FOREST FIRE MANAGEMENT MANUAL

Ministry of Environment, Forest and Climate Change

Himachal Pradesh Forest Department

german cooperation
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HP-FES

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Smoke rising from surface fires in the forest of Himachal Pradesh

Contents

	Page Number
1. Introduction	1.
2. Background	5.
2.1 Forest fire	5.
2.2 Types of forest fires	7.
2.3 Factors affecting forest fire	13.
3. Impact of fire on forests	17.
4. Human use of fire that results in forest fires	31.
4.1 Human-caused forest fires	31.
4.2 The results of accidental fire	34.
5. Fire management	39.
5.1 Fire prevention	39.
5.2 Development of fire management strategy with communities	45.
5.3 Fire suppression	50.

CONTENTS

1. Introduction

Figure 1.1: Almost no other tree species can establish in pine forests that are burned regularly. Such pine forests are gradually transformed into fire savannas.

Intentional fires are the main factor degrading forests in India. They can cause already degraded forests to degrade even further. In most cases they keep forests from developing into denser and more diverse formations. Frequent fires only allow those species to grow which are fire adapted. Furthermore, fire alters soil fertility and increases its susceptibility to erosion.

Forests provide us with many services called Forest Ecosystem Services (FES). Some of these services are obtained with the help of fire (e.g. maintaining grazing areas and some NTFP). However, in many instances, fire has a detrimental effect on important FES like water regulation and erosion control. Therefore, the management of forest fire must be made a priority if we want to optimize the full potential benefits forests can provide us.

Figure 1.2: If fires are prevented for about 100 years in pine forests, fire sensitive oak and other broad-leaved trees and shrubs can establish during this time. However, the pine component will be lost.

This training manual, developed by the Forest Department of Himachal Pradesh and GIZ, is designed to guide forest managers how best to manage forest fires. It not only includes technical aspects of fire management, but also the steps that need to be taken to manage social drivers behind intentional forest fires.

2. Background

2.1 Forest Fire

For a forest fire to occur there must be three elements present. If one of these elements is removed a fire will go out.

- **Oxygen** normal air contains 21% oxygen enough to sustain combustion.
  - Small fires can be smothered with a blanket, by shoveling dirt on them or by using a fire extinguisher which use either smothering foam or retardant to put out a fire
- **Heat**
  - A heat source is needed to ignite (e.g. a match) and to sustain the fire combustion process. (enables the fire to spread)
  - Add a substance, most often this is water, to reduce the heat and the fire will go out.
- **Fuel**
  - Flammable (burnable) material
  - Remove the fuel manually or mechanically ahead of the fire
  - Without fuel a fire will stop

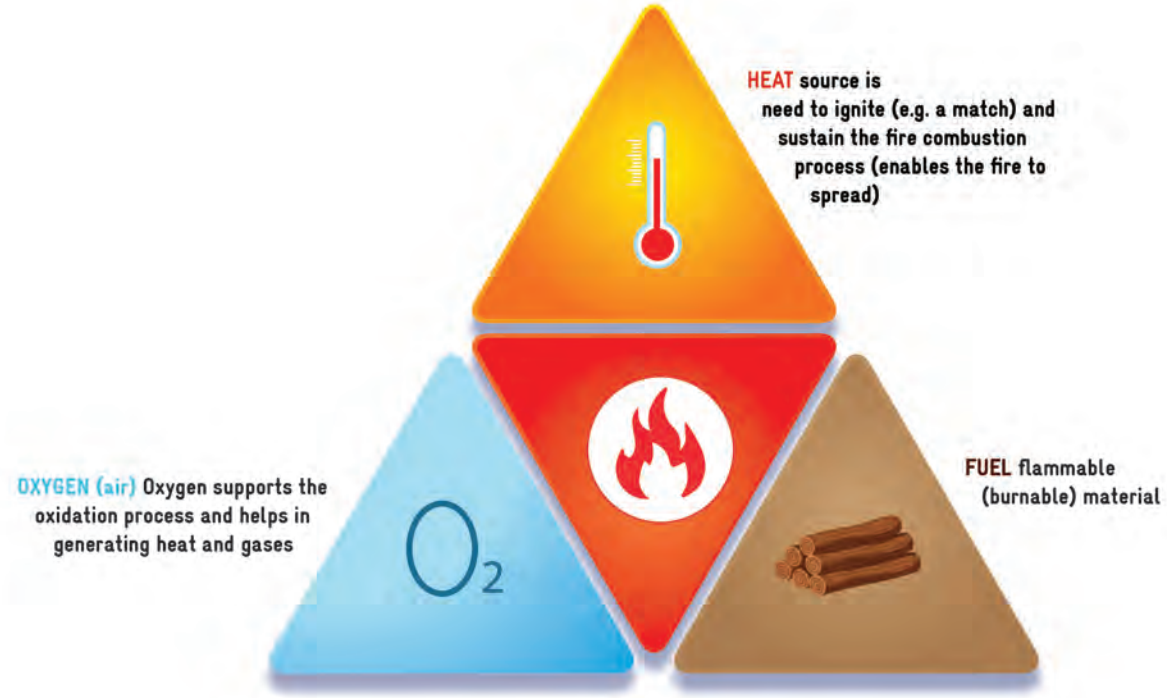


Figure 2.1: The Fire Triangle

2.2 Types of Forest Fires

Forest fires are commonly referred to by the class of fuel (ground, surface, or crown) in which they are burning. Having an understanding of the different types of forest fires is crucial because each fire type requires different suppression methods. There are generally three types of forest fire

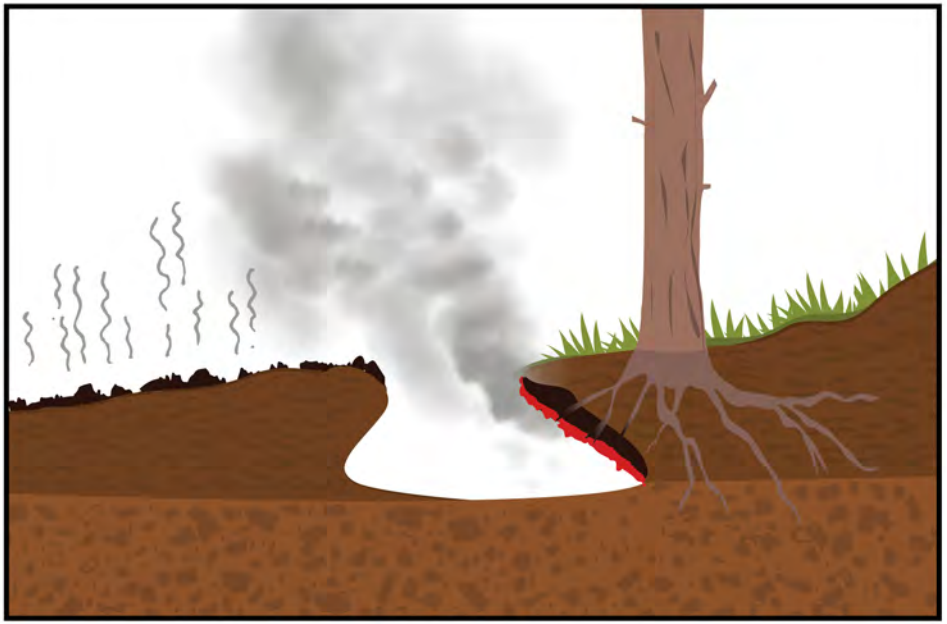


Figure 2.2: Ground Fire

Ground Fire

A ground fire burns sub-surface organic materials (humus, peat, roots, dead vegetation) under the surface litter. Characteristics include:

- Fires may smoulder (burn very slowly), and go unnoticed for weeks or months, especially during prolonged drought.
- Are difficult to fully put out and could potentially emerge at the surface and re-ignite surface fuels.

Figure 2.3: Surface Fire

Surface Fire

A surface fire involves the burning of fuels on the forest floor surface like litter, woody debris, grasses or shrubs, or other vegetation at or slightly above ground level. Characteristics include:

- The most common fire type
- Fire behavior can vary from very low to extreme
- Heavily influenced by the forces that drive fire behavior (weather, fuel and topography)

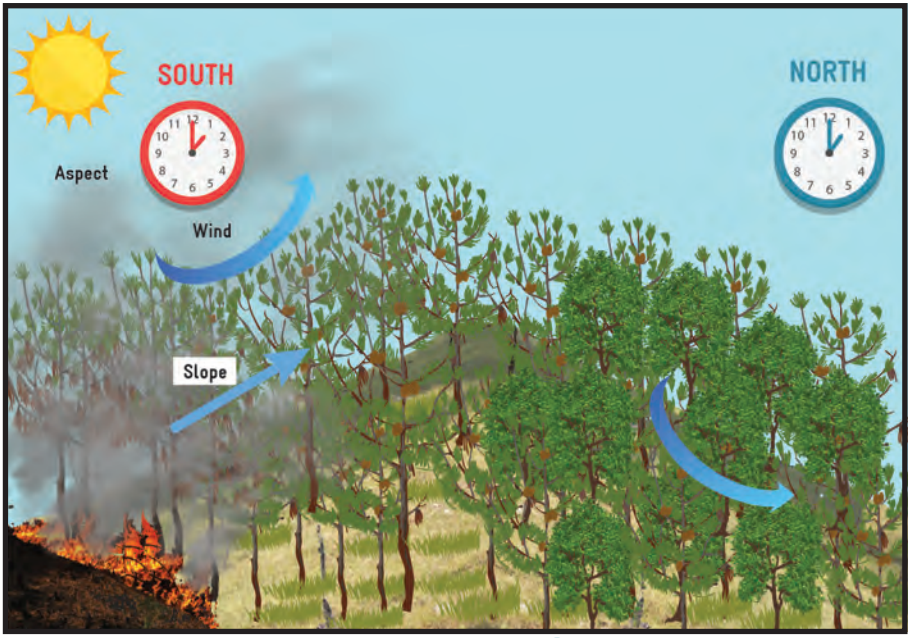
Figure 2.4: Crown Fire

Crown Fire

A crown fire burns in the tree canopy and spreads from tree top to tree top, above and ahead of an intense surface fire. Convective and radiant heat from an intense surface fire will ignite the treetops and result in a crown fire that burns independently of the surface fire. Characteristics include:

- Display the most extreme form of fire behavior, fastest moving type of forest fire and highly destructive and difficult to contain.
- Intense surface fire will follow shortly after the passing of a crown fire.
- Spot fires ignite outside the perimeter of the main fire, may appear in great numbers and some may occur in advance of the main fire.
- May only travel short distances, need heavy fuel loads, fuel continuity, and strong winds.

2.3 Factors affecting forest fire



Very high risk and severity at indicated time

High risk and severity at indicated time

Figure 2.5: Time of risk of fire

Fire behavior is influenced by how fuels, weather and topography interact.

Wind

Wind plays a critical role in determining fire behaviour. Wind directly affects the fire spread and its direction. A strong wind will result in an intense and fast moving fire. It supplies oxygen (air) to the fire which causes the fire to burn at a greater intensity and it will bend the flames over the fuels ahead of the fire increasing the rate at which they dry out and ignite. Wind also lifts burning embers and ash ahead of the main fire causing new fires (spot fires).

Slope

A fire burning upslope preheats the fuels ahead of the fire at a faster rate than on level ground. The steeper the slope, the greater this affect. The opposite is true for a fire travelling down slope.

Aspect

The aspect of a slope is the direction it faces – north, east, south or west. Aspect affects fire behaviour in two ways:

- **Drying effect**

  A south facing slope will receive more sunlight over the course of the day which will dry out the vegetation more quickly. In contrast, a north facing slope will receive less sunlight over the course of the day and vegetation will remain moister and cooler. As a result, fire behaviour will be more intense on south facing slopes than on north facing slopes. The drying of fuel on eastern and western slope is similar to northern slopes (peaks at 9 am) and southern slopes (peaks at 6 pm) respectively. So, it is important to know that the maximum heating effect varies with the time of day and the direction the slope is facing. For example, when a fire is expected to arrive at a west facing slope in the late afternoon, fire intensity will increase and the method of extinguishment must be adapted.

- **Vegetation effect**
  The type and amount of vegetation on a site is mostly determined by climate and soil factors, but the aspect-fire relationship cannot be ignored. South facing slopes will generally be sunnier, drier and warmer and therefore be more prone to fire than northern slopes. Thus, the vegetation on south facing slopes will be more sparce due to effect of fire, than on north facing slopes which burn less often as they are cooler and wetter. The vegetation on these north facing slopes has a greater chance to grow thicker.

If all the factors that promote fire come together in a fire, the fire is said to be in alignment.

3. Impact of fire on forests

Figure 3.1: Pine forest directly after burning

Forest fires are naturally occurring in many forests worldwide. They can play a key role in shaping ecosystems by serving as an agent of renewal and change. But fires can be deadly, destroying homes, wildlife habitats and resources, and polluting the air with emissions harmful to human health. Fires may also cause the degradation of the soil by decreasing its water retention capacity, increasing the rate of soil erosion and the loss of nutrients. The blackened soil surface increases the surface temperatures because the blackened surface, without vegetation heats up more easily which affects the microclimate. Additionally, fires release carbon dioxide—a key greenhouse gas—into the atmosphere.

Importantly, fires that damage or destroy forests are unable to sequester optimal amounts of carbon dioxide and forests that are regularly burned are less structured and biodiverse than those forests not burned regularly.

Destruction of foliage

Trees have survived a surface fire by insulating bark, but the released heat has scorched the lower canopy and reduced the capacity for photosynthesis.

Figure 3.2: Destruction of foliage

Figure 3.3: Top-kill understory vegetation

Understory vegetation top-kill due to surface fires

Young understory trees and shrubs are often killed fully or partially by a surface fire. Some species have the capacity to re-sprout from surviving roots or the lower stem. Some species retain this capacity even after very hot fires and they consist only of a few live shoots and the old, burned branches (see picture). The next fire may burn the old branches fully and any new living branches and sprouts are killed. If fire reoccurs very often, e.g. several times in a year or year after year, even fire tolerant species will not be able to survive because the resources necessary to re-sprout become depleted by having to re-sprout repeatedly. Plants, that do not have the capacity to re-sprout, die much sooner (after one intense fire) leaving only those plants that can re-sprout to survive.

Figure 3.4: Destruction of fire sensitive trees and regeneration

Fire intolerant species and tree regeneration

Regular forest fire selectively kills those species which are fire sensitive while those resistant to fire remain. This is clearly seen in Pine-Oak forests of the Western Himalayas. Pine trees regenerate in open areas and are fire resistant while oak preferably grow under a tree canopy with lower levels of light. Oak are fire sensitive thus, regular fires prevent oak species from regenerating and establishing. Pine trees are fire resistant and have a higher probability of regenerating under high fire frequencies if sufficient light is available. Therefore, regular fires remove oak from pine forests, resulting in pine monocultures. Once the regular fires are stopped, oak and other fire sensitive tree species will germinate and establish in pine forests.

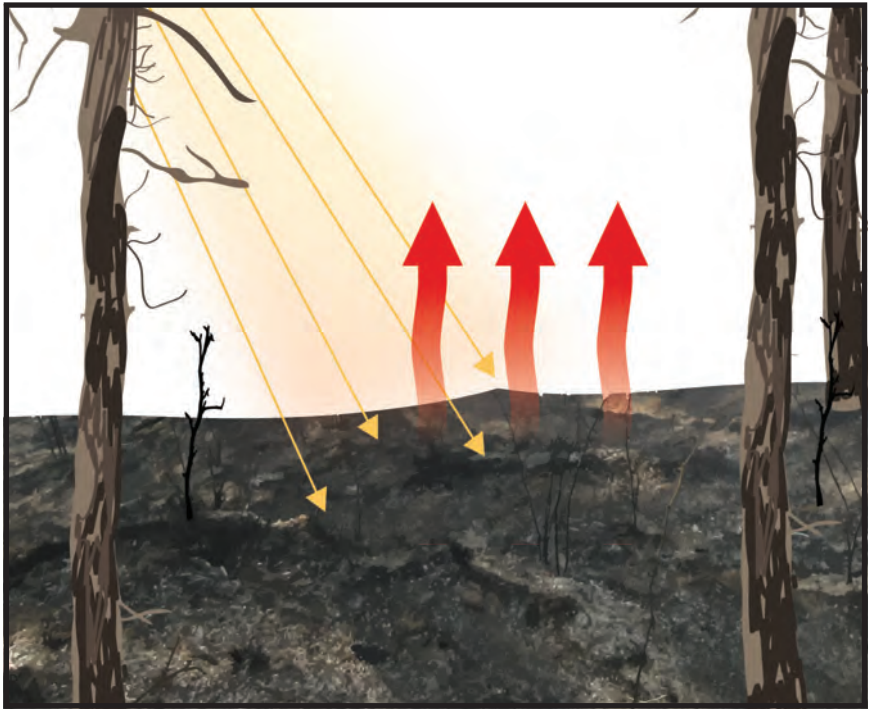


Figure 3.5: Change in microclimate

Change in microclimate

Trees, shrubs and herbs shade the forest floor, lower the wind speed and release water through their leaves to the air (evapotranspiration). This creates a microclimate that is a bit more humid and cooler than outside the forest. The removal of some tall trees and low growing plants by fire causes changes to this microclimate. The humidity is lowered and the forest floor surface heats up more easily. These new conditions allow for only a few species like pine trees and grasses to grow here. For most of the broad-leaved trees, such an environment is unfavorable. If the fires are not regular, the fire sensitive plants are able to return and with them the cooler and humid microclimate re-establishes.

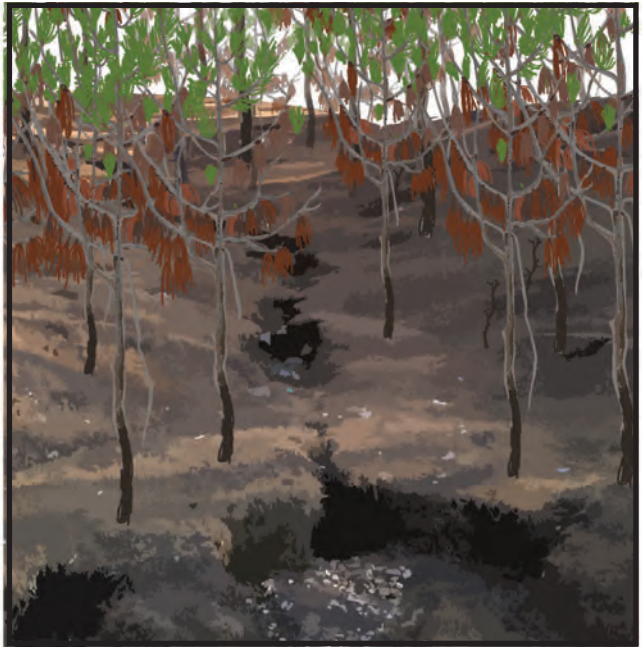


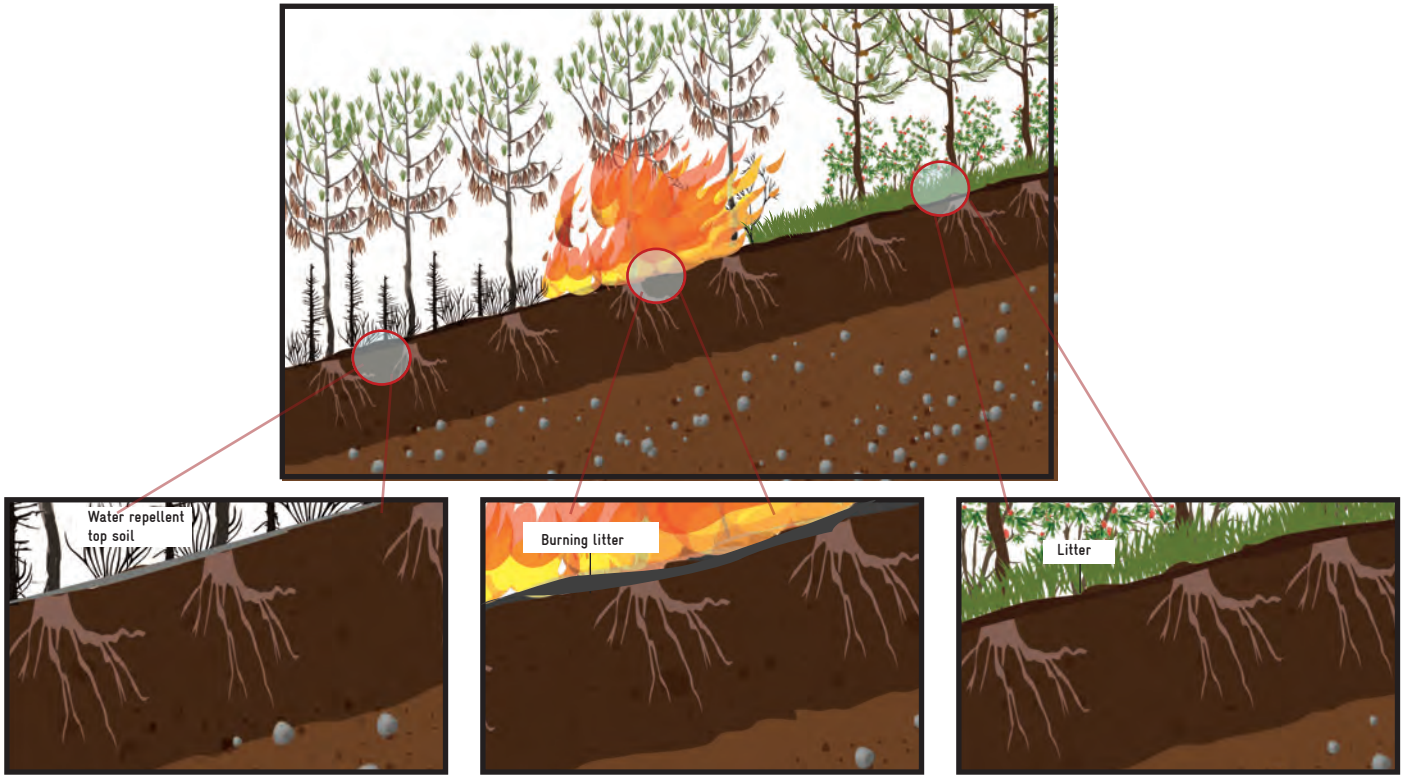
Figure 3.6: Soil erosion

Soil erosion

An intact forest, one with multiple layers of vegetation, reduces the impact of heavy rainfall on the soil. A fire that destroys plant material and the litter layer leaves the soil unprotected. Heavy rainfall on exposed slopes dislodges soil particles and sets them in motion causing soil erosion and the loss of soil fertility.

Destruction of humus

Forest fires can burn the leaf litter layer and other organic matter layers on the forest floor. The loss of these protective layers makes the soil vulnerable to erosion, especially during heavy rains when surface water runoff is likely to occur. Fire may also hinder water infiltration as under some conditions some soils, when heated become temporarily water repellant. The result is also surface water runoff and erosion. Soil erosion almost always results in a loss of soil fertility.

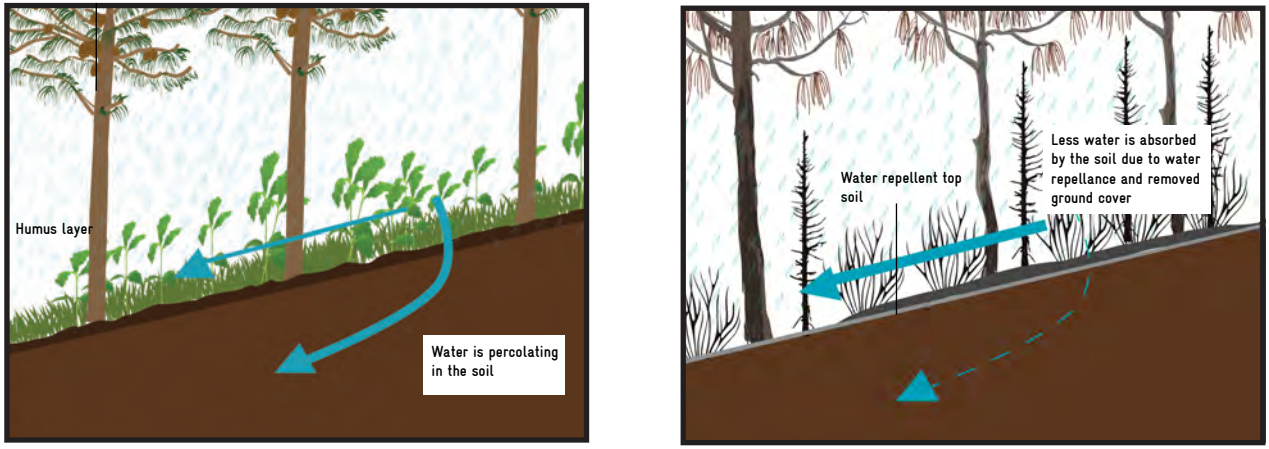


After fire: The ground vegetation and humus layer are burnt, the soil contains many unbound nutrients and only a small amount of water can penetrate the soil

During fire: The fire burns the vegetation and induced chemical reactions in the soil that releases nutrients and increases the water repellency of the soil

Before fire: Ground vegetation and tree regeneration have emerged

Figure 3.7 An intense forest fire may cause the soil to become temporarily water repellant



Before fire

After fire

Figure 3.8: Impact of forest fire during rain

There are several ways in which fire reduce the ability of the forest floor to minimize water loss:

1) Humus is an important “water tank”. Once destroyed by fire, the water storage capacity is lost.
2) The heat coming from burning surface fuels in an intense wild fire can result in the soil underneath becoming increasingly water repellant **(hydrophobic)**. Although this condition is temporary, lasting weeks to months, in the event of heavy rains while the condition is still in effect, can lead to surface runoff, erosion and loss of soil fertility.

4. Human use of fire that results in forest fires

4.1 Human-caused forest fires

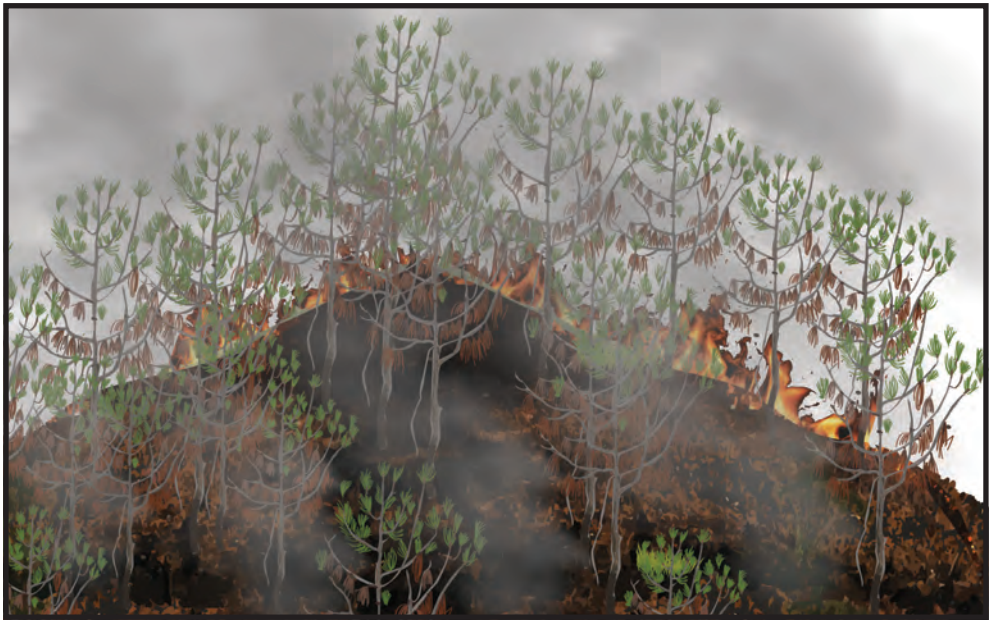


Figure 4.1: Intentional fires set to burn old grass and brush to open the forest and improve grazing. They may escape into adjacent forests where fire is undesirable because of the damage caused.

Fire has been used to influence vegetation structure since man first learned how to use fire. It burns the dead parts of last years' grasses, making available the ash and its nutrients to the soil facilitating a fresh flush of grasses. These grasses are rich in nutrients and thus very important for healthy livestock. At the same time fire also clears the land of brush and trees and prevents the succession grasslands to woodlands.

Fires lit to improve grazing are in most cases uncontrolled and often escape into areas which are not used for grazing, for example, in forests, where fire is undesirable. These escape fires prevent the development of dense forests with a diverse set of species. Consequentially, society will not receive the benefits derived from well-developed forests like the regulation of water flow, clean air and an increase of soil fertility, an increase in tree growth rates and some NWFP. At all times the use of fire should be strictly regulated and carefully managed by trained personnel, especially when done in or near forests. The concern being that if not done in a managed way, given the right conditions, fire can and easily does escape and do great damage. Areas that are no longer used for grazing should be protected so that they do not burn, for example due to escape fires, so that a new forest, with all its benefits, can develop.

Ideally the use of fire should be strictly regulated and carefully managed, by trained personnel, when used in or near forests as fire can easily escape given the right conditions. If fire is used to support grazing, areas that are no longer needed for grazing, they should be prevented from burning, no escape fires, to allow for a new forest to

Figure 4.2: More area is burnt than required. This causes great damage

4.2 The results of accidental fire

Figure 4.3: Fire escaping from a fire set to burn trash: Trash that is burning unsupervised and uncontrolled on the edge or in the forest often escapes and burns down, or causes damage to the surrounding forest.

Figure 4.4: Fire set to clear a roadside vegetation escaping into the forest

Unsupervised use of fire while clearing the roadsides as well as burning litter and other residuals can result in the fire escaping into the forest. Large areas of valuable forest can get burned.

Figure 4.5: Fire escaping from agricultural land entering - a plantation of broad-leaved trees and destroying it

Many farmers maintain their agricultural fields with fire. The fires are often uncontrolled and can spread to adjacent forests, especially if the forest is situated uphill from the agricultural land. These fires kill trees (natural and planted), destroy wildlife habitat and reduce the fertility of the forest soil as described in chapter 3.

Figure 4.6: Carelessness of tourists visiting forests

Often forest visitors behave carelessly in forests. They make bonfires, smoke cigarettes and often burn trash and are not careful enough to make certain that all fires are properly put out before leaving and thereby potentially causing a wildfire. These fires can destroy large areas of beneficial forest. Such behavior needs to be prevented. Make sure all fires are completely extinguished before leaving.

5. Fire management

5.1 Fire prevention

Figure 5.1: Constructing a fire break to prevent a fire set for grazing opportunities from escaping into the forest

The use of fire near or within forests should be strictly regulated and supervised by knowledgeable, responsible people as fire can get out of control causing untold damage to valuable forest. If fire is used to support grazing, areas that are no longer needed for grazing should be protected from fire to allow new forest to develop.

Figure 5.2: Preventing trash burning fires from escaping

Landfills are a better option but when there is no other way to dispose off waste other than by burning, it needs to be done in a strictly controlled fashion by responsible people. The waste should only be burned during favorable weather conditions and done in a fire-proof container (metal or brick) which has a spark arrestor (a screen that stops burning embers from escaping) or be done on mineral soil where the nearest flammable materials are at least two meters away. Fire fighting equipment/tools should be close at hand. A water filled bucket, shovel and a rake at a minimum while the burning is taking place

Figure 5.3: A road side is cleared manually without using fire

If fire is used for whatever reasons, it should be done in a manner that always keeps the fire under strict control. Fire should be set starting from a control line away from the forest and burn towards the road.

Figure 5.4: Fire prevention from burning of agricultural land

To avoid these fires from escaping into the forest they need to be controlled by adequately trained personnel. The planning for such a burn (make a fire plan) must start long before the agricultural land is burned. Villagers who are benefitting from the forest, forest department staff and the owner, or leaser of the agricultural land all need to be involved in writing the fire plan. The date needs to be flexible depending on the condition of the fuel and the weather e.g. temperature, wind direction and speed. Manage the fire (keep it small and under control at all times) so that it cannot escape into the forest (see chapter 5.3)

Figure 5.5: Campfires are only allowed on well-designed camping sites

Patrol and control are the only ways to avoid such accidents. Where the forest department or other forest owners want to enhance such recreational activities, they must provide secured fireplaces and clear instructions to the users.

Figure 5.6: Control line: constructing a control line by removing fuel and digging down to mineral soil

Control lines are constructed, or naturally existing fire barriers are be used to control and fight forest fires. They can be used as fire breaks to prevent controlled fires from spreading/escaping or they can be constructed when suppressing active forest fires. Some examples of existing control lines include roads, areas of sparse fuel, streams, ponds, rockslides or previously burned areas. Usually, constructed control lines are cleared strips from which all flammable material has been removed by scraping or digging down to mineral soil using hand tools or bulldozers. Control lines are constructed to isolate the burned
area from the unburned area to create a gap in the flammable materials which prevents the fire from spreading. Control lines can also be used as 'safe strips' from which to start "burning out" to remove fuels in front of the advancing fire.

Control lines should be built as close to the fire edge as conditions safely permit. They are constructed from the rear of the fire along the fire edges to narrow down the advancing head fire (see the chapter 5.3). Control line width should not be wider than necessary depending on vegetation height. Vegetation should be cleared at a width of 1.5 times the height of the surrounding vegetation and /or 2.5 times the flame length of the main fire.

Any control line must be commenced at an anchor point. This is an area of low fuel that will prevent the fire from burning around the end of the constructed control line.

Material should be scraped away from the edge of the control line nearest the fire. The last person in the team should check that the control line has been constructed properly. Heavy fuels or steep slopes should be avoided when constructing control lines. Existing fire barriers, e.g. roads and streams, should be used to save time and energy.

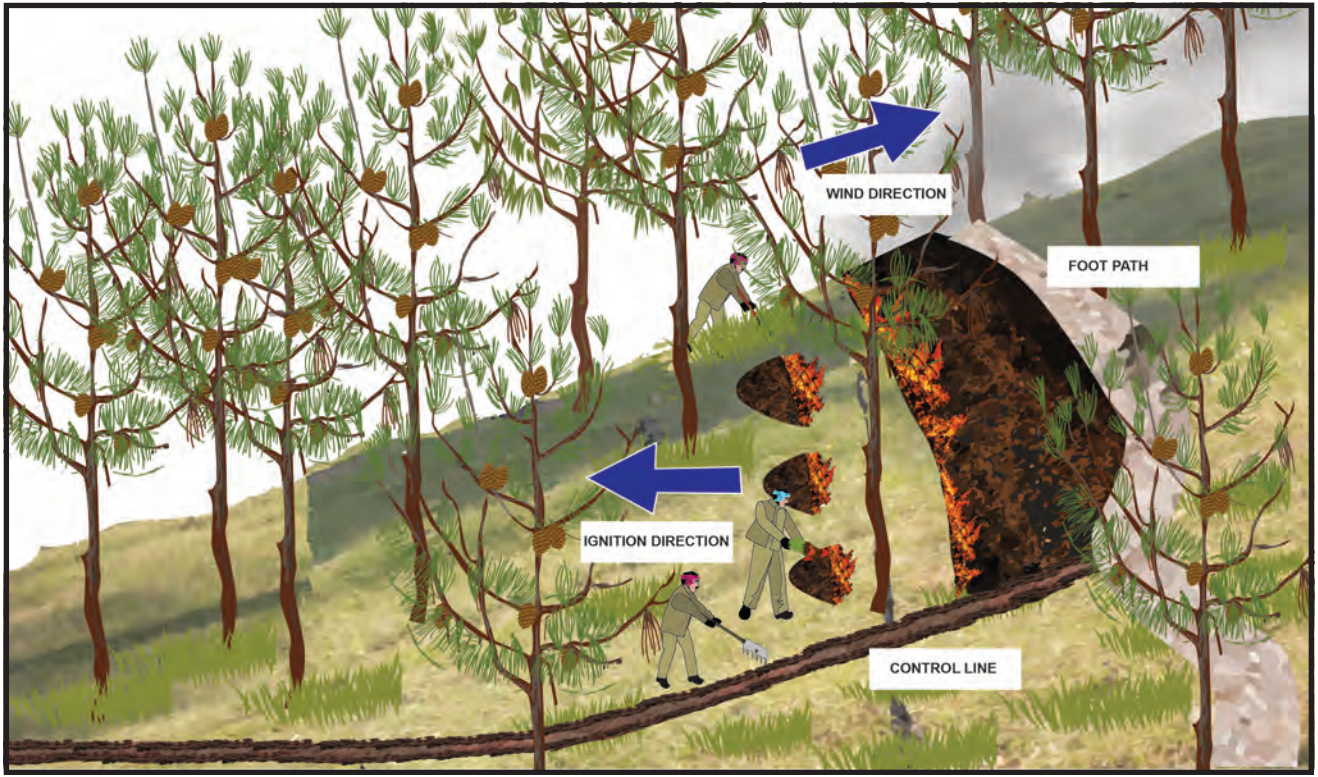


Figure 5.7: Controlled burning

Controlled burning is the planned application of fire under favorable environmental conditions to control fire intensity. Controlled burning can be used to reduce fuel loads and to create fire breaks for fire prevention when conditions safely allow. Usually such controlled burns are done as low intensity burns with the objective to consume some portion of the surface fuel with little damage to middle or over storey vegetation.
The most appropriate technique to achieve low intensity burns is the use of backing fires. Backing fires are lit against the wind, downslope or a combination of both. In this way fire spread and flame lengths are reduced. With the exclusion of the influences of wind and slope the fire can be said out of alignment of the main factors that support fire behavior (compare 2.3).

All controlled burns require pre-fire site preparations like control lines or fire breaks. It is strongly advised to only perform controlled burning when the necessary skills have been acquired by official training.

5.2 Development of fire management strategy with communities

Figure 5.8: Making a wild fire prevention plan

Planning

Identification and marking of areas that should not be burned must be carried out by the village community in cooperation with the forest department.

Figure 5.9: Community identifying the fire source

Figure 5.10: Community discusses prevention measures

Identification of the source

The community members identify the source from which fire can occur. This includes groups of people who might be responsible for the fires.

Making arrangement within the community

The community members should discuss and agree on various aspects. E.g. Patrolling fires which are set to burn agricultural land and stopping people from intentional forest burning.

5.3 Fire suppression

5.3.1 Methods of extinguishment

The removal of one of the three elements that makes up the fire triangle, or "breaking the fire triangle", will successfully suppress forest fire. There are a number of common fire suppression strategies that all aim at removing one element of the fire triangle:

Remove oxygen supply – this can be done by throwing soil on a fire or beating out the fire along its edge using a fire beater

Remove the heat – water absorbs heat energy through steam. The application of water is a very effective way of extinguishing a fire. Water must be directed at the base of the flames where combustion is occurring

Remove the fuel – Techniques which involve the removal of fuel are known as "dry firefighting techniques". Using hand tools to create a control line or to create fuel breaks are effective dry firefighting techniques. Backburning and other tactical fire operations are also examples of removing fuel in front of a forest fire.

Often it will be a combination of techniques that successfully extinguishes a forest fire. Removing the oxygen supply by adding dirt to the fire is better suited for the mop-up stage of a forest fire, while removing the fuels in front of the fire might be used to knockdown the head of the fire to gain control of the advancing forest fire.

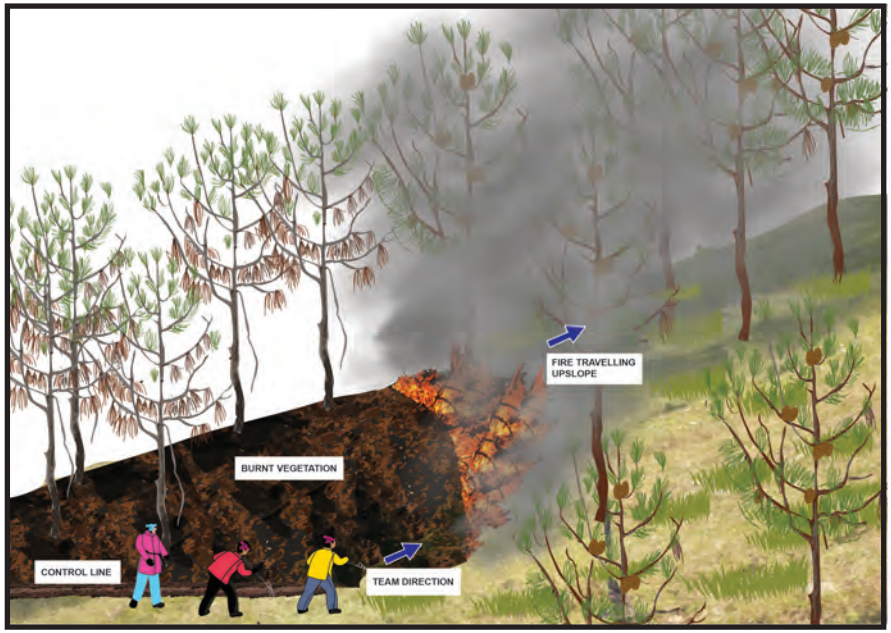


Figure 5.11: Direct attack

5.3.2 Direct attack

- Used mainly on low intensity forest fires that can be easily and safely attacked
- Control efforts, including fire line construction, are done at the perimeter, which becomes the control line
- Suppression efforts should focus on the flanks of the fire, starting from the rear and working towards the head of the fire
- Begin fire line construction at an anchor point, (i.e. a road, stream or burned area to minimize the chance of being flanked by the fire).

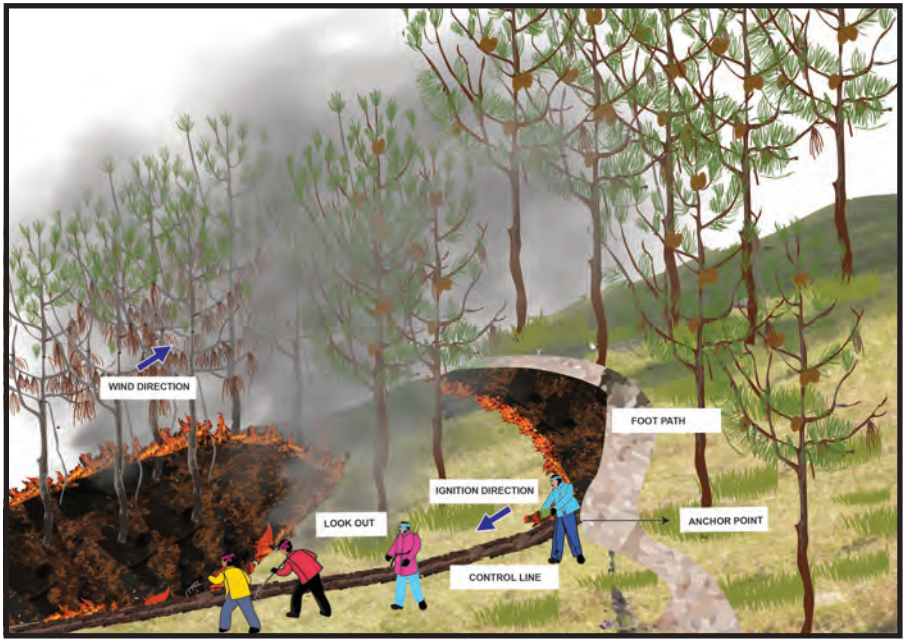


Figure 5.12: Indirect attack

5.3.3 Indirect attack

- Used for forest fires of great intensity, large physical areas, or those with limited access.
- This strategy often involves the use of fire against fire strategy (i.e. back burning) as an offensive strategy.
- Uses an existing natural barrier or constructed control line that is a good distance from the fire.
- In accordance with correct terrain and weather conditions, a back burn is lit to slowly burn away from the control line towards the main fire and thus removing the fuel from the main fire.

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