Prescribed burning of understory vegetation and accumulated debris in a pine plantation. Photo: GFMC

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Integrated fire management in tropical forests and open landscapes

Johann Georg Goldammer

"Safe fire management practices are fundamental, but to be truly effective they must be ecosystem-based, be applied with community cooperation, and follow national guidelines."

Introduction

Humans have used fire over millennia for sustainable cultivation and for maintaining tropical forest and open savanna landscapes, but in recent decades, fire has been excessively applied for land conversion, becoming an omnipresent agent in the degradation and destruction of native vegetation. Wildfires across the globe affect up to 600 million hectares annually; savanna ecosystems in Africa and South America account for more than half of all burned areas. Understanding fire ecology and fire use in tropical vegetation types demonstrates, however, that the effects of fire — unwanted and adverse impacts vs. ecologically and economically benign effects — are so varied as to make generic fire management advice impossible.

Land managers face the challenge of carefully investigating the specific real and potential roles of fire in their areas of responsibility or jurisdiction.

This is required in order to assess the extent to which fire exclusion or fire use is compatible with other management and conservation objectives, and to incorporate this knowledge in an integrated fire management (IFM) system. See Box 1.

This article discusses fire management options and practices for fuel management, fire suppression and prescribed burning. These must involve community cooperation and be implemented under national fire management policies and planning.

Box 1. Integrated fire management

The concept of integrated fire management (IFM) was introduced in the early 1990s. Initially it focused on forests, defined as a "*Designation of fire management systems which include one or both of the following concepts of integration: (1) Integration of prescribed natural or human-caused wildfires and/or planned application of fire in forestry and other land-use systems in accordance with the objectives of prescribed burning; (2) Integration of the activities and the use of the capabilities of the rural populations (communities, individual land users) to meet the overall objectives of land management, vegetation (forest) protection, and smoke management (community-based fire management).*" (GFMC 2017c).

The concept of integration addresses two dimensions: (i) ecosystem-based components and derived fire management objectives; and (ii) cultural and socioeconomic dimensions of fire management, as encompassed in community-based fire management, or CBFiM (GFMC 2017a).

Introduction of the IFM concept coincided with the first attempts to replace fire exclusion policies by applying IFM principles; e.g., Indonesia in 1991 (Goldammer 1993b), Sudan in 1991 (Bayoumi 2001), Namibia in 1997 (Goldammer 2001; Kojwang 2001), and Ethiopia in 2000 (MoA 2000). Since then, the concepts of IFM and CBFiM have evolved, and building on these, fire management guidelines for comprehensive approaches have been developed (ITTO 1997; Goldammer and de Ronde 2004; FAO 2006). See the GFMC online repository (GFMC 2017d) for these, and for guidance, principles and strategic actions not addressed in this article.

Fire management options – basic considerations

Different tropical fire regimes reveal the functional roles of fire in a range of ecosystems, with variable adaptations from fire dependence to fire intolerance. In response, fire management planning must have a solid basis, giving priority to the most vulnerable ecosystems. There are three basic options: fire exclusion; no fire management; and integrated fire management. In effect, integrated fire management embraces all possible treatments – fire exclusion, integration of uncontrolled but tolerable or desired wildfires, and application of prescribed fire. The ecological and economic implications of each treatment are summarized in Table 1.

Fire exclusion

Equatorial rainforests are extremely sensitive to fire and require strict exclusion of fire in order to not jeopardize conservation or management objectives. This is also the case in forest plantations stocked by fire-sensitive trees, and in tropical peat-swamp forests. In these cases, fire management requires strict fire prevention and control and an efficient fire protection organization.

No fire management

Vast areas of tropical and subtropical open deciduous and semi-deciduous forests, grass, bush and tree savannas burn annually or in short-return intervals. Burning patterns (timing, frequency) may align with traditional land treatment practices, or may be subject to chance (e.g., caused by lightning), and there may be no alternative but to let fires burn due to a lack of fire management capability, access, infrastructure and resources for suppression. Uncontrolled fire regimes in fire-climax savanna and forest landscapes may be tolerable, however, if there is no additional degradation (e.g., from overgrazing).

Integrated fire management

The implementation of integrated fire management, with the active participation of local communities, can increase productivity and sustainability. Implementing IFM principles can, for example, lead to increased tree cover in savanna landscapes or on degraded forest land. Applying IFM, however, requires a thorough understanding of the impacts of fire in specific tropical vegetation types, and the capability to actively manage all fire situations. This includes preventing and suppressing all undesirable fires, taking advantage of the benign effects of fire to achieve management goals

Table 1. Ecological, economic and management aspects of integrated fire management treatments in various tropical forest, forest sub-types and savannas

	Ecological and economic aspects of fire	Deciduous broadleaved forests (e.g., *Tectona, Shorea*)	Coniferous forests (e.g., *Pinus* spp.)	Industrial plantations (e.g., *Pinus* and *Eucalyptus*)	Silvopastoral systems (e.g., open pine forests with grazing)	Grass savannas (e.g., extensively grazed lands)
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 species Pines only on dry shallow and disturbed sites Overall increase in species diversity High water-retaining and soil-protection capability	High risk of uncontrolled high-intensity stand-replacement wildfires due to fuel accumulation	Undesirable increase in species not suitable for grazing purposes Replacement of grass layer by succession	Progressive successional development towards brush/tree savannas or forest Promotion of less fire-tolerant species
	Economic and management implications	Economic timber production difficult because of high species diversity Increase in non-timber forest products	Economic timber production difficult because of high species diversity	Timber production feasible Extreme high risk of destruction of plantations 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 get out of control	Tendency to 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 on degradation factors involved
Prescribed fire (integrated fire management)	Ecological impacts	Controlled selection of tree species Advantageous for stimulation and harvest of selected non-timber forest products	Controlled favouring of desired fire-tolerant species Reduction of stand-replacement fire risk	Maintenance of desired plantation monocultures Reduction of stand-replacement fire risk Increased vitality	Controlled promotion (stimulation) of desired tree and fodder plant species	Controlled promotion of desirable grass/herb layer and tree/shrub regeneration
	Economic and management implications	An integrated fire management system requires availability of relevant ecological background knowledge, trained personnel, and the infrastructure and facilities to prevent and control undesired wildfires and to conduct safe prescribed burning operations				

Adapted from Goldammer (1993a)

Sheep grazing under high pruned *Pinus radiata* in New Zealand in a silvopastoral system that acts as a fuelbreak. Photo: GFMC

by prescribed burning, and defining and controlling the threshold between desired and undesired effects of uncontrolled natural and human-caused fires. The effects of fire on ecosystem properties and stability, including carbon sequestration capacity, tend to vary depending on seasonality. For instance, fires burning at the peak or end of the dry season are generally more severe and destructive due to extreme fire weather and accumulated fuels, whereas fires in the early dry season tend to be less intense and severe and cause less damage.

Fuel management

Preventing wildfires in forests and open landscapes and within or at the interface of residential areas includes a range of measures for reducing the amount of combustible materials (fuels) that may ignite and contribute to the spread, intensity and severity of a wildfire. The most important fuels in forests are surface fuels (grasses, herbs, shrubs) that allow horizontal fire spread, and understorey trees and "aerial fuels" (dead branches and hanging foliage) that have the potential to become "ladder fuels," which allows the vertical development of a surface fire into a crown fire. The treatment of these fuels can be practised inside the forest stands to be protected, or in buffer zones (wildfire protection corridors / fuelbreaks).

Firebreaks

These are strips several to many metres wide, where all combustibles are removed and the soil is exposed. The width varies with fuel loads and the risk of fire jumping over the firebreak, which can happen even with those 25 m or wider. Creating and maintaining such large and unproductive strips of land is costly, and firebreaks on steep slopes are also susceptible to erosion.

Agricultural fuelbreaks

The concept of a fuelbreak is different. These are generally wide (up to several hundred metres), and flammable vegetation is modified so that fires burning into them can be more readily controlled. In the tropics, it has been successfully demonstrated that fuelbreaks can be maintained economically by having them integrate agricultural or agrosilvopastoral land uses that involve cultivation and the removal of aboveground biomass. The species to be planted depend on the site and climate conditions, but some basic principles should be observed.

Fuelbreak design must consider the need for growing crops, and flammable residues must be removed prior to periods of high fire danger. Growing millet *(Pennisetum glaucum*) on fuelbreak strips is an example. A staple food in much of Africa and Asia, the grain is usually harvested at the beginning of the dry season, and the highly flammable stems and leaves are left in the fields until the end of the dry season. In fuelbreaks, farmers must remove these crop residues before the start of the fire season. Other species suitable for agricultural fuelbreaks are creeping plants such as beans or groundnuts, which do not carry surface fire due to more frequent tillage and their low and spaced growth.

Community members with personal protective equipment and backpack pumps fighting a surface fire, Terai, Nepal. Photo: Sundar Sharma

Pastoral and silvopastoral fuelbreaks

Integration of grazing is another method of reducing the flammability of surface fuels on treeless strips (pastoral fuelbreaks) or on silvopastoral or shaded fuelbreaks with grazing under widely spaced trees. Grass could be natural or seeded, and prescribed grazing (Goldammer 1988) and browsing of brush and seedlings reduces the total fuel load. If grazing/browsing is selective, leaving certain species unaffected, cutting or prescribed burning will be necessary to reduce the fuel load. Pastoral fuelbreaks may include firebreaks such as small strips along each side; these are mandatory if prescribed fire is applied for maintenance. Shaded fuelbreaks are managed for livestock and timber, and possibly other tree products. Trees offer shade and shelter, improving animal welfare and performance. High pruning of the trees that removes fuel is necessary, and also increases the light available for grass growth and improves timber quality (and value).

Fuelbreaks without other land use

All combustible material must be cut by hand or machine and burned, removed or chipped and left on site. A compact layer of chipped fuels is generally less flammable than other fuels and any surface fire is easy to control. The use of prescribed fire on fuelbreaks follows the general concepts described below.

Fuel management inside forests

The choice of fuel reduction methods requires careful economic planning, as pruning, thinning and removal of understorey vegetation and other surface fuels are labour intensive. Costs can be reduced if the material is used by local people or sold; e.g., for fuelwood or woodchips. Fuels inside forest or plantations adapted to low-intensity surface fires can also be treated by prescribed fire (under-canopy = underburning) to reduce fuel accumulation (see below).

Fire suppression

Most advanced technologies for wildfire suppression have been developed in industrialized nations, and are less commonly used in tropical countries due to a lack of infrastructure, trained personnel and financial resources. It has been recognized, however, that most fire situations throughout the world can be successfully managed by experienced professional and volunteer firefighters, or by adequately trained community members. The success of ground crews depends on the availability of appropriate hand tools and personal protective equipment, and the provision of basic training in fire suppression and firefighter safety.

These are the most important techniques and most appropriate hand tools for each type of fire suppression:

1. Extinguishing surface fires by dowsing or beating, using fire swatters and backpack pumps (collapsible bags holding around 20 litres of

water, with a hand pump and nozzle, the simplest and most efficient, flexible and economical of all dowsing options).

2. Creating firelines or control lines (firebreaks made after a fire has started, to prevent its spread), using machetes, mattocks and similar tools for cutting and clearing vegetation and exposing the soil.
3. Setting tactical fires (also called suppression fires, backfires or counter fires, using drip torches or other means of ignition), which are very successful when applied by experienced fire teams. Many rural people in the tropics also have a lot of knowledge on how to use backfires, but these fires can be dangerous when they are started by people with no experience.

Fire safety training, including the use of backfires and prescribed burning techniques, must be mandatory for communities involved in any fire management activities.

Extensive information on fire suppression techniques is available from handbooks (e.g., de Ronde et al. 1990; Goldammer and de Ronde 2004), and from online resources for training firefighters. For example, the EuroFire Competency Standards and Training Materials, developed by the Global Fire Monitoring Center (GFMC) for training European fire and rescue service personnel, is now available in 22 languages (GFMC 2017b). It includes examples of and illustrations for the safe use of prescribed burning and backfires (Figure 1).

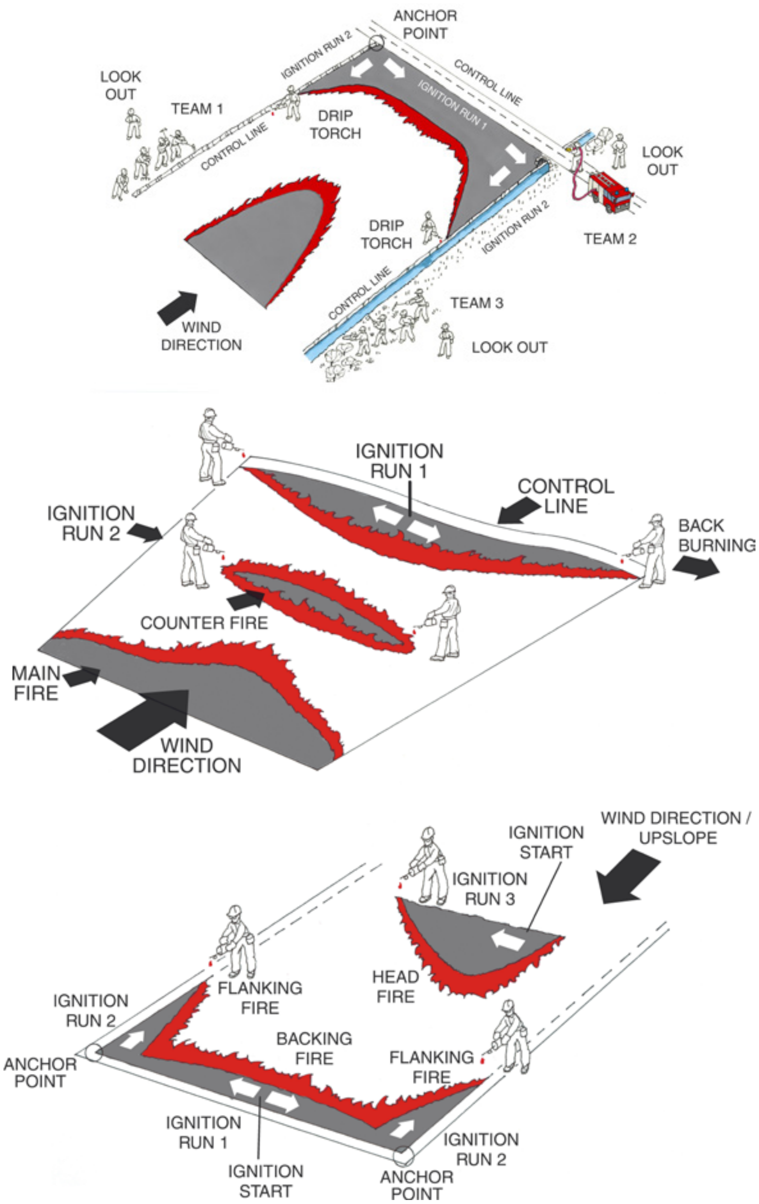

Figure 1. Examples of safe backfiring. Source: GFMC 2017b

Prescribed burning

Prescribed burning is the controlled use of fire to vegetation fuels under specific environmental conditions in order to create a fire of the desired intensity and rate of spread to meet a range of management objectives. It is also necessary where forests would otherwise be endangered by total fire exclusion, or by uncontrolled fires. In the tropics, prescribed burning is often called "early burning," and fires are usually set in the early dry season to prevent the risk of their becoming uncontrolled when vegetation is even drier.

Extensive expertise is available on prescribed burning in pine plantations (e.g., de Ronde et al. 1990) to meet various management objectives (Table 2). The main goal is to use low-intensity underburning of forests or plantations to reduce the accumulation of surface fuels, which greatly reduces the risk of damaging, high-intensity wildfires. Such fuel-reduction burns also speed up the recycling of nutrients from woody matter that would otherwise be slow to decompose. The interval between successive burns depends on the tree and understorey species, fuel accumulation rates, values at risk, and wildfire risk.

Table 2. Objectives for using prescribed fire in pine plantations

Objective	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 understorey	Reduce potential wildfire intensity and severity, remove surface and ladder fuels	Stand/tree damage (crown, bole or roots)	Partial removal (mechanical treatment 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 seed fall	Encroachment, sprouting, or germination of undesired plants	Partial removal (herbicides to kill undesired vegetation)
Improve accessibility	Thinning of post-harvest slash, rank understorey	Improve access for silvicultural operations, aesthetics (recreation)	Reduction of understorey stature	Partial removal (herbicides to kill undesired understorey)
Increase growth/yield	Raw humus layer (forest floor), understorey 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 and 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	Browsing or peeling of sensitive trees may jeopardize the concept	Mechanical removal of dead fuels and vegetation
Improve fire protection	Surrounding buffer zone, fuelbreaks and firebreaks	Reduce spread and intensity of wildfires (outside of stands)	Residents may miss shade and aesthetic values of trees nearby their houses	none

Adapted from Goldammer (1993a)

The safest technique for underburning plantations is using a fire that burns against the wind (backing fire), started along a downwind baseline such as a road or a plough line. The wind (at preferred speeds of 2–5 km/h) keeps flames bent over and cools the air above the flaming front, thus reducing the risks of crown scorch or crown fire. Relative humidity strongly influences the moisture content of fine fuels, which is the most important parameter affecting prescribed fire behaviour. For a successful burn, relative humidity should be 30–50% and the moisture content of the litter layer should be greater than 30–35% (de Ronde et al. 1990). Most of the experience in prescribed underburning is from pine and eucalyptus forests and plantations, but much of this expertise can be adapted to tropical deciduous and semi-deciduous forests. Extensive knowledge is also available in the use of prescribed fire to maintain or restore open savanna "fire ecosystems."

(a) Starting a prescribed fire in a Kenyan tree-grass savanna using a traditional ignition device; (b) Aerial view of the resulting fire, with roads as fire-breaks and an aircraft for safety patrols; (c) Equipped community members setting a backfire in a sal (*Shorea robusta*) forest, Nepal; (d) Prescribed underburning in a *Pinus taeda* plantation, Paraná, Brazil, after aerial fuels (dead branches, hanging needles) have been removed to a height of ca. 2 m. Photos: GFMC (a, b, d); Sundar Sharma (c)

Burning logging debris and managing smoke

Another application of prescribed fire in the tropics is for burning logging debris on forest land, before sowing crops or conversion to other land uses. This requires less experience as there are no standing trees that need to be protected, but the amount of wood to be burned is considerably higher than the biomass combusted by underburning. Precautions are needed to avoid fires escaping into other areas, and to prevent hazardous near-ground concentrations of smoke. Both risks can be controlled by using appropriate burning techniques and by observing the factors that influence fire behaviour, such as the spatial arrangement of fuels, fuel moisture, fire weather, etc.

There are two basic burning patterns for logging debris: broadcast burning (use of the ring fire technique, also called centre or circular firing), and pile or windrow burning. The ring fire technique is preferred as it reduces near-surface air pollution. The aim in piling logging debris before burning is to prolong fire residence time to ensure that large logs burn thoroughly. The use of heavy machinery, however, tends to add large amounts of topsoil to the piles or windrows. This makes the interior moist so that fuels hardly dry at all. Consequently, oxygen for complete combustion is lacking, resulting in a fire that can smoulder for weeks and that reduces near-ground air quality. In contrast, convection from the ring fire technique produces smoke columns into the atmosphere, but attention must be given to the risk of creating spot fires in adjacent fire-prone area from burning or from smoldering material that rises with the smoke.

Escaping fires can be prevented by constructing firebreaks around the area to be burned beforehand, and by using ignition patterns such as the ring fire technique that drive the fire into the centre of the burn area. The ring fire technique is useful in clearcut areas where a hot fire is desired in order to burn logging debris and unwanted vegetation as much as possible prior to planting. As with the backfire technique, the downwind control line is the first to be ignited. Once the baseline is secured, the perimeter is ignited so the flame fronts all converge toward the centre. Often, one or more "dot fires" are also ignited in the centre and allowed to develop before the perimeter of the burning block is ignited, to create in-drafts that help pull the outer circle of fire toward the centre, thereby reducing the threat of the fire escaping or of heat damage to adjacent areas.

Prescribed burning plans

Although detailed burning methods for tropical forests are not yet available, many principles and considerations of prescribed burning in pine and eucalyptus plantations can be used in planning. A successful prescribed fire is one that is executed safely, is confined to the planned area, burns with the desired intensity, accomplishes the prescribed treatment, and is compatible with resource management objectives. Prescribed fire planning should be based on the following six factors (de Ronde et al. 1990):

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 pre-burn environmental factors, expected fire behaviour, and foreseeable fire effects;
4. the existing art and science of applying fire to a site;
5. previous experience from similar treatments on similar sites; and
6. smoke impacts from a health and safety standpoint.

Prerequisite conditions

Safe fire management practices are fundamental, and to be truly effective they must be applied with community cooperation and follow national guidelines.

Effective community cooperation

Surveys of fire causes reveal that the most important reason for the careless use of fire is a lack of awareness of the economic and ecological benefits of forests and forest protection. It is also recognized that conflicts between forestry and agricultural land users can provoke careless and intentional setting of forest fires.

Tropical forest fire managers rely heavily on a positive relationship between the forests they manage and the people living and working in rural areas. Mutual confidence and public support are promoted through participatory approaches, and by employing local people, especially in fire prevention and wildfire hazard reduction measures such as establishing and maintaining firebreaks. Integrating agriculture and grazing into fuelbreaks (as described above) creates additional confidence and local participation through cost-free leasing of fuelbreak land to local farmers and livestock owners.

Other measures that stimulate cooperation in fire prevention are bonus incentives that provide funding for communities if no fire occurs on specific land during a specific time. These must be accompanied by targeted public information through the media, social media, schools, churches, etc. In addition, since the use of fire remains vital in many tropical land-use systems, fire management extension services must be established to provide information and training to communities on safe and controllable burning techniques that keep fires within intended areas and reduce the risk of accidents.

The concepts of participatory, community-based fire management are increasingly being applied in many countries. Background information, case studies and outreach materials can be found on the GFMC web site (GFMC 2017a), including the easy-to-read Guidelines on defence of villages, farms and other rural assets against wildfires: guidelines for rural populations, local communities and municipality leaders (Goldammer et al. 2013).

Fire prevention planning in a community in Mozambique. Photo: GFMC

National fire management policies and implementation plans

National fire management policies are an essential foundation for informed and coordinated fire management activities. These policies must address all vegetation types: natural vegetation (including forests and non-forest ecosystems), plantation forests, protected areas, wetlands and peatlands, agricultural land, pastureland (rangeland), abandoned (formerly cultivated) land, and vegetated land contaminated by industrial or chemical waste, land mines or unexploded ordnance.

To develop truly cross-sectoral, consent-based fire management policies, legislation, regulations and implementation strategies and plans, some countries have established national inter-agency fire management centres or advisory boards. To be effective, these must involve line ministries, other public institutions, and civil society organizations, including local communities, agricultural associations, land and forest owners, NGOs and volunteer groups. Relevant ministries and government agencies are those responsible for forestry, environment (for all issues potentially affected by fire, including climate change), agriculture (regarding fire use in farmland and rangeland), public health (to protect people from the adverse effects of smoke pollution), emergency planning (civil protection, fire and rescue services), foreign affairs (for trans-boundary fires, pollution and international protocols), and defence (for assistance in wildfire emergencies).

For policies, strategic planning and decision making to be effective, some key principles should be considered:

- **Evidence**: Use sound interdisciplinary scientific knowledge and consider technological capabilities and innovation, such the revival of traditional, benign land-use practices.
- **Inclusion**: Address fire problems at the landscape level by including and integrating all relevant institutional mandates and the contributions from civil society.
- **Coherence**: Harmonize the fire management mandates and activities of government institutions and other stakeholders with cross-sectoral national policies and implementation plans.
- **Cohesiveness**: Consider national fire management plans obligatory for individual institutional and sectoral planning and implementation.
- **Coordination**: Continuously monitor the implementation of actions under national fire management plans in a highly coordinated manner and make the results publicly available.

Themes to be addressed in national policies should include, but not limited to, the following.

- **Research, information and analysis**: Establish a national unit of competence in fire management to assist all participating agencies and other stakeholders in the joint implementation of policies; e.g., by creating a national fire management body or office.
- **Legal framework and institutional responsibility**: Review and update legislative and regulatory frameworks to define the responsibilities and obligations of government agencies and civil society (particularly local communities and individual land owners and land users) in fire management planning, capacity building, fire prevention, preparedness and response.
- **Reduction of fire hazard, risk and vulnerability, and prevention of fires**: Systematically implement technical fire prevention measures in forest, agricultural, pastoral and abandoned land. Prioritize public awareness of the negative consequences of fires and the need for active participation in fire prevention, notably by local communities in fire-prone regions in order to defend their assets against fires.
- **Preparedness (provisions to improve fire response and safety)**: Provide appropriate training for firefighters and other personnel from agencies responsible for forest fire suppression, including volunteers, to ensure their competency, efficiency and safety. Establish wildfire early-warning systems to provide and disseminate warnings of high fire danger and thus allow for preparedness and early alerts at local and national levels.
- **Response (wildfire suppression)**: Ensure that specialized forest fire suppression units and sub-units are available in areas of high fire risk and that they are appropriately equipped. Land management authorities (e.g., agencies responsible for forestry, protected areas and agricultural land) must provide budgets for training and equipping specialized fire management teams in areas of high fire risk.
- **Post-fire measures**: Reduce the threat and consequences of secondary wildfires effects, such as erosion, lack of regeneration potential, reduction of water-holding capacity, increase in surface runoff and risk of flash floods, mudslides, landslides and rock falls.
- **International cooperation in fire management**: Share knowledge of fire science and management, and actively participate in regional and global networks to ensure that countries take advantage of international state-of-the-art expertise.

Conclusions

Complex and ambiguous phenomena and problems are associated with fire use and wildfires affecting tropical forests, and other ecosystems and land-use systems. The socioeconomic and cultural conditions in tropical environments are decisive in shaping fire regimes. Managers of forests and other land resources throughout the tropics are facing tremendous pressures posed by humans, the climate crisis and fire.

This article provides a basis for understanding fire-induced processes, and for the need to develop adequate fire management concepts and implementation strategies, highlighting basic processes, phenomena and solutions. These are challenges for decision makers, while the complexity of interactions between land use and other human activities, tropical vegetation characteristics, climate and climate change may also mean that decision makers require expert assistance in capacity building for fire management at local and national levels.

In addition to publishing fire management guidelines and textbooks, the Global Wildland Fire Network is available to provide assistance, through 14 regional networks and eight regional fire management resource centres (GFMC 2017e). Four of these operate in the tropics: East Africa (based in Madagascar), West Africa (Ghana), Southeast Asia (Indonesia), and South America (Brazil). In conjunction with the International Wildfire Preparedness Mechanism (IWPM), the centres facilitate exchange of knowledge and expertise in fire management, both within regions and globally (GFMC 2017e).

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