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FOREST FIRE: A REVIEW

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ABSTRACT

Fire is a vital and natural part of the functioning of numerous forest ecosystems. Forest fires are considered to be a potential hazard with physical, biological, ecological and environmental consequences. In India, forests fires are the most significant, and a steadily increasing factor in the degradation process, although the extent of total damage is widely disputed. In this review ecological, economic and social impact of the forest fire and possible future strategy to combat forest fire through skill development of affected societal groups has been described.

Key words: Forest Fire, Ecology, Biodiversity, Disaster management.

Introduction

Forest fire is mostly an anthropogenic phenomenon which burns valuable flora and fauna and sometimes also involves villages and structures. Every year, the world faces extreme wild fires, which affect million hectares of forest including biodiversity of wild fauna and flora, ecosystem structure and functioning, and landscape stability. The earliest evidence of fire is found in the Carboniferous age around 400 million years ago forming fossilized coal deposits (Spinage, 2012). Spatial and temporal variation in severity within a fire can have long-lasting impacts on the structure and species composition of post-fire communities and the potential for future disturbances (Ryan, 2002). In addition, fire has been an integral part of the forest environment and has played an important role in shaping the flora and fauna. A fire may be either beneficial or detrimental to individuals of a particular species but the effect of a single fire is not as environmentally significant as a change to the fire regime (Smith, 1995). Fire may also play a role in recycling nutrients from the ground-layer vegetation and litter to the over-storey trees, thereby, counteracting the infertile substrates and arrested decay (Vogl, 1974). Areas under larger burned patches have higher cover of tree seedlings and shrubs, greater densities of opportunistic species but have lower species richness (Turner *et al.,* 1997). Climatic abnormalities are making forest ecosystem more susceptible and increase the risk of burning. Increased dry spells could also place dry and moist deciduous forests at increased risk from forest fires. There is growing scientific evidence that climate change will increase the number and size of wildfires globally (Mukhopadhyay, 2009). Therefore, from the last century, great efforts and vast resources have been applied to understanding and managing fire in forest (Knorr *et al.,* 2011). Climate variability is expected to increase across the globe (IPCC, 2007), which will lead to increase in air or land surface temperature along with prolonged droughts and also reduced rainfall will make the forests more vulnerable to forest fires.

Forest fires are considered to be a potential hazard with physical, biological, ecological and environmental consequences. In India, forests fires are the most significant, and a steadily increasing factor in the degradation process, although the extent of total damage is widely disputed. Technically, fire is defined as the rapid combustion of fuel, heat and oxygen. All these three elements are in some proportion to start and spread fire. It is a chemical reaction of any substance that will ignite and burn to release a lot of energy in the form of heat and light. To start a fire an external source of heat is required along with the oxygen. Heat is measured in terms of temperature and fuel is any material capable of burning. In forests, fuels are vegetation, branches, needles, standing/ dead trees, leaves, and man-made flammable structures.

Forest fire does not depend on any single factor instead its behaviour, intensity and spread depends on various integrated factors. The major factor which interacts includes viz., vegetation type/density, biophysical factors, physiographic, topography, edaphic factors and most importantly the anthropogenic factors.

Ecological, economic and social impacts of the forest fire

The ecological and socio-economic consequences of wild land fires in India include:

- Loss of timber, loss of bio-diversity, loss of wildlife

Forest fire is the common hazard which impacts the ecology of forest, biodiversity and plant community composition of the forests.

habitat, global warming, loss soil of soil fertility, soil erosion, loss of fuel wood and fodder, damage to water and other natural resources, loss of natural regeneration. Estimated average tangible annual loss due to forest fires in country is ` 440 crore (US$ 100 millions approximately).

- The vulnerability of the Indian forests to fire varies from place to place depending upon the type of vegetation and the climate. The coniferous forest in the Himalayan region comprising of fir (*Abies* spp.), spruce (*Picea smithiana*), *Cedrus deodara, Pinus roxburgii* and *Pinus wallichiana* etc. are prone to fire.
- As per the estimates projected in the (ISFR, 2015) different forest type groups, the Table 1 reveals that Tropical thorn and Tropical Dry Deciduous Subtropical Broad leaved Hill Forests and subtropical Pine forests are more prone to fire..

Wildfire statistics

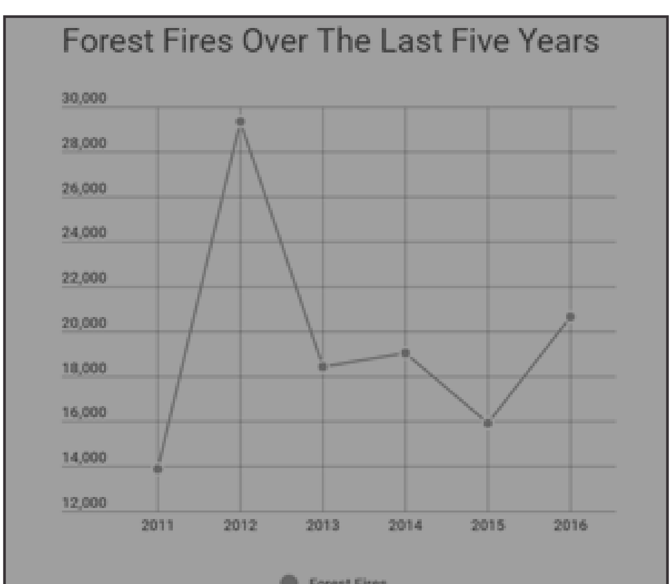
In India there are no comprehensive data to indicate the loss to forests in terms of area burned, values, and volume and regeneration damaged by fire. The available forest fire statistics are not sufficient because they under estimate fire numbers and area burned. However, Forest Survey of India in a country-wide study in 1995 estimated that about 1.45 million hectares of forest are affected by fire annually.

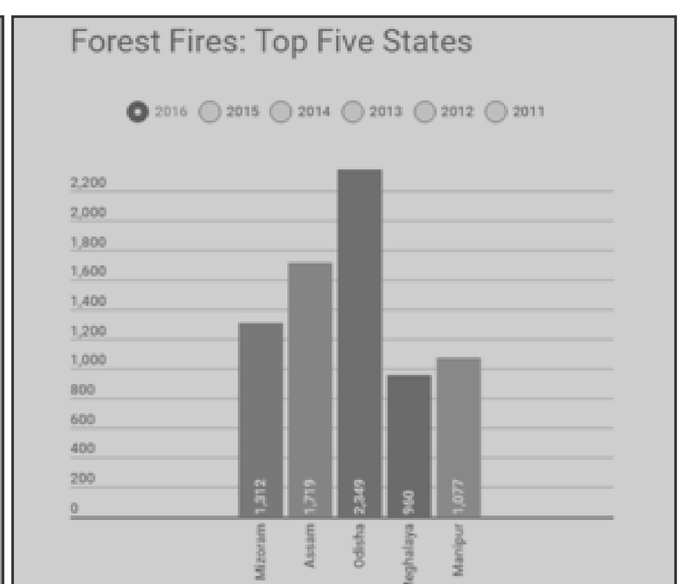
As many as 117,369 forest fires instances were reported since 2011 in the country. Forest fires are a nationwide phenomenon but they vary in intensity and nature; the season for forest fires is from February to June.

Table 1: Forest type group-wise percentage forest cover area in different Fire incidence classes

FT Group	Forest Type Group	Fire incidence class			
		Heavy	Moderate	Occasional	No fire
1	Tropical Wet Evergreen Forests	1.10	3.12	24.96	70.82
2	Tropical Semi-Evergreen Forests	0.74	3.22	63.87	32.17
3	Tropical Moist Deciduous Forest	0.77	5.81	59.70	33.72
4	Littoral and Swamp Forest	0.00	6.25	17.50	76.25
5	Tropical Dry Deciduous Forests	3.95	8.51	52.94	33.60
6	Tropical Thorn Forests	6.36	13.94	56.97	23.73
7	Tropical Dry Evergreen Forests	11.11	27.78	38.89	22.22
8	Sub-tropical Broadleaved Hill Forests	0.00	5.80	83.33	10.87
9	Subtropical Pine Forests	4.49	24.08	44.90	26.53
11	Montane Wet Temperate Forests	0.00	4.77	52.37	42.86
12	Himalayan Moist Temperate Forests	1.18	12.60	41.51	44.71
13	Himalayan Dry Temperate Forests	0.00	6.25	31.24	62.51
14	Sub-Alpine Forests	0	2.18	13.13	83.69
15	Moist Alpine Scrubs	0	0	12.91	87.09
	National Level	2.40	7.49	54.40	35.71

Source: FSI, 2015





Source: Lok Sabha 1, 2; Figures for 2016 as on 21.04.2016; Ranking based on 2015 figures.

While 54% recorded forested area is prone to fire, only about 6% Indian forests are prone to severe fire damages annually. The north-eastern state of Mizoram reported 2,468 forest fires-the most in 2015. Assam (1,656) was second, followed by Odisha (1,467), Meghalaya (1,373) and Manipur (1,286). The top five states accounted for 52% of all forest fires across the country in 2015. The eastern state of Chhattisgarh reported the most forest fires-2,422-in 2016 (as on April 21, 2016), followed by Odisha (2,349) and Madhya Pradesh (2,238). More than 95% forest fires are caused by the negligence of human beings. The remaining 5% fires are caused by natural reasons like lightning and extreme rise in temperature. "These (fires) are not new but this time due to the heat, the moisture level has reduced, which at times leads to situation like the ones in Uttarakhand and Himachal Pradesh," environment and forest minister Prakash Javadekar said on May 4, 2016 (https://www.saddahaq.com/forest-fires-surge-30-in-2016).

Adverse Effects of fire on Forest

Effect of Forest Fire on Regeneration

Fire affects forest resources in a variety of ways; regeneration is destroyed or dies back, thereby delaying the establishment of a new crop and extending the rotation. To reverse the impact of fire in teak plantations, in Maharashtra, it is a standard practice to cut the young trees down to ground level this stimulates a new vigorous shoot from the base, one year's growth is lost but plantation is saved. Fires are reported to damage seriously the regeneration of important tree species in Sal forest, Chir pine regeneration is similarly killed or set back. Young eucalyptus plantations frequently require replanting and coppice regeneration dies back (or must be cut back) after fire (Maithani *et al.,* 1986). Mortality may result from intense fires in older crops, although the trees develop thick bark that protects them. Eucalyptus appears to suffer more than the indigenous species and the effects of fires are apparent in reduced stocking per hectare and lower yields at maturity. In the Haldwani area, the actual yields obtained from pulpwood plantations, compared with theoretical yields derived from yield tables, indicate an average stocking of about 60 per cent. However, it is not possible to say how much of this reduction is due to fire and how much is attributable to other causes (Gane, 1987).

Effect of Forest Fire on Productivity

Loss of annual increment results from the defoliation that accompanies fires and the consequent check to tree growth. Repeated burning leads to site deterioration, changes in soil nutrient status and accelerated erosion due to the destruction of the ground flora; these also reduce the rate of growth. In India the only available evidence, on the growth losses attributable to wildfires, is a paper by Rawat (1949) on the results of controlled burning in the Sal plantations of Bengal, which shows that fires significantly reduced the diameter growth of trees. Australian studies indicate that the volume increment of various species of eucalyptus is reduced after fires and that the effect persists for several years. The cumulative loss of annual increment depends on the severity of the fire, but generally lies in the range of one to three years' growth. Timber quality is affected by scorching from the base of the tree, which damages the cambium, leading to defective butt logs. Fungal infection may occur through the damaged tissues and cause rot. The records of timber sold through the Ballarshah Depot of the Forest Development Corporation of Maharashtra revealed that the average price received in 1984/85 and 1985/86 for fire-damaged logs was 9.8 per cent lower than the average price of all logs sold. In the Nainital chir pine forests in Uttarakhand, resin tapping affects the yield of merchantable timber by damaging the lower part of the tree; the scars enable fires to bump into the heartwood and, in some cases, kill the tree. These tangible losses may produce a knock-on effect in the form of a reduction in output and employment in industries dependent on wood as raw material. For example Chatterjee (1978) estimated that for sawnwood, each rupee's worth of output created ` 2.169 of employment and ` 11.994 of non-labour value added. Despite the fact that these multipliers were based on 1965 prices, they suffice to evidence the effect of fires on the wider economy.

Effect of forest fire on species composition

Fire determines the floristic composition of an area by affecting the establishment and growth of different species, which continue to occupy a site after the fire. A species can be removed if fire occurs too often, too early, or late in its life cycle. For instance, a non-sprouting species may be lost if fire occurs before seed has been produced, or if fire occurs after the species has died and seed pool is unavailable (Chandler *et al.,* 1983). Two strategies typically characterize the response of different species to fire frequencies; those that sprout can withstand repeated fires while those that produce seed are favored by infrequent fire (Keeley, 1981). Numerous studies have attempted to define the temperature required to kill vascular plant tissue. A temperature above 60°C has been considered as a lethal temperature required killing shoot tissues of land plants. Plant species surviving fires known as Pyrophytes coppice and have responses resulting into offspring from seed. The ability of an individual plant to sprout following a fire is dependent on the location of its dormant buds, the subsurface distribution of reproductive structures and the depths below the surface from which new shoots can develop. These morphological characteristics, combined with fire severity, typically determine the number of growing points that are able to survive a fire. Fire is linked to plant invasions. Gaps created by high-intensity fires are particularly susceptible to invasion by exotic species for example of *Imperata cylindrica* quickly recovers after fire and may respond with an increase in cover. Invasive species depletes the biodiversity of an area through allelopathic path ways. The extent of the damage depends upon the frequency and intensity of fires, the type of forests, availability of fuel and local climatic factors. Forest fire in Sal (*Shorea robusta*) and Teak (*Tectona grandis*) forests takes the form of ground fires and though they have a higher frequency, they mostly affect the regeneration and the ground flora which normally recovers during the monsoons. Species like *Lantana camara*, *Eupatorium glandulosum*, *Parthenium hysterophorus*, *Cassia tora*, *C. occidentalis* etc. have invaded several of the significant sites of forest biodiversity conservation. However, in oak forests, the fire takes the form of a canopy fire and the whole oak tree catches fire and burns for several days, as its calorific value is high. Subsequently, the middle storey vegetation such as dwarf bamboo, *Viburnum* sp, *Edgeworthia* species aggressively colonizes the burnt area and prevents the climax species. The oak and coniferous forest affected by the major forest fire which occurred during the 1970s in West Sikkim is yet to recover fully.

It is generally believed that fires are bad but they are actually necessary to promote diversity (Douglas and Ballard, 1971; Kovacic, 1998). The composition of forest species have changed after fire, this may be good or bad depending on the utility of the stands that preceded and succeeded the fires (Lutz, 1956). The state of the ecosystem, namely the set of fire regimes that prevail in a landscape, pre-conditions the responses of biodiversity and ecosystem processes to any particular fire. Awareness of this fundamental principle and the concept of fire regimes is a mandatory pre-requisite for decision-making and evaluation of ecological effects of any fire, for example, a high intensity fire in a mature forest will not be a disaster provided that some part of the habitat provides corridor for free movement of animals (Bradstock and Gill, 1999). In Tehri-Garhwal, field data analysis suggest that low intensity surface ground fire were less detrimental to forests of *Shorea robusta*, *Tectona grandis* and *Pinus roxburghii* trees but herbs and shrubs were most suffered. Some trees suffered fire scars which were vulnerable spots for infestation by insects and pests. It was also observed that fire alone is not responsible for degradation of area but it's the combination of fire and grazing; because grazing is quite ubiquitous in Upper Himalaya especially goat, sheep rearing which are browsing animal causing more damage to regeneration (Parashar and Biswas, 2003). Some of the species, which were totally exterminated, were *Vitex negundo*, *Hypericum* sp. Thus, fire has decreased floral diversity of burnt area to a considerable extent. Therefore, fire tolerant species, either indigenous or extotics that are able to re-sprout and develop quickly tend to become important components of the post-fire community.

Effect of forest fire on Soil

Fire effects on soil may have strong influences on the composition and structure of post-fire forests (Jain *et al.*, 2008). In tropics recently, demographic and land use changes have made fire a matter of serious concern (Goldammer, 1990). The role of fire on forest soil is very complex and less studied in comparison to its aboveground effect (DeBano *et al*., 1998). These effects directly depend on fire intensity and the duration of combustion. Depending on the fire severity, these changes in soil properties may be beneficial or deleterious to entire ecosystem (Neary *et al*., 1999; Verma and Jayakumar, 2012). Fire can influence a variety of soil physical and chemical properties including the loss of structure and soil organic matter, reduced porosity and increased pH (DeBano, 1990; Certini, 2005). Change in soil properties after fire produces varying responses in the water, vegetation dynamics and fauna of ecosystems. The wide range of effects is due to the inherent pre-burn variability in these resources, fire behaviour characteristics, season of burning, and pre-fire and post-fire environmental conditions such as timing, amount, and duration of rainfall (Clark, 2001). These changes can also result in various indirect impacts including increased water repellence, which results in decreased infiltration and increased runoff that often results in increased erosion (DeBano, 2000).

Fire has impact on important physical characteristics of soil like soil colour, texture, pH, bulk density and water holding capacity. Soil colour and texture get altered completely in severely burned soil. At higher temperature, reddening of soil matrix occurs. Redder hue appears in the burned soils is apparently because of Iron oxides transformation and complete removal of organic matter (Ulrey and Grahm, 1993; Certini, 2005). While in low to moderate fire ground is covered by a layer of black or grey ash (Certini, 2005). Surface patches of reddened soil indicate the place where soil was severely burned and are detectible by a characteristic increase in magnetization compared to surrounding soil. Hence, the long term pattern of forest fire intensities over a landscape may be detectable as the spatially heterogeneous accumulation of thermally produced iron oxides in soils (Goforth *et al.,* 2005). The composition of soil texture viz. sand, silt, and clay have high temperature thresholds and are not usually affected by fire unless they are subjected to high temperatures at the mineral soil surface. The most sensitive textural fraction is clay, which begins changing at soil temperatures of about 400^{0}C when clay hydration and clay lattice structure begin to collapse. The presence of ash may increase soil pH due to high pH of ash (Molina *et al*., 2007; Schafer and Mack, 2010). Bulk density of forest soils increase significantly because of collapse of aggregates and clogging of voids by the ash and dispersed clay minerals, as a consequence, soil porosity and permeability decreases (Certini, 2005). Bulk density increases with ash depth (Cerda and Doerr, 2008).

The most spontaneous change soil experience during burning is loss of organic matter (Certini, 2005). The organic horizon is critical component of ecosystem sustainability in that it provides a protective soil cover that mitigates erosion, aids in regulating soil temperature, provides habitat and substrates for soil biota and can be major source of readily mineral nutrients (Neary *et al*., 1999). It plays an important role in soil cation exchange capacity (CEC) and retention of ions (Craswell and Lefroy, 2001). The effect of fire on organic matter is highly variable from total destruction of soil organic matter to partially scorching depending on fire severity, dryness of the surface organic matter and fire type (Neary *et al*., 1999; Gonzalez *et al*., 2004), soil type and nature of the burned materials. Low-intensity fire usually results in little change in soil carbon, but intense prescribed fire or wildfire can result in a huge loss of soil carbon (Johnson, 1992). Whereas increasing the fire frequency results in an increase in carbon in the fine fractions of the soil and an increase in organic carbon in soil, while soil texture, on the other hand, controls the magnitude of the increases in both the abundance of organic carbon (Bird *et al.,* 2000). It is formed after forest fire in the forest floor. Charcoal can promote rapid loss of forest humus and belowground carbon during the first decade after its formation, because charred plant material causes accelerated breakdown of simple carbohydrates (Wardle *et al*., 2008). The nutrient elements may be lost to the atmosphere, deposited as ash, or remain in incompletely burned vegetation (Boerner, 1982). Kutiel and Naveh (1987) reported that after forest fire soil nutrient decreases but their plant available forms increases. Burned soils have lower nitrogen than unburned soils, higher calcium, and nearly unchanged potassium, magnesium, and phosphorus stocks (Neff *et al*., 2005). The immediate effect of fire on soil nutrients is in terms of its loss through volatilization due to of high temperature (Neary *et al.,* 1999; Certini, 2005). The most significant short term effects of the forest fire are the increases in the soil solution concentrations and leaching of mineral forms of N, S, and P (Murphy e*t al*., 2006). However, the total amount of nitrogen decreases (Knight, 1996). Mg, Ca and Mn are relatively less sensitive in comparison to nitrogen because of high threshold temperature (DeBano, 1990). Phosphorus, Potassium and Sulfur is partially affected in high intensity fire (DeBano and Conard, 1978).

Forest fire can significantly alter microbes that affect large-scale processes such as nutrient cycling (Neary *et al*., 1999). Fire affects biological organisms either directly or indirectly. Direct effects cause short-term changes due to direct exposure of particular organism where enough heat is transferred into the organism's immediate surroundings to raise the temperature sufficiently to either kill or severely injure the organism. Infact, peak temperature often exceeds those required for killing most living being (Neary *et al.,* 1999). The immediate effect of fire on soil microorganism is a reduction of their biomass. Indirect effects usually cause long-term changes in the environment that can involve competition for habitat, food supply and other more changes that affect the re-establishment and succession animals.

The bacterial population generally increases after fire events (Saravanan *et al*., 2013). There are only few studies conducted on soil bacteria after forest fire suggesting that Bacterial community structure is significantly changed. Aerobic heterotrophic bacteria, including the acidophilic and sporulating ones, were stimulated by fire while cyanobacteria, was clearly depressed. In the long term, the positive effect of fire on bacteria was nullified except on the sporulating ones reached the unburned soil values, cyanobacteria also increased. Vazquez *et al.* (1993) reported that the soil incubation improved the beneficial and diminished the negative fire effect on the micro biota, whereas Jaatinen *et al.* (2004) found that there is no significant effect of forest fire on methane oxidizing bacteria.

The fungal population follows reducing trend in the burnt area in comparison to the unburnt areas. Since fungal spores are the main propagules for reproduction of fungi, elimination of spores during fire reduces the fungal population in soils. Renbuss *et al.* (1973) reported that fungal population growth was very slow in the burnt soil. Wright and Tarraunt (1957) observed decrease in soil fungal population after burning.

Stendell *et al.* (1999) studied that the total ectomycorrhizal biomass in the unburned plots did not differ for any core layer, while in the burnt site, the destruction of the litter organic layer resulted in an eight-fold reduction in total ectomycorrhizal biomass. Forest fire can affect arbuscular mycorrhizal (AM) fungi by changing the soil conditions and by directly altering AM proliferation. Rashid *et al.* (1997) suggested that compared with a nearby control area, the burnt site had a similar number of total spores but a lower number of viable AM fungal propagules.

Could El Nino have played a Role in Forest Fire?

Fire is a vital and natural part of the functioning of numerous forest ecosystems. Human have used fire for thousands of years as a land management tool. Fire is one of the natural forces that have influenced plant communities over the time and as a natural process, it serves an important function in maintaining the health of certain ecosystems. However in the latter part of the twentieth century, changes in the human fire dynamics and an increase in El Nino frequency have led to a situation where fires are now a major threat to many forests and the biodiversity therein.

In many forest ecosystems, reduced precipitation before and during the dry season can reduce fuel moisture and lower humidity near the surface, allowing fires to more easily escape from human control, and spread more rapidly over the landscape. Besides of temperature, vapor pressure deficit of air is also an important climate variable for fire. Vapour pressure deficit is a measure that combines temperature and relative humidity near the surface. Warmer temperatures and lower humidity cause vapour pressure deficit to increase which can dry fuels rapidly and allow fires to grow very fast. From a wildfire perspective, interactions between El Nino and climate warming can create new extremes in fire behaviour that are driven both by rainfall deficits and extreme temperatures. India has variety of dense forests in tropical south, Himalayan Mountains and the wet north-east regions. Forest vegetation ranges from tropical evergreen forests (Western Ghats / Eastern Himalayas) to alpine forests (Himalayas in north) to semi-evergreen, deciduous, sub-tropical broad-leaved hill forests, sub-tropical pine forests and sub-tropical montane temperate forests. The Himalayan forests ecosystems are vulnerable and very sensitive to changing climatic scenario especially rising atmospheric temperature due to several ongoing interventions. Dongre (2016) stated that large number of forest fires occurs annually in India, as maximum forest belongs to tropical deciduous types.

A total of 18,451 incidents of forest fires were reported from across the country in 2013, compared with 19,054 in 2014 and 15,937 in 2015. As a major forest fire ravages the forests of Uttarakhand, some experts suggest poor rainfall, El Nino and climate warming as causes, while some others point fingers at miscreants.

According to Regional Integrated Multi-Hazard Early Warning System The 2015-16 El Nino which is one of the strongest on record, has turned global weather systems upside down. In 2015, Indonesia was severely hit by forest fires, affecting 2 million hectares of land along with 45 million people and 250,000 hectares of crop area in 2015. According to NASA US, said that one of the most predictable consequences of a strong El Niño is a change in rainfall patterns over Indonesia. “This dry weather was especially problematic because it intensified seasonal fires, which are intentionally lit by farmers to clear land and manage crops.”

According to James Randerson, professor of Earth System Science at the University of California, Irvine, environmental factors are critically important in determining the severity of a fire season. “In many forest ecosystems, reduced precipitation before and during the dry season can reduce fuel moisture and lower humidity near the surface, allowing fires to more easily escape from human control, and spread more rapidly over the landscape,” Randerson explained. “Low fuel moisture levels also make fires hotter, allow them to consume more fuel, and kill more of the trees inside the fire perimeter,” he said in an email to Mint.(http://www.livemint.com/Politics/pzqeyf4y9sKu52DDbXMKcI/Understanding-the-Uttarakhand-forest-fire.html)

Work done by Forest Research Institute, Dehradun on Forest Fire Management

The importance of taking up systematic research in the field of forest fire protection was realized as early as in 1956 when the first expert committee of FRI headed by Prof. Champion, made a very specific recommendations regarding the need to study and monitor forest fire in the country. Accordingly, a scheme was formulated in 1959 but it could not be sanctioned. Moreover, the ninth and tenth Silviculture Conferences held in 1956 and 1961 at FRI, Dehradun, recommended that FRI should take up research and development studies to strengthen knowledge related to forest fire management in India.

The Forest Research Institute a center of excellence with multi-disciplinary strength has played significant role in conservation and management of forests throughout the spatial extent of the country. Over the years FRI has prepared working plans, management plans of several

Forest Divisions of the country by adopting the most scientific National Working Plan Codes. Additionally, FRI has carried out several activities with respect to forest fire management and some of the major initiatives are given below: -

Capacity building of Forest Departments and other stakeholders: As an important mandate FRI has conducted several workshops and trainings to enhance capacity of the Forest Departments for science based management of forests and conservation of biodiversity. These training programmes have modules with respect to forest fire mitigation. Furthermore, a training programme on "Forest Fire Disaster Mitigation" for Forest Department officials of various states organized by Forest Research Institute, Dehradun, in 2015 in collaboration with the National Institute of Disaster Management, New Delhi.

Awareness creation among different stakeholder: Since the institute is of par excellence working on forest management in India several numbers of visitors (students, research institutes, Forest Department personals, technologies) are visiting FRI to gain knowledge with respect to forest resource management. The institute also organizes mass awareness programs at FRI and also in remote locations for dissemination of knowledge and creates awareness.

Development of revised forest management plans: As premier institute in the field of forestry research and management planning, FRI has prepared management plans and working plans for several forested areas of different State Forest Departments. As an important strategy, Management Plans developed by FRI have included prescriptions on forest fire management and controlling mechanism.

In addition to the work done in past there is an urgent need to strengthen the capacity and resources of the FRI specially in the Forest Fire Management sector by establishing a knowledge management center, developing resources for capacity building on forest fire management of various stakeholders mitigating the forest fire incidences and developing forest fire resilience by generating awareness and other forestry interventions among the society residing in the forest fringe areas as in the event of forest fire these are most affected group.

Operational Fire Management Systems and Organizations

Monitoring and management of forest fires is very important in tropical countries like India where 55 per cent of the total forest cover is prone to fires annually causing adverse ecological, economic and social impacts (Gubbi, 2003). Studies on the impacts of tropical wildfires on the environment indicated high carbon emissions (Hao *et al*., 1996), emissions of large amounts of trace gases and aerosol particles (Crutzen and Andreae, 1990), black carbon (Dwyer *et al.,* 1998) release of almost 100 million tons of smoke aerosols into the atmosphere as a result of biomass burning (Hao *et al*., 1996). These sub-micron smoke aerosols play a major role on the radiation balance of the earth atmospheric system. Also, there is widespread concern about the loss of biodiversity, effects on atmospheric chemistry and increase in surface albedo and water runoff due to biomass burning. In India, about 55% of the forest area, which is predominantly covered by deciduous forests, is prone to fires every year causing loss of about rupees 440 crores (~104 million US dollars). Despite the natural fires, the major sources of forest fires in India are anthropogenic, which include shifting cultivation practices, controlled burning, deforestation, fire wood burning and others. The conventional methods of fire protection cover an elaborate network of fire lines (fire breaks), fire watch towers, block lines and manual fire control systems which at times becomes practically difficult due to lack of man-power, resource constraints and time effective control mechanisms. On the other hand, application of remotely sensed data along with Geographical Information System (GIS) is capable of addressing the problem with good scientific and technical strength in a time effective and cost effective way Murthy *et al.* (2006).

Murthy *et al.* (2006) developed the "Forest Fire Decision Support System" (FDSS), The user requirements in forest fire management stands at three different levels viz. pre-fire (preparatory planning for fire control), during fire (fire detection, spread and control planning) and post fire (damage assessment and mitigation planning). These requirements could only be met from comprehensive spatial and temporal data of different dimensions emanating from satellite and ground based sources. The role of various scientific organizations and forest departments is very critical. Fire detection, spread and control planning are the important issues for the 'During Fire 'scenario. Considering the large extent of area of operations and huge number of fire occurrences simultaneously occurring in a day, the identification and combating becomes difficult. Conventional methods of identification of active fire locations need to be augmented with advanced technologies like satellite remote sensing. The remote sensing system should have the capability to provide 3-4 signals on a daily basis backed up with robust process algorithms, data dissemination and reception systems.

Community Involvement

In India, Joint Forest Management (JFM) Committees have been established at the village level to involve people in forest protection and conservation. At present there are 36,165 JFM committees throughout the country, covering an area of more than 10.24 million hectares. These JFM committees also have been given responsibilities to protect the forests from fires. For this purpose, the Modern Forest Fire Control plan is being revised and JFM is being made an integral component of the forest fire prevention strategy (Bahuguna, 1999). Use of aircraft and helicopters has not been very cost effective in the fire management program and the Air Operation Wing is being closed down. For emergency purposes, however, a provision for hiring aircraft for transportation of crews and water is being maintained. The Government of India has issued national forest fire prevention and control guidelines. Salient features of the guidelines include identification of vulnerable areas on maps, creation of a data bank on forest fires, evolving fire dangers, fire forecasting system, provisions for a crisis management group, involvement of JFM committees, and efficient enforcement of legal provisions (Bahuguna and Singh, 2002).

The Need of the Fire Management

In India, there is an urgent need to initiate research in the fields of fire detection, suppression, and fire ecology for better management of forest fires. The research and technology developed in western countries could also be tested for the Indian environment. Thus, it is essential that original research specific for Indian conditions be conducted. The incidences of forest fires in the country are on the increase and more area is burned each year. The major cause of this failure is the piecemeal approach to the problem. Both the national focus and the technical resources required for sustaining a systematic forest fire management programme are lacking in the country. Important forest fire management elements like strategic fire centres, coordination among Ministries, funding, human resource development, fire research, fire management, and extension programmes are missing. Taking into consideration the serious nature of the problem, it is necessary to make some major improvements in the forest fire management strategy for the country. The National Master Plan for Forest Fire Control proposes to introduce a well-coordinated and integrated fire-management programme that includes the following components:

Prevention of human-caused fires through education and environmental modification. It will include silvicultural activities, engineering works, people participation, and education and enforcement. It is proposed that more emphasis be given to people participation through Joint Forest Fire Management for fire prevention.

Prompt detection of fires through a well coordinated network of observation points, efficient ground patrolling, and communication networks. Remote sensing technology is to be given due importance in fire detection. For successful fire management and administration, a National Fire Danger Rating System (NFDRS) and Fire Forecasting System are to be developed in the country.

- Fast initial attack measures.
- Vigorous follow up action.
- Introducing a forest fuel modification system at strategic points.
- Firefighting resources.

Each of the above components plays an important role in the success of the entire system of fire management. Special emphasis is needed on research, capacity building, and strengthening the various related stakeholders through skill development, and technological up gradation

वनाग्नि : एक पुनरीक्षण

सविता, एस.के. शर्मा, हुकुम सिंह एवं ओमबीर सिंह

सारांश

वनों में सबसे आम जोखिम वनाग्नि है। वनाग्नि भी उतनी ही पुरानी है जितने की स्वयं वन हैं। ये न केवल वन सम्पदा के लिए बल्कि क्षेत्र की जैवविविधता एवं पारिस्थितिकी तथा पर्यावरण को गंभीर रूप से विक्षुब्ध करके प्राणिजात एवं वनस्पति के सम्पूर्ण अधिशासन के लिए भी संकट खड़ा कर देती है। इस संक्षिप्त पुनरीक्षण में वनाग्नि के पारिस्थितिकीय आर्थिक एवं सामाजिक प्रभाव तथा प्रभावित सामाजिक समूहों के दक्षता विकास के जरिए वनाग्नि का नियंत्रण करने हेतु संभावित भावी रणनीति का वर्णन किया गया है।

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