Forest Fires (Prediction, Prevention, Preparedness and Suppression)

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Introduction

The problems and negative impacts associated with large-scale uncontrolled forest fires have increased worldwide over the past two decades. Globally an estimated 300–400 million hectares of forests and woodlands burn annually, emitting an estimated 9.2 billion tonnes of greenhouse gases; however, fire is a vital and natural part of some forest ecosystems, and a multitude of plants and tree species have become fire-dependent. In the early 1990s global changes had reached proportions that led to the global meeting in Rio de Janeiro (Earth Summit, 1992). Changes in the global fire dynamic and an increase in weather disturbances like El Niño have now created a growing awareness that fires are a major threat to many forests and their biodiversity therein, directly contributing to the climate change process.

In particular, tropical rainforests which were thought to be resistant to fires are now experiencing large-scale fires because of unsuitable silvicultural management practices. Globally 95% of all fires originate from various human activities; therefore these activities can be predicted and to some degree prevented well in advance. The difficulty lies in predicting and minimizing the impacts of the remaining 5% of all fires which are mostly caused by lightning.

There is therefore a need to develop proactive fire management strategies aiming at preventing fires from happening, i.e., allowing for the use of fire in useful or 'good' fires, but preventing destructive or bad fires (wildfires) from starting.

Fire preparedness includes a variety of activities with the aim of improving the capabilities to react in case of fire (reactive fire management strategies). Fire preparedness may have a totally different connotation depending on the country concerned.

Fire suppression or firefighting is the procedure or activity of mitigating the results of fire that already has started.

The fire itself consists of three separate components (oxygen, heat, and fuel) which are joined together. If any one of these components is removed, a fire will die.

The last step in extinguishing a fire is called mopping up, which ensures that the fire is dead and can no longer spread. After the fire is removed, the first silvicultural aspects can start, with the aim of rehabilitating the burned forest.

Background to Fire Management

The problems and negative impacts associated with large-scale uncontrolled forest fires have increased worldwide over the past two decades. By far the worst forest fires in recent times, in an economic sense, occurred between 2000 and 2003 in Australia and in the USA. However, the worst fires from an environmental, ecological, and climatological point of view took place between 1997 and 1998 when millions of hectares burned and smoke blanketed large regions of the Amazon basin, Central America, Mexico, and South-East Asia. Estimates suggested that these fires had an adverse impact on as much as 20 million hectares of forests worldwide, contributing to an estimated 13–40% of annual global carbon emission of fossil fuels, primarily through the burning of deep peat soils in South-East Asia. (Peat is a renewable natural resource which will start to replenish once the water table level of the burned area is returned to the level preceding the drainage.)

Global Warming

Contributors to the increase in global warming are found in deforestation, in shifting cultivation and land use changes which normally account for 20% of annual global carbon dioxide emissions.

Globally an estimated 300–400 million hectares of forests and woodlands burn annually, emitting an estimated 9.2 billion tonnes of greenhouse gases; however, fire is a vital and natural part of some forest ecosystems, and a multitude of plants and tree species have become fire-dependent over the last 15 000 years, due to human-induced fires.

Historical Use of Fire

Fire has been a part of the natural landscape for millions of years, forming these landscapes long before human beings arrived. The use of fire by hominids is thought to be 1.5 million years old. During the early period of human use of fire, fire was mainly developed to protect humans; later, fire was refined into a formidable weapon in hunting by perfecting techniques of prescribed or controlled burning. The Aborigines of Australia have skillfully been using controlled burning in northern Australia over an annual area of 30 million ha for more than 40 000 years to maintain the health and vigor of certain ecosystems, to produce seeds, to hunt, for signaling, and for warmth.

Expansion of the Concept of Fire Management

There is a growing awareness that fire needs to be managed at an ecosystem level. Forest fire management is a narrower concept, referring to the management of fires confined to forest areas; however, the majority of fires which currently destroy forests are caused by fires outside forests that spread into forests. Restricting fire management activities to forests is one reason why fire has become an escalating problem and a strong threat to present efforts in sustainable natural resource management.

Global Changes

The increasing global problem of wildfires (fires burning out of control) was first recognized in the early 1970s, when rapid population growth was experienced throughout the developing world; wildfires started to destroy forest vegetation and biomass, resulting in considerable soil erosion by wind and water.

Previously, fire had been used in shifting cultivation, with people frequently moving from one site to another, allowing for fallow periods between cultivations. However, due to population growth, this was no longer possible, and people developed semipermanent agriculture, coupled with traditional annual burning. In parts of Africa, the fire cycle was reduced from once every 10 years to an annual event. Most ecosystems, despite being adapted to fire, could no longer be sustained due to the drastic changes in fire frequency. Fire-adapted ecosystems have adapted to 'fire regimes' that are spaced out over a period of many years to allow for natural regeneration of the forest. If no fire occurs in these ecosystems, then many woody species do not regenerate, and frequent fires can destroy regeneration.

Fire and Food Security

In the savanna ecosystem, where 50% of all global fires occur, the importance of managing fires primarily centers on food security for local people rather than on the traditional concern to protect forest resources in the form of timber and wood products. The hundreds of millions of people living in this environment are traditionally called farmers, and yet they are using hundreds of different non-wood forest products (NWFP) for their daily survival, particularly in the poorest households.

Any uncontrolled fire occurring in this forest environment immediately results in local food shortage. The above areas, where forests are providing a large share of the local food, are largely devoid of global forest as well as fire data (**Figure 1**).

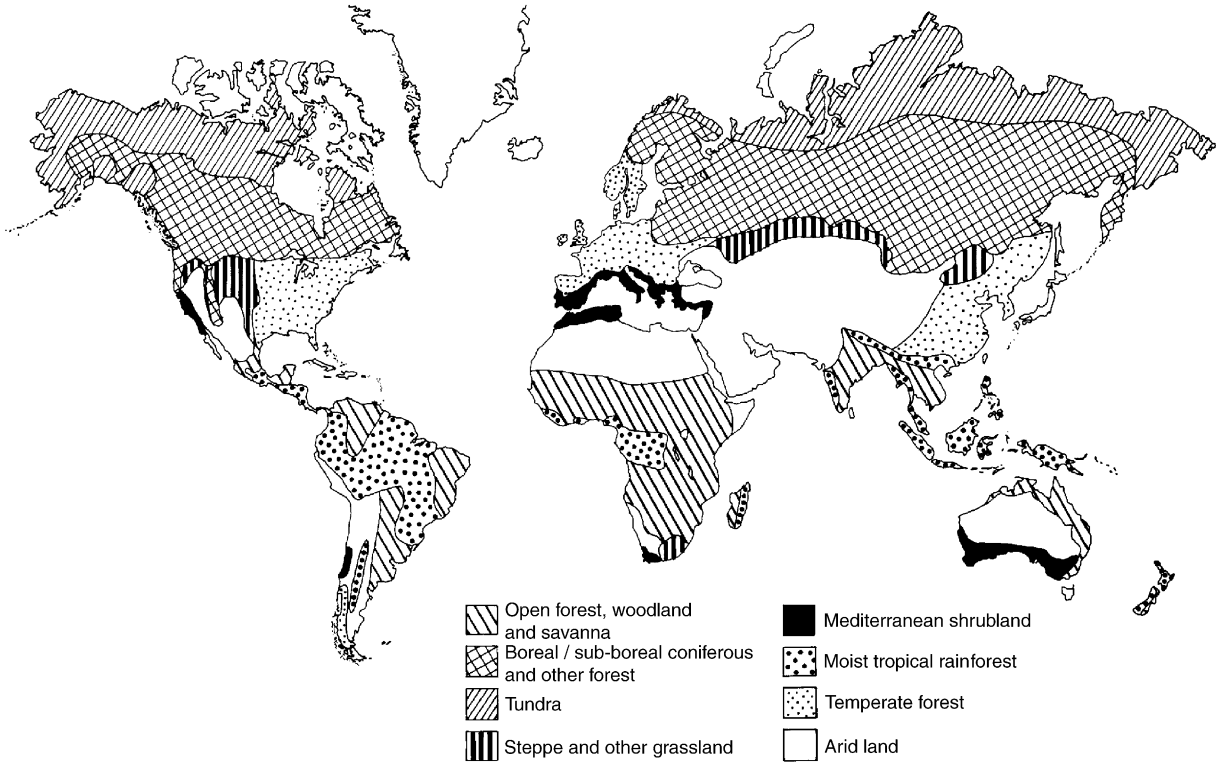

Figure 1 Patterns of fire: a map of global fire data. Source: Global Fire Monitoring Center (GFMC).

Fire Regimes

Fire regimes consist of three factors: fire intensity (severity), fire frequency (how often), and fire season (time of year). For example, the natural cycle of fire in southern Africa is 12 years, decreasing to 8 years towards equatorial Africa. The present almost annual widespread burning has already severely damaged many forest ecosystems in southern Africa, degrading them to bushland and gradually to open eroded seasonal grasslands.

Extensive fire research carried out for more than 45 years in Kruger National Park in South Africa and several other sites confirms the above assumption. The use of fire (silvicultural prescribed burning) needs to be more widely spaced out than the present 7-year cycle applied in the parks and other protected areas to maintain the natural composition of species.

Population Growth

Simultaneously, with the population growth in developing countries, other global changes in the shape of rapid industrialization also took place, resulting in severe industrial pollution and in the extended use of fossil fuels.

The combined effect of these trends resulted in a rapid increase in greenhouse gas emissions which in turn gradually started to change the traditional global weather patterns. This had a negative impact on human life and natural resources, affecting landscapes and livelihoods, causing haze pollution and deposition of unwanted pollutants, drought, insufficient food and widespread flooding.

In the early 1990s global changes reached proportions that led to the global meeting in Rio, Brazil. Changes in global fire dynamics and an increase in weather disturbances such as El Niño have now created a growing awareness that fires are a major threat to many forests and their biodiversity, and directly contribute to the climate change process.

Fire Prediction

Fire prediction used to be an activity carried out by the meteorological institution in each country; in a number of countries it is still the main source of fire information. However, in many countries the national weather service does not have the necessary facilities and field measuring points available for full coverage of the entire country, nor the communication equipment needed to relay information to the central unit. In these cases, fire predictions should be based on the existing database on local fire occurrence.

Silvicultural Factors Contributing to Changes in Fire Prediction

Tropical rainforests, in particular, which were once thought to be resistant to fire, are now experiencing large-scale fires due to unsustainable management practices. Contributing factors include:

- forest operations often prepare for a ready access into the forest in the form of immigration
- lack of management and protection of the forest after harvesting operations
- accumulation of forest debris after logging.

Temperate forests in the USA and eucalyptus forests in Australia, where controlled fires were deliberately suppressed for management and political reasons, are now experiencing devastating wildfires due to an unnatural accumulation of fuel exacerbated by extreme weather conditions. Large-scale fuel reduction programs are now underway in many regions to reduce the potential risk and severity of fires, especially in urban interface areas.

Human-Induced Fires

Globally, 95% of all fires originate from various human activities; these activities can be predicted and to some degree prevented well in advance. The difficulty lies in predicting and minimizing the impact of the remaining 5% of natural fires which are mostly caused by lightning. Predictions of lightning fires can also be made by special sensors measuring all lightning strikes; in recent fires in Australia more than 50 fires caused by lightning were burning simultaneously in Victoria.

Fire Danger Rating

Fire prediction is generally based on an approved national forest fire danger-rating system (FFDRS). The most widely applied system globally is the Canadian danger rating system which consists of two subsystems, fire weather index (FWI) and fire behavior prediction (FBP). Whilst weather application with current remote sensing facilities is quite accurate, FBP is still largely unknown in determining fire danger in many countries. Therefore the international fire community is presently carrying out extensive research in this area to develop reliable prediction systems. Another global dilemma soon crops up once fire prediction is accurately carried out; is the predicted fire a so-called 'good' fire that should be allowed to burn, or is it a 'bad' fire that should be extinguished? The Canadian FFDRS allows for 'let burn' decisions to be made by fire management due to low population densities in some geographic areas.

Fire Prevention

Since 95% of all global fires are caused by human activities it is clear that fire prevention strategies can play a key role in mitigating the global fire situation. There is a need to develop proactive fire management strategies aimed at preventing fires from happening, i.e., allowing fire to burn in useful or good fires, but preventing destructive or bad fires (wildfires) from starting and spreading.

Experience from a number of countries shows that fires cannot be prevented by tightening laws and regulations or by increasing supervision. Sustainable solutions require the ownership of local people in managing fires, including incentive schemes to assist the country in reducing wildfires.

Very little information and research exist about the reasons for forest and biomass fires; natural fires apart, it is difficult to prevent fires if the reasons why these wildfires occur are not known.

Efficient and effective fire prevention work requires networks to be established at global, regional, and national levels to exchange information on best practice raising awareness and training of multiple level and sectoral stakeholders.

Initial Steps in Fire Prevention

The work on forest fire prevention starts by finding out why wildfires burn; when the reasons are ascertained, then strategies for fire prevention can be prepared. Without knowing the reasons for burning, no effective awareness program can be developed, and it is impossible to direct the awareness program to the right target population (such as children, women, men, farmers, hunters, beekeepers, tourists, campers).

There are a variety of reasons why wildfires appear; more often than not, it is a question of ownership or proprietorship of the resource base – land or crop tenure rights can differ between formal laws and customary (traditional) laws. Success points to local management of forest and vegetation fires incorporating the transfer of 'fire ownership' (including land-use rights) from the government to local communities or villages. The term 'fire ownership' implies that, instead of being a top-down government law enforcement activity, fire management becomes a local activity in which fire is used daily as a management tool by the local population.

Integrated (Forest) Fire Management

Transfer of forest fire ownership needs to be coupled with an integrated forest fire management (IFFM) approach, in which a variety of stakeholders each have their agreed roles and responsibilities in managing fires.

The traditional role of agriculturists lighting fires and foresters extinguishing them no longer applies, yet this is still the approach in many countries.

IFFM requires stakeholders to have their agreed roles in fire prevention. At a national level there is a need to involve several ministries outside agriculture, forestry, and the environment, primarily the Ministry of Education and Ministry of Health. The entire population needs to be educated about the environmental functions of trees and forests, about their interdependence with rainfall, soil erosion, harvesting, and global climate. In addition, education and training are needed on the safe use of fire for a multitude of activities, primarily related to managing land and vegetation clearing.

Incentive Schemes

Incentive schemes in managing vegetation and forest are always coupled with the development of methods in how to quantify (in financial terms) the motivation and benefits for local people to participate in managing fires. In the savanna ecosystem, where 50% of all global fires occur, the importance of managing fires primarily centers on food security for local people rather than on the traditional concern to protect forest resources in the form of timber and wood products. These people are using hundreds of different NWFP for their daily survival, particularly the poorest households. The use of prescribed (controlled) fire to protect their resources is a sufficient incentive for the local population to manage their fires. In other parts of the world, people appreciate clean air, scenic beauty, or clean water as an incentive for managing fires, while others appreciate a safe environment surrounding their home, as in the USA lately.

Preparedness

Fire preparedness includes a variety of activities with the aim of improving the capability of reacting in case of fire. Fire preparedness requires the development of reactive fire management strategies.

However, fire preparedness may have a totally different connotation depending on the sociocultural and economic situation at the site of the fire. The preparedness also depends on whether the local people are using fire as a management tool in their daily lives or whether the fires in the area are caused by lightning, as two examples below illustrate.

In the USA

Fire preparedness at a district level may mean that budgets have been approved, funds allocated,

staff trained, equipment tested, fuel reductions carried out, firefighters are on standby, the daily fire danger rating is monitored, and the general public have been informed about the fire weather. Satellite and aircraft are being used to monitor and detect any fires at the National Emergency or Alarm Centers. In addition cross-border collaboration agreements have been prepared and signed with a number of countries, such as Canada, Australia, and New Zealand; of annual operating plans/guidelines with these countries have been revised and signed.

In Namibia

The same preparedness at district level means that local communities have been applying prescribed burning or overgrazing using of cattle in strategic areas. Fuel breaks have been constructed in other areas, e.g., around local schools; the traditional chief or leader has been informed about the intention to burn a grass sward around the riverbank at road crossings. Locally, all farmers know the fire weather; additional training means that they understand the implications of fire weather and the skill of using fire in a controlled way, considering the local fire behavior and depending on the type of burn envisaged. Fire detection is generally carried out by local farmers gathering various NWFPs in the forest or herders moving their herds through the silvopastural areas. IFFM approaches mean that the local Council of Chiefs (Khuta) has been informed about the plans to burn some parts of the communal pasture areas at road crossings, thus expanding the activities (from silvicultural forest fire management) to silvopastural fire management. Traditional leaders in neighboring Botswana have also been informed about forthcoming planned burns.

Fire Suppression

Fire suppression or firefighting is the procedure or activity which mitigates the results of a fire that has already started.

Fire consists of three combined components (oxygen, heat, and fuel): removing any one of these components will kill a fire.

In forest fuel the principal inflammable component is carbon. The reaction is expressed as: carbon plus oxygen gives carbon dioxide plus energy ($C + O_2 = CO_2 + \text{heat energy}$).

Suppression (combating fire) can be subdivided into tactics and techniques.

Tactics

Once remote sensing or aerial detection data and images/pictures have been analyzed it is time to start developing the tactical approaches to combat the fire.

Tactics describes how to use human resources, and equipment in the right place at the right time; techniques refers to the technical application in a given fire situation (handtools, pumps, water, foam, aircraft, etc.).

The tactics for extinguishing the fire depend on the resources at hand; it is difficult to remove or reduce oxygen, but it may partly be done. Air contains 21% oxygen; if this proportion is reduced to 15%, it will extinguish the fire. This is most commonly done in the case of light fuels whereby burned gases from the fire are fanned back towards the fire using a fire swatter, thus reducing the oxygen mix; or it may be done by putting sand or soil on top of fire. These methods both remove oxygen and remove heat (applying cold soil onto the source of the heat).

Heat is removed by applying a coolant, usually water, on to the fire; once the heat drops below 220–250°C, the fire will be extinguished.

Fuel can be removed in advance by applying prescribed burning or by other means, or during the fire by manual or mechanical means or by 'back-burning,' i.e., removing the fuel as well as oxygen in the face of the advancing fire.

Tactics will select the combination of activities that together will extinguish the fire. In industrialized countries, fire suppression methologies are well developed, including the use of aircraft, the use of chemical fire retardants mixed with water, and heat-spotting cameras. All these technologies require a high level of sophistication, heavy investment in equipment, and targeting the removal of heat.

In many tropical countries, especially developing countries, the peak fire season usually coincides with a water shortage. Therefore fire management is directly coupled with fuel management, using fire to remove fuel as well as extinguishing fire by lighting another fire. This involves concentrating on removing the fuel as well on a small-scale removal of oxygen, which again is only possible in light fuels.

Incident Command System

In the case of a fire accident or natural cause of fire, a reactive fire management strategy is needed to suppress these fires. Fire suppression is the straightforward action of killing the fire as fast and efficiently as possible.

Therefore it also resembles a military command system; the most efficient system developed for forest fire control is the so-called incident command system

(ICS) which may also be applied to all other kinds of national emergencies whether involving just a few or thousands of people.

Techniques

Firefighting aims to stop the running edge of the fire either by constructing a fire break (a line where all burnable material has been removed) or by applying water or a foam mixture to reduce the surface tension of water droplets for easier penetration into the soil or biomass layer (the same principle as used in dish-washing detergent).

The attack towards the fire may be direct or, if this tactic is not possible, the fire may be attacked indirectly from the flanks of the fire to narrow the moving fire edge. The fire may also be extinguished using another fire either to consume the fuel or the oxygen in front of the advancing fire; this technique is also called backfiring or backburning.

Mopping up

Mopping up is the last step in the process of extinguishing the whole fire. It may also imply that the fire in most of the area surrounding the burning spot is contained in such a way that the fire can no longer escape.

The size of the area to be mopped up depends on the fuel as well as on the location of any smouldering fires in relation to the perimeter of the area.

The failure or success of the entire fire suppression operation may depend on the quality of the mopping-up operation; in addition this may require lengthy patrolling of the burned area, even weeks or months after the initial fire was burning.

Once the fire is 'killed' and the danger is over, one may begin to plan the silvicultural rehabilitation of the burned area.

See also: **Ecology**: Human Influences on Tropical Forest Wildlife. **Environment**: Impacts of Elevated CO_2 and Climate Change. **Landscape and Planning**: Perceptions of Nature by Indigenous Communities.

Further Reading

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