fire - A fire that advances from top to top of trees or shrubs more or less independently of the surface fire. Sometimes crown fires are classed as either running or dependent, to distinguish the degree of independence from the surface fire.

Drip Torch - A hand-held apparatus for igniting prescribed fires by dripping flaming fuel on the materials to be burned. The device consists of a fuel fount, burner arm, and igniter. The fuel used is generally diesel or stove oil with gasoline added.

Early Burning - Prescribed burning early in the dry season before the leaves and undergrowth are completely dry or before the leaves are shed, as an insurance against more severe fire damage later on.

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 supress a fire.

Fire Danger Rating - A fire management system that integrated the effects of selected fire danger factors into one or more qualitative or numerical indices of current protection needs.

Fire Hazard - 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.

Fire Intelligence - All infrastructures, communication, base data and other hard- and software that provide the inputs to an information and decision-support system in fire management.

Fire Management - All activities required for the protection of burnable forest values from fire and the use of fire to meet land management goals and objectives.

Forest Residue - The accumulation in the forest of living or dead mostly woody material that is added to and rearranged by human activities such as forest harvest, cultural operations, and land clearing.

Fuelbreak - Generally wide (20 - 300 meters) strips of land on which the native vegetation has been permanently modified so that fires burning into them can be more readily controlled. 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.

Ladder Fuels - Fuels which provide vertical continuity between strata. Fire is able to carry from surface fuels into the crowns of trees or shrubs with relative ease and help assure initiation and continuation of crowning.

Mass Fire - A fire resulting from many simultaneous ignitions that generates a high level of energy output.

Preattack Planning - Within designated blocks of land, planning the locations of fire lines, base camps, water supply, sources, helispots, etc.; planning transportation systems, probable rates of travel, and constraints of travel on various types of attack units; and determining construct particular fire lines, their probable rate of line construction, topographic constraints on line construction, etc..

Prescribed Burning - Controlled application of fire to wildland fuels in either their natural or modified state, under specified environmental conditios 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.

Shaded Fuelbreak - Fuelbreaks built in timbered areas where the trees on the break are thinned and pruned to reduce the fire potential yet retain enough crown canopy to make a less favorable microclimate for surface fires.

Smoke Management - The application of knowledge of fire behaviour and meteorological processes to minimize air quality degradation during prescribed fires.

Surface Fire - Fire that burns only surface litter, other loose debris of the forest forest floor, and small vegetation.

Values-at-Risk - Any or all of the natural resources or improvements which may be jeopardized if a fire occurs.

Wildfire - Any fire occurring on wildland except a fire under prescription.

Wildland/Residential Interface - That line, area, or zone where structures and other human development meets or intermingles with undeveloped wildland or vegetative fuels.

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