Chapter 9

Wildfires in India: Tools and Hazards

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ABSTRACT
Fires, set by humans, have both positive and negative outcomes. Throughout India, this practice has been followed for thousands of years, thereby shaping the Indian landscape over the years. This chapter describes the many reasons, as far as they are now known, why people in India set fire to the landscape, and to what extent these fires are hazardous. Review shows that large destructive fires are infrequent in India, most being low-intensity fires that burn only the ground vegetation in their respective ecosystems. Over the years, fires have had a strong impact on ecosystems and their functioning. A study of the different reasons why people burn forests reveals one and perhaps the most important reason is that fire is essential for people's livelihood. This chapter also highlights that the way in which fire is used and its role in managing segments of the landscape are not in accordance with the current forest fire policy. We suggest a more flexible approach that allows for the inclusion of fire as a tool in local fire management systems.

9.1 INTRODUCTION

India's landscape as it appears today is to a large degree a product of extensive fires. Reports of fires in India first appear in historical records, but fires have been applied to landscapes long before that (Pyne, 1994). Fires help determine forest structure and composition, alter soil properties (Shakesby, 2011), and contribute to air pollution (Singh and Panigrahy, 2011). However, our understanding of Indian wildfires is superficial. We know that the majority of fires are caused by humans (Bahuguna and Upadhyay, 2002; Pyne, 1994) and that the motivation for setting them varies across the country (see below). However, the proportional breakdown of the different causes of wildfires in India is unknown due to lack of empirical assessments. Nevertheless, it is emerging that these fires

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are important for local livelihoods as they make available many important domestic and commercial goods Schmerbeck et al. (in press). Lack of empirical data leaves gaps in the understanding of issues such as how many of the 275 million people (estimated by the World Bank (2006)) rely on the burning of India's forests, how much area needs to be burned to satisfy the requirements of forest dwellers, and how much more area gets burned beyond their needs.

In India, two fire management practices are followed: First, the British Raj implemented the official regime constituting the "ban and punishment policy," and the second involves a need-based application of fire by several forest-dwelling groups. This contradictory policy has been a source of conflict since its inception in the British Raj leading to resistance of this fire-suppression ordinance in many parts of India, christening it "oppression of the people" (Pyne, 1994). Over millennia, forest dwellers have depended on landscapes using fire as a tool to gain benefits from cultivated and uncultivated land. Burning modifies vegetation for a short term, for instance, grasses suitable for livestock grazing resprout after fire. A change of species composition from fire tolerant to fire intolerant is prevented by the regular application of fire. But regular burning also precludes the services that accrue from advanced successional stages of vegetation.

This chapter provides an overview of fires in India: those that are used as a tool and those that are hazardous. We begin with a section on the history of fire and what is presently known about the fire regime and continue with a general outline of the ecological impacts wildfires have in India. This is followed by a section on the utilization of fire as a tool in India's forests and on the hazardous effects of fires in India. To conclude, we provide an outlook on the research needs and management implications that we see in this context.

9.2 FIRE HISTORY AND REGIMES IN INDIA

For millions of years, lightning fires have driven the evolution of fire-adapted traits in plants (Keeley et al., 2011). Today, large areas occupied by flammable biomes in the tropics and subtropics are mostly attributed to anthropogenic burning. Yet the occurrence of natural fires and flammable ecosystems predate anthropogenic burning by millions of years. Recent evidence shows that the expansion of C_4 grasslands during the late Miocene was driven by natural fires rather than by decreasing atmospheric CO_2 (Keeley and Rundel, 2005). We know from palynofossil records that fire was present in south Asian forests and grasslands for at least the last 20 million years (Mathur, 1984). This is also reflected in the Pleistocene faunal records from India indicating that environmental conditions favoring fire as an important factor to shape habitats existed then (Badgley, 1984).

There is no way to prove for how long India's forests have been exposed to anthropogenic fires. Gadgil and Meher-Homji (1985) (as cited in Saha (2002), p. 1) think that humans have been burning forests in India for 50,000 years, while Goldammer (1993) reports that the dry deciduous forests of Asia have been affected by human activities, including human use of fire for about 12,000 years. Misra (1983) pointed out that India's tropical, subhumid, and dry deciduous forests, which once covered vast areas of the country, have been almost entirely replaced by savannas due to human-influenced fire regimes. Thus, the anthropogenic modification of these ecosystems has been ongoing for a long time (Bor, 1938; Karanth et al., 2006; Noble, 1967; Thomas and Palmer, 2007).

Whenever people moved, they took fire with them. After the Aryan invasion of India, around 2000 BCE, pressure on the forest slowly began to increase. This increase according to Stebbing (1922) was the result of constant invasions by peoples from central Asia who brought their herds of cattle with them. To feed the herds, they slashed and burned forests to create grazing grounds. This land conversion process peaked under the reign of the Muslims around AD 800. The original land owners were driven into the remaining forests (Stebbing, 1922) where they practiced shifting cultivation and used the forest as a source of raw materials.

It is believed that the contemporary crisis in forest and fire management is profoundly embedded in historical processes through which state forestry institutions have evolved (Chakraborty, 1994; Poffenberger and McGean, 1996). Regular forest management started in 1864 with the appointment of Dietrich Brandis, a botanist from Germany, as the first Inspector General. Following the passing of the first Forest Act in 1862, Brandis' main objectives were to demarcate and limit entry to forests reserved for the government, to protect these forests from fire, illegal felling and grazing, and to organize the forest administration (Hesmer, 1986; Mammen, 1964).

The dynamics of fire regimes in India today are largely a consequence of imperial expansion and the perception of fire under the British Raj (Pyne, 1995; Rakyutitham, 2000). Rakyutitham (2000) maintains that conventional views of environmental problems are influenced and defined by powerful groups within a society, and such views usually become unquestioned "knowledge." This was certainly the case during the time of the British Raj, which introduced European fire practices as an inextricable part of colonial enterprise. Before the arrival of the British, the practice of land burning was deeply embedded in India. Both Indian culture and society depended on the benefits of burning (Pyne, 1995). The British foresters in India saw fire as a destructive agent that reduced state revenue from forests and destroyed property and therefore had to be suppressed and excluded (Pyne, 1997). For colonial authorities, fire was not only an element that was difficult to control but also one that had to be controlled in a "civilized" society. Consequently, the Raj banned agricultural practices involving fire (Pyne, 1995).

Local people opposed to the commercially oriented colonial policy continued to practice the annual burning of forest as a form of protest and as an attempt to restore customary practices to their traditional lands. The role of the community versus that of the state in managing forest resources has been debated for as long as local people and the state have been depending on forests (Poffenberger and McGean, 1996; Springate-Baginski and Blaikie, 2007).

As the forest area declined, British foresters began to realize at the start of the twentieth century that too much fire protection had changed the forest structure and composition as fire had been maintaining it. They recognized that "fire had not been random and ravenous… but was applied to particular sites at particular seasons for particular purposes and for particular people" (Pyne, 1994, p. 13). In 1914, fire was formally reintroduced as a forest management practice in India, and British foresters tried to reintroduce fire into the landscape. They launched an elaborate fire management program including fire lines, block lines and guidelines, and early clearing and burning. However, historical fire regimes could not be restored.

9.3 FIRE AND ECOLOGY

In large parts of India, the landscapes consisting of tropical and subtropical fire-prone savannas and woodlands have been shaped by a long history of human-influenced fire regimes. In the seasonal tropics, unlike the humid or moist tropics, fire is an ecologically important disturbance factor. The dry deciduous forests and savanna grasslands of the Indian subcontinent have coevolved with fire and many of the plants have adapted to fire. Although fire impacts are widely recognized as important ecological factors in some of India's ecosystems, many ecologists still fail to incorporate the role of fire into their thinking about natural ecosystems (Keeley and Bond, 1999, 2001; Saha and Howe, 2001). Fire has a strong ecological impact on organisms directly (Bond and van Wilgen, 1996) and indirectly, for example, by changing soil properties (Mataix-Solera et al., 2011; Shakesby, 2011; Shakesby et al., 2007) and hydrological cycles. A sound understanding of the fire ecology in south Asian ecosystems is a prerequisite to the identification of social and ecological constraints and benefits of fire. So far, there are no studies available that allow us to reconstruct how ecosystems in India would have looked without human-caused fires burning over wide areas over a long time. We can only guess the structure and functioning of ecosystems under a scenario without fires.

Fire-dependent ecosystems are those where fire is an essential process in maintaining species composition, biodiversity, and structure. They are often referred to as fire-adapted or fire-maintained ecosystems. Frequent fires maintain fire-dependent vegetation formations by selecting for fire-tolerant species (Furley et al., 2008) such as those that are able to coppice (Bond and van Wilgen, 1996), mainly from meristems below the soil surface (Saha and Howe, 2003). These formations are characterized by a wide grass/tree ratio and an abundance of C_4 grasses (Ratnam et al., 2011; Veldman et al., 2012) and other light-demanding plant species. A change in the fire regime, for example, due to fire suppression, "releases ecosystems" from their "arrested states" (Favier et al., 2004; Hopkins, 1992) allowing for an increase in the proportion of woody species. Under tree canopies, C_4 grasses get shaded out and are replaced by C_3 grasses, and eventually, shade-tolerant tree species establish (Ratnam et al., 2011) if their propagules reach the site. In the absence of fire, and where soil properties and precipitation allow, succession may convert savanna and open forests into closed forests.

Examples of fire-dependent ecosystems can be found throughout south Asia. It is apparent that most of the open forests, savannas, and grasslands found in India today have developed as a consequence of human-influenced fire regimes. These new regimes have replaced the different forms of closed forest formations that once existed (Blasco, 1983; Cole, 1986; Goldammer, 1993; Misra, 1983). Today, <3 percent of India's land area is occupied by forests with >70 percent crown cover (Forest Survey of India (FSI), 2011) and half of all these forests are considered to be fire-prone (FSI, 1995). The fire susceptibility varies greatly between the different states (33 percent in West Bengal to 93 percent in Arunachal Pradesh) (Government of India, 1999). However, studies covering more than one year on dry forest ecosystems in India suggest an increase in tree diversity over time (Puyravaud et al., 1995; Saha, 2003; Saha and Howe, 2003).

The fire-influenced dynamics described above, between open grass-dominated systems and closed tree-canopy systems, have altered the abundance of large herbivores and predators dependent on them (Landsberg and Lehmkuhl, 1995). As long as grass-dominated ecosystems are maintained by fire, herbivores will have abundant forage (Johnsingh, 1986; Main and Richardson, 2002; Tomor and Owen-Smith, 2002). After a fire, the number of herbivores increases due to the higher nutrient levels available in the herb layer (Carlson et al., 1993; Moe and Wegge, 1997). However, in India, fire is employed to conserve the habitats of large herbivores, for example, the one-horned rhinoceros (*Rhinoceros unicornis*) and predators like tigers (*Panthera tigris tigris*) (Landsberg and Lehmkuhl, 1995). These fires are even set in areas where fires would be very unlikely without human ignition, for example, the Manas National Park (Takahata et al., 2010).

9.4 FIRE AS TOOL

The answer to the question "Why do people set fires to the land?", is more or less known in India. However, detailed studies show that unknown motivations to set fire exist within different cultural and ecological contexts, giving a fair idea as to what motivates people to set fires, but we have only a vague idea as to how many fires there are on a national or local scale. Regarding the motivations to apply fire to a particular landscape, Pyne (1994) refers to observations made by a forest officer in the Ghumsur Forest in Orissa at the beginning of the twentieth century who held bamboo cutters and forest license holders responsible for many of the fires. Additionally, fires helped to smoke bees out of trees for their honey, burn under Mango and Mohwa trees (also Mahwa or Mahua (*Madhuca longifolia*)) to clear the forest floor (to facilitate the finding of fallen fruits and flowers), roast tree seeds, burn the undergrowth around villagers (to increase visibility and reduce cover for tigers and panthers), clear land, produce better quality pastures, and to drive game out of the forest for hunting. A more quantitative observation was made at around the same time by the forest administration of the Madras presidency for 1922−1923 (Forest Department Madras Presidency, 1923), which stated that of almost a third of all forest fires started outside of the Reserved Forest, one-third could not be explained. Almost half of the remaining third were caused by hunters using fire to drive game and by graziers burning pastures to produce new grass shoots. Uncertainties that exist in the historical forest records mean that a large fraction of fires cannot be allocated to a cause. A further problem with the records is that they fail to provide reliable data about the total number of fires. Information regarding fire occurrence is obtained from Moderate Resolution Imaging Spectroradiometer (MODIS) data, but it can be expected to miss a great number of fires (Hawbaker et al., 2008).

However, from what is known today, the reasons why fires are lit in India can be allocated to six broad categories: (1) cultural, (2) utilization of nonwood forest products (NWFPs), (3) collection of wood products; (4) accessibility and safety, (5) pasture (land clearing) and hunting (game drives), and (6) agriculture.

9.4.1 Culture

Local people from Rajasthan's Satukonda Wildlife Sanctuary and Kumbalgarth National Park state that fires are lit annually to worship their Gods, with fires forming a golden necklace to worship the deity. Such observations made by the authors in the field have not been documented in detail for India until now. However, Krishna and Reddy (2012) state that "ethnic belief of tribes to worship the God" is the main source of wildfires in Rajasthan.

The use of fire is something that is inherited in India, and it has been so since the beginning of Indian culture (Pyne, 1994). Among some rural people there is also the belief that fire will initiate rain. This belief has been reported from Mexico by Goldammer (1978), and when local people in south India were asked for the reasons behind the annual fires in a dry forest (Schmerbeck, 2003), they gave the same answer. Roveta (2008) studied the use of fire among members of the Soligar tribe of the Biligiriranga Swamy Temple Wildlife Sanctuary, and learned that the burning of the forest floor for ceremonies and recreational purposes accounted for 11 percent of the importance fire had among other purposes.

However, considering the broader picture, it is felt that a much stronger motivation for setting fire to a particular part of the landscape exists as the potential for tangible gain.

9.4.2 Nonwood Forest Products

Since the hunter-gatherer times, NWFPs or forest products not obtained by the harvest of trees, have been important to humans. In this chapter, the term NWFP will be used according to Wickens (1994), who describes it as "all the biological material (other than wood products as defined above) that can be utilized within the household, be marketed or have social, cultural or religious significance" (p. 56). However, this definition does not include forage.

In India, for people who depend on forests, NWFP often plays a key role in their livelihoods (Hunter, 1981; Yadav and Dugaya, 2013). The provision of many of these products is strongly linked with fire because the products are obtained from forest ecosystems in which fire plays an important role. Case in point is the Tendu tree (*Diospyros melanoxylon*), a deciduous tree occurring in dry forest of the Indian Deccan, the leaves of which (Tendu Patta) are used for the production of small cigarettes (*bidis*) in India. This is the most well-known example of a commercial NWFP requiring fire for its production. The trees used for the Tendu Patta production are shrubby, and this appearance is a result of regular burning, which keeps the tree from growing to its full size. Fire also triggers the flushing of new leaves that are collected while they are still in an early stage of development. The *bidi* business is large, but just how large depends on the source of the figures. According to Lal (2012), 7.5 million people are employed part time to pluck tendu leaves, and 4.4 million women and children are engaged in manufacturing these cigarettes. In 2002–2003, the World Bank (2006) estimated that 360,000 ton of tendu leaves were produced, which is around 100,000–200,000 ton less than that in the previous two decades (1980–2000). But these figures are uncertain because it is difficult to obtain data for tendu and *bidi* production (Lal, 2012). Nevertheless, the tendu and *bidi* business give an indication of the extent to which products tied to fire cause an impact on the livelihood of rural people. There are several such examples to understand this connection between fires, products, and livelihoods; however, they are not all as commercially important as tendu leaves are. Table 9.1 provides a list of known NWFPs to date in India that are produced, utilized, or benefit from the use of fire. The fact that there are only a limited number of studies that have been done on this topic makes it likely that there will be more NWFPs added to the list in the future.

The importance of NWFP for the livelihoods of forest dwellers varies from location to location. Schmerbeck et al. (in press) found that there was a strong variation in the importance of forest products between villages in one area of Andhra Pradesh, and that the NWFPs that were made available by regular forest fires served mainly domestic purposes.

TABLE 9.1 The Role of Fire in Producing and Utilizing Nonwood Forest Products (NWFPs) from Indian Forests

NWFP	Species	The Role of Fire	References
Tendu leaves	*Diospyros melanoxylon*	Maintaining shape of plants and enhancing leaf flush	Hunter (1981), Saigal (1990), Goldammer (1993), Yadav and Dugaya (2013)
Honey	Miscellaneous	Induction of flowering and the production of smoke to drive away bees	Schmerbeck et al. (in press), Schmerbeck (2003)
Roofing material	Mainly C_4 grasses (e.g., *Themeda cymbaria, Cymbopogon* spec.)	Regular fires maintain abundance of required grasses	Roveta (2008)
Amla fruits	*Phyllanthus emblica*	Control of hemiparasites and enhancing production	Kohli (2010), Ganesan and Setty (2004), Rist et al. (2010)
Mahua seeds and flowers	*Madhuca longifolia* (syn. *Madhuca indica*)	Fire is lit prior to flowering/ fruit ripening. The cleared and blackened ground improves access and the visibility of fruit	Saigal (1990), Pyne (1994), Nanda and Sutar (2003)
Tree seeds	*Terminalia chebula Buchanania lanzan*	Enhancing production	Kohli (2010)
Brooms	Several grass species (e.g., *Aristida setacea*)	Regular fires maintain abundance of required grasses	Kohli (2010), Roveta (2008)
Eatable tubers and roots	Miscellaneous	Fire improves growing conditions for the species and makes the plants accessible	Kohli (2010), Roveta (2008)
Fertilizer	All	Postfire rains transport ash to agricultural fields	Pyne (1994), Roveta (2008)
Leaf cup	Unidentified	Fire triggers the flush of leaves	Kohli (2010)

9.4.3 Wood Utilization

The role of fire in timber production has been reported from colonial times in India. Pyne (1994) provides a nice overview of the position held by the forest administration regarding the role of fire in forest management. The British administration applied the European forest protection policy to the Indian forest with the goal of protecting several timber species (mainly Sal, Teak, and Chir Pine stands) as well as commercial bamboo from fire. This policy thoroughly changed the ecology of the ecosystems involved and made the regeneration of the targeted species uncertain. Even though the debate regarding the role of fire never led to a clear consensus, it became evident that fire was required for the continuity of many species on a given site. However, today timber production is not a priority in India so the use of fire plays a minor role in the debate about forest fires.

Much more important and under estimated by scientists, ecologists, and land managers in India is the role of fire in producing fuel wood. This connection has been observed in a few local studies (Schmerbeck et al. (in press); Roveta, 2008; Schmerbeck, 2003) and has been referred to in some studies outside India (e.g., Hough, 1993 (Benin); Vayda, 1996 (Indonesia); Laris, 2002 (Malawi)). Light-to-medium-intensity fires fully or partially kill the above-ground parts of woody plants. Because the majority of these fires are of a low intensity, the wood is not fully burned and leaves behind dry wood that can be collected for fuel wood. Fire also clears the ground and makes the area more accessible for fuel wood collection. Such practices involving fire can be improved through regulation by the forest administration, which manages the collection of dead wood (Schmerbeck, 2003). Also observed by Schmerbeck (2003) was the collection of bark from *Euphorbia antiquorum*, a tree-like xerophytic plant, after it had been killed by fire. The bark was used to produce charcoal locally. The charcoal was sold in a nearby town to goldsmiths who valued this fuel for its steady flame.

9.4.4 Accessibility and Safety

Pyne (1994) again provides us with an eye-witness account of fire used to make an area safe from dangerous animals. He describes a practice used by tribes during the British Raj: “A veteran Conservator of Forests, G.F. Pearson, noted that even the Ghonds, a long-enduring tribe of Indian central forests, ‘never go into the jungle now, where tigers are supposed to live, without setting it on fire before them, so as to see their way’” (pp. 3, 4). However, fire does not only provide safety from large predators but also safety from poisonous vertebrates and invertebrates (e.g., snakes, scorpions, and leaches) as well as insects like ticks (Roveta, 2008).

Although it cannot be empirically proved, it seems likely that keeping the landscape, especially the forested parts, easily accessible is more important to the people than making an area safe; nonetheless, forest clearance achieves both objectives. Roveta (2008) quotes a respondent to a survey who stated “I was walking in the forest with my father—at that time I was very young—and the path was closed by the bushes, therefore my father decided to set fire in

FIGURE 9.1 A degraded dry forest in Tamil Nadu, South India: wildfire provides accessibility by reducing thorny woody species and grasses. *Photograph courtesy: Joachim Schmerbeck.*

order to clean the way" (p. 37). It is just such human behavior (making a decision to burn) that caused the growth of such pioneering, and thus the conditions for the growth of woody thorny bushes and tall grasses in the first place. Both these species make it difficult to move through the forest, while after a fire, it becomes very easy (Figure 9.1).

Access improvements also allow herders to more easily move their livestock from one place to the other (Roveta, 2008). The close connection that exists between accessibility and use of forest products in the context of wildfires is illustrated by Kohli (2010). She investigated the utilization of tangible ecosystem services that depend in one way or the other on the presence of wildfire. She surveyed 557 households in 14 villages adjacent to a dry forest in Andhra Pradesh. Respondents were asked to rank the importance of ecosystem services associated with wildfire. Highly ranked was the accessibility to the forest due to burning, while at the same time there were some household respondents who did not even mention accessibility.

9.4.5 Pasture and Hunting

The practice of setting fire to vegetation to improve forage is a worldwide practice. The principle is straightforward: forage species, mainly grasses, are set to fire, but the grasses are not entirely consumed. Fire removes the parts of the grass that are above the soil surface, and often nothing but the bare soil remains. The ash fertilizes the soil leading to a fresh flush of grasses (Laris, 2002). These fresh grasses, due to their higher nitrogen (Lü et al., 2012) and crude protein content (Mbatha and Ward, 2010), are a better quality fodder than are grasses that sprout without being burned. Based on the frequency with which fires are mentioned in the literature in connection with forage improvement (Hough, 1993; Kepe and Scoones, 1999; Laris, 2002; Mistry et al., 2005; Shaffer, 2010; Vayda, 1996), this use of fire is likely predominant worldwide. In India, fires set to enhance the availability of fodder for domestic animals are the most common cause of wildfires (Brandis, 1897/1994; Goldammer, 1993; Government of India, 1999; Kohli, 2010; Sinha and Brault, 2005; Schmerbeck and Seeland, 2007; Roveta, 2008). However, none of these studies looked at the amount of area burned compared to the actual requirements for forage ground or fodder.

The effect that fire has on the quality of resprouting grasses also attracts wild herbivores. Hunters use fire in this way to attract prey. Further, poachers have been known to use this same tactic, although much less land gets burned in this manner. The early inhabitants of the country also used fire for hunting (Goldammer, 1993; Government of India, 1999). Fire is used today to provide habitat for herbivore species targeted in biodiversity conservation approaches (Takahata et al., 2010). It has been reported that fire is used by Australian Aborigines (Gott, 2005) to drive prey out of thick vegetation into the open where it can be killed. Although, there are no recent reports from India about the use of such sophisticated practices, it is likely that they did occur in India as historic records allocate a significant proportion of the fires to this reason (Forest Department Madras Presidency, 1923).

9.4.6 Agriculture

A look at a fire distribution map of India (Vadrevu et al., 2013) reveals two main wildfire hotspots: the north western plains and the forests of the northeast. The cause of the wildfires in the northwest has been linked to an agricultural practice: that of setting fire to postharvest fields (Kharol et al., 2012). In the northeast, wildfires are mainly caused by slash-and-burn agricultural practices in forests (Vadrevu et al., 2013). The burning of postharvest fields and slash-and-burn agriculture are also practiced elsewhere in India, but nowhere are these as frequent as in these two regions.

Burning in the agricultural sector has often been reported as a cause of forest fires. In fact, a large proportion of the total wildfires in India are caused by farmers. This happens when postharvest fires escape and end up burning forests (Forest Department Madras Presidency, 1923; Kurian and Singh, 1996; Roveta, 2008) and also when clearance fires, used for clearing land for agriculture, escape into forests (Bahuguna and Upadhyay, 2002; Government of India, 1999). When fire is applied to agricultural fields, it is considered a tool but when it gets out of control (escapes) and starts a forest fire, it is an accident. The figures available for such accidents range from 40 percent (Vadrevu et al., 2008) to 69 percent (Singh and Panigrahy, 2011) of the total fires in India annually. Fires have a strong impact on air quality

(Kharol et al., 2012; Singh and Panigrahy, 2011) and may influence agricultural soils (Mataix-Solera et al., 2011) and water regimes.

In the northeast of India, fires are mainly caused by shifting cultivation carried out in forests. In India, the practice is known as "Jhum," (Semwal et al., 2003). Kingwell-Banham and Fuller (2012) reviewed the practice of Jhum in India and Sri Lanka and identified five ethnic groups, based on language families that were practicing Jhum. Most of the groups from India were in the northeast, the northeast peninsula, and in the southern part of the Western Ghats. According to these authors, the groups practicing Jhum are a mix of three different strategic groups. Only one of these groups consists solely of shifting cultivators, while the other two groups also consist of hunter-gathers and settled agriculturalists. However, it is in the north east region of India where Jhum is clearly most intensively practiced judging by the number of the fires (Vadrevu et al., 2013) and the number of groups practicing it (Kingwell-Banham and Fuller, 2012). However, the number of people demanding land for shifting cultivation in the northeast is increasing. The increasing number of people and their land-use practices result in some serious consequences such as a loss of soil fertility, decreasing forest cover, a reduction in market crop productivity (due to shorter agricultural cycles), reduced system stability and resilience, loss of biodiversity, and large-scale desertification (Ramakrishnan, 2007).

9.5 FIRE AS A HAZARD

A common definition of natural hazards is the threat of a naturally occurring event with a negative effect on people or the environment (Wisner et al., 2004). During the annual long and intense dry seasons in the region, fires are a regular phenomenon, and many of them have the potential to cause major damage. Most fires in India do not directly threaten lives and property, but they may have a strong impact on human health by way of the haze and smoke they produce. However, some fires do directly affect lives and property even though they are rare. By far, the most serious negative effect of such hazardous fires in India includes the loss of livelihood for tribal and rural poor people. Additionally, they result in a loss of timber, NTFPs, fuel wood, fodder, and soil fertility. They also degrade catchment areas when a certain threshold for fire occurrence and frequency is reached. Further, they damage cultural heritage sites and the land-use systems that provide the basis for the livelihood of forest-dependent people living in rural India (Poffenberger and McGean, 1996). Hazardous fires that burn sensitive mountain ecosystems can be the indirect cause of landslides, mudslides, erosion, increased water run-off, flash floods, and soil depletion. Although official statistics and information on fire losses are rather weak, the costs to regenerate forests damaged by forest fires are estimated to be Rs 4,400 million (US$96 million) annually (Bahuguna and Upadhyay, 2002).

Regular fire use for land-use activities increases the probability of uncontrolled fires. Some of the affected ecosystems are extremely sensitive to fire, but without subsequent ignitions, these ecosystems can recover (Cochrane, 2002; Myers, 2006). An overall trend of increased ignitions and the consequent dramatic changes in vegetation structure and fuel characteristics can be observed. This is especially the case where fire creates a positive feedback loop that leads to increasing flammability and drier conditions even in nonfire-prone vegetation (Cochrane, 2001; Goldammer and Mueller-Dombois, 1990). The excessive use of fire in association with an increase in population and land-use changes has led to a shift in vegetation types toward more pyrophytic (tolerate fire) plants as described above. The impact of these changes is strongly dependent on the social and ecological effects of contemporary fires. Despite the existence of traditional fire management systems such as Jhum, an increase in population pressure has resulted in land use changes and the migration of people into formerly untouched areas increasing the incidence of fire (Poffenberger and McGean, 1996). All areas, not only those with fire-prone vegetation types like tropical grasslands, savannas, and dry deciduous forests, have experienced decreases in tree cover and density.

Another hazardous side effect of the widespread burning practices in India is air pollution and the contribution of atmospheric aerosols and trace-gas emissions. Carbonaceous or black carbon (BC) aerosols cause strong atmospheric heating and large surface cooling that is as important to south Asian climate forcing as greenhouse gases (Babu et al., 2002; Badarinath et al., 2009b). The phenomenon is most persistent in south Asia, and has also been identified around large metropolitan areas in many tropical locations (Andreae et al., 2005). The continuous increase of BC aerosols over northern India and the southern slopes of the Himalayas has resulted in the formation the dense "brown clouds" that plague south Asia each winter. The clouds affect precipitation patterns, cause the melting of Himalayan glaciers, and result in increased heating rates in the lower and midtropospheres (Gautam et al., 2009; Gautam et al., 2010; Lau et al., 2006; Prasad et al., 2009; Ramanathan et al., 2001). The emissions from rural fire activities may have significant implications on atmospheric chemistry, climatic changes, and human health (Badarinath et al., 2009a; Vadrevu et al., 2011; Sharma et al., 2010). A thick blanket of haze formed by a mix of wood and dung fires, fossil fuel burning, wildfires, agricultural fires, and dust has been seen to develop during the beginning of winter from air masses building up against the Himalayas under continuous west wind situations. Lawrence and Lelieveld (2010) identified the largest concentrations of BC aerosols over the Indian subcontinent with the main sources being fossil fuel and biomass burning. Widespread burning of biomass, such as dried twigs, leaves, and dung and agricultural slash-and-burn practices, are common across poor, rural Asian areas where extensive forest and agricultural fires occur in India, especially in the north western part during

October and November each year due to crop residue burning (Sharma et al., 2010). Badarinath et al. (2009a) identified biomass-burning aerosols over Arunachal Pradesh during shifting cultivation practices. Gustafsson et al. (2009) suggested that biomass burning and particularly small-scale burning practices are the main cause of the dense brown clouds that affect the health of people inhaling the pollutants that are causing bronchitis and asthma. Smoke from agricultural burning contains numerous substances that can harm human health, including carbon monoxide, nitrogen oxides, and particulate matter (Lawrence and Lelieveld, 2010). The soot in the brown haze can be potentially linked to the hundreds of thousands of deaths each year mainly from lung and heart diseases (UNEP, 2011). Additionally, the brown cloud acts as a "global dimmer" through absorbing heat trapped by greenhouse gases. It also affects the regional climate, crop growth, and glacier melting through extended dry spells and increasing wildfire events (Ramanathan et al., 2007).

9.6 OUTLOOK

From our review, it is obvious that wildfires in India play a minor role as a hazard but are an essential tool for landscape management. However, the air pollution caused by agricultural burning not only impacts the health of people in close proximity to the burned fields but also those who live at great distances from them. To prevent such fires, we need to discover/develop alternative agricultural systems that do not require postharvest burning. An alternative system will likely mean more work for farmers and cost more to implement than the existing agricultural burning systems. Given this, it will be a challenge to convince farmers to change their practices.

It is most important to prevent agricultural fires from escaping into adjacent forests. This requires planning, basic fire knowledge, and strict regulation. For farmers who are cultivating encroached forestlands, the control of fire is certainly more difficult, and the risk of forest fires is greater compared to farmers burning agricultural land outside of the forest. But if wildfires are to be prevented, the cultivation of encroached forestlands should be banned.

Although accidental forest fires provide services from the forest, they are not necessary services; therefore, accidental forest fires can be seen as a less complex issue than fires put to a landscape by multiple stakeholders with a number of different motivations. When looking at the broad range of uses for fires, it appears to be impossible to totally avoid wildfires in India. There will always be somebody who requires wildfires for one reason or the other.

The aim of a national fire policy therefore cannot be to absolutely prevent wildfires, but rather to reduce their number and regulate the use of fire. The greatest chance of success for this policy lies within uncomplicated social settings, for example, where only one group of people burn the forest for one reason. The implementation of a fire reduction program in such places requires a number of key pieces of information upfront. First, how much land is required by the people to fulfill those needs that require the use of fire? Second, when fires are eliminated/reduced, there will be a response in the vegetation and we should be able to estimate/calculate future fuel loads and the susceptibility of the new ecosystem to fire. This knowledge will also allow for silvicultural operations toward demanded forest formations beyond fire-prone stages. Third, it is necessary that the forest functions and ecosystem services of the future forest are known to be able to plan their role in landscape management. Such an approach will allow for watershed or landscape-based planning that optimizes the management of the landscape in terms of its provision of ecosystem services.

A national or statewide fire prohibition policy will not achieve the desired results. Instead, a new fire policy must be worked out, one that provides a frame work allowing for many different fire applications based on the knowledge about local social settings, motivation for the use of fire, and the response of ecosystems to fire regimes.

It is important that decision makers at all levels are informed about the current extent of wildfires in India, the impact they have on ecosystem functioning, and the unavoidable trade-offs regarding the supply of ecosystem services under a changing fire scenario. Even though research of this sort is limited in India, there is sufficient knowledge available from international literature sources. With this information, fire policies at the state and national levels can be established. The policies should allow for fire regimes that are adapted to local settings, and the policies are expected to reduce the area burned.

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