Forest Fires in India

WORKSHOP PROCEEDINGS

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These are the proceedings of a workshop held in Madurai, Tamil Nadu, between the 19th and 23rd of February 2007 for the preparation of a research project on wild land fires in India. These proceedings comprise extended abstracts of the presentations made during the workshop and a summary of the discussions during the workshop. The workshop was organised by the Institute of Silviculture, University of Freiburg (Germany), ATREE Bangalore and Delhi (India) and the Evergreen Trust, Genguvarpatti (India). It was supported by funds from the Foundation for Ecological Security, Anand (India) and ATREE.

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Introduction

India has a policy of fire suppression which dates back to the first formal articulation of forest policy in 1927. Yet, even today, almost a century later, fire continues to be an annual phenomenon in almost all Indian forests. This obvious contradiction between fire policy and fire reality raises a number of questions regarding the drivers of fire, the role that fire plays in ecological processes, the extent of fires in India, and the existing fire policy. For instance,

- Are occurrences of fire natural or anthropogenic?
- Are fires beneficial or detrimental in their effect on ecosystems and on human society?
- What proportion of forests burn annually?
- Are some ecosystem types more prone to fire than others?
- Is our century-old fire policy still relevant in today's altered landscape?

Issues such as these motivated the organization of a workshop on forest fire in India, which was held in February 2007. The workshop was jointly organized by Joachim Schmerbeck of the Institute of Silviculture, University of Freiburg, and Ankila Hiremath of the Ashoka Trust for Research in Ecology and the Environment (ATREE), in collaboration with the Foundation for Ecological Security (FES) and the Evergreen Trust.

The workshop drew participants from different parts of India as well as from Indonesia, Germany, Switzerland, and the US. Participants represented a diversity of backgrounds – scientists and social scientists, managers and practitioners. Unfortunately, representatives of neither the Indian Ministry of Environment and Forests, nor the National Remote Sensing Agency were able to attend the workshop, though both agencies have expressed their interest in being associated with future initiatives resulting from the workshop.

Forest Fires in India: Dealing with the issue - The project idea

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Forest fires are a driving factor in shaping forest vegetation and landscape in many parts of India. Even so, very little is know about the extent of these fires, the causes of ignition, and the role fires play in local forest management practices and in the supply of forest services. We describe this situation briefly with the aid of a case study. We also discuss the theoretical context of forest fires and highlight the need for a research initiative on wild-land fires in India.

Scientist and practitioners dealing with forests in India widely agree that most of terrestrial India was almost entirely forested prior to the arrival of humans. Today only around 20% of these forests remain and directly, or indirectly, these forests serve the needs of a large fraction of India's population. Many of these forests have an open structure, which is mainly caused by the way forest products are utilised, within which fire plays a vital.

An example of fire utilization can be seen in the Kadavakurichi Reserved Forest, a 10 km², degraded dry-tropical forest in the plains at the foot of the Palni Hills, Tamil Nadu. The forest is located on a small hillock with an elevation ranging from 300 to 700 m asl. It receives 750 mm avg. rainfall annually. We collected information about the kinds and intensity of forest uses in the 19 villages that surround the area and conducted an extensive vegetation survey in plots that were evenly distributed throughout the forest. The entire study area was divided into five watersheds that included the forest as well as the areas surrounding it. Forest fires observed during the study period were recorded at the watershed level.

The forest consists of thorny and shrubby vegetation with an average height of 2 meters, alternating between thorny thicket, savanna, and grassland. The forest is mainly used for fuel wood collection and for grazing livestock, and as a source of products like green manure, honey, and medicinal plants. We used a multiple regression to test the extent to which site conditions explained the existing vegetation. The results showed that vegetation parameters such as the presence and structure of trees, shrubs, and grasses were only very weakly predicted by different site conditions such as soil type, aspect, slope, etc.. The only significant correlations were either very obvious (e.g., negative correlation between area covered by rock and biomass of a plot) or were human driven (e.g., positive correlation between increasing elevation and tree size). In the second step, the significantly different intensities to which different watersheds were used were factored into the regression model.

However, this only served to increase the predictive power of the model slightly, thereby indicating that there must be other factors that help to shape the current vegetation structure and distribution.

The forest fires that occurred during the study period could not be assessed at a plot level, as we worked with temporary plots. But records of forest fires over the last two years of survey indicate that fire occurred in small patches or over large areas covering almost the entirety of the hillock. The fire traces on trees and shrubs that have been recorded are evidence that fire occurred even in places where no fires were observed during the study period. It is therefore very likely that fire is one of the important factors, if not the most important factor, that shapes the vegetation in these areas, even if other anthropogenic activities differ among locations.

Kadavakurichi is composed of different types of representative degraded dry forests that can also be found at lower elevations of the Palni Hills, the Sirumulai Hills, and other nearby hilly areas in Tamil Nadu. Fires can be observed in all of these forests annually throughout the year, suggesting that fires maintain the forests in a degraded state, similar to the Kadavakurichi forests.

The literature on fires in Indian forests shows that they play a vital role throughout the country. They have been mentioned throughout the period of scientific forestry as a major cause of degradation of forests. Very few empirical studies have been done on the reasons for these fires and in most cases their origin remains unclear. Available evidence suggests that fires are employed to maintain the grass layer for cattle grazing and that they facilitate the collection of several non-wood forest products (NWFP). It can be stated that fires are set to gain a certain benefit or, in other words, to obtain a specific ecosystem service, using the Millenium Assessment's definition of the term to include both tangible products as well as intangible services. The list of tangible products obtained with the help of fire is a long one, and ranges from fodder and NWFP to fuel wood and charcoal. The intangible services obtained with the help of fire are more difficult to assess and so far there have been very few studies on this topic in India. Fires certainly have an effect on biodiversity, carbon sequestration, water regulation and air pollution. These services do not necessarily affect those who set fires, but they matter on a larger scale. Services that are relevant at a local level are of more of a traditional or religions nature (e.g., at Kadavakurichi one reason that emerged during the study was that fires were believed to cause rain when set). At any rate, the reasons for the use of fire vary strongly at the local level and can only be generalised to a certain extent.

We propose a theoretical framework (Fig. 1) to try to explain the linkages between fire application, vegetation dynamics caused by fire, and the provision of ecosystem services.

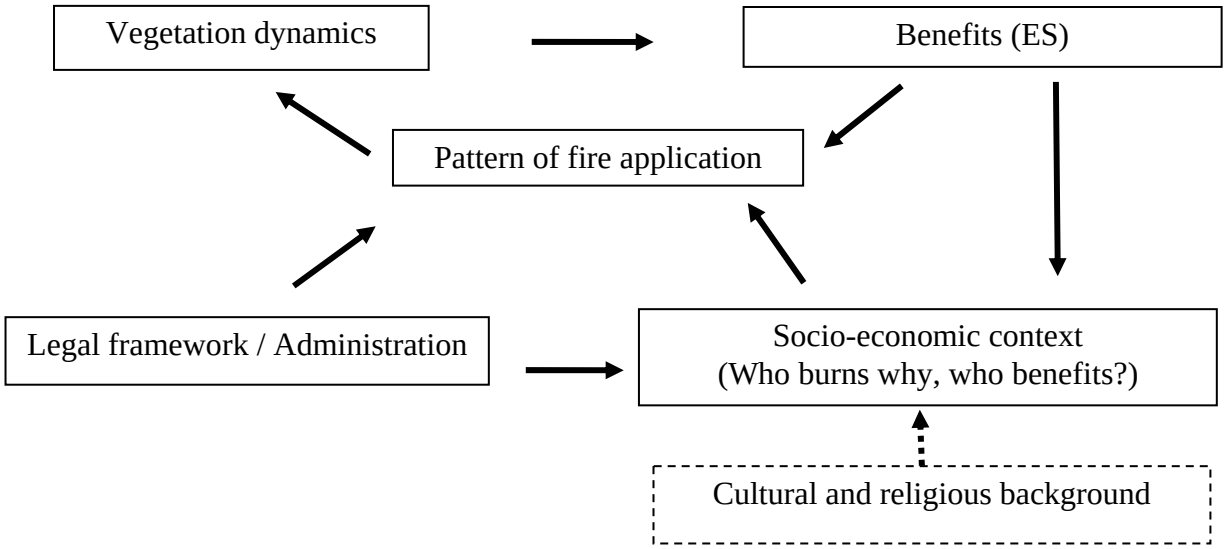

Figure 1: Factors influencing the pattern of fire application and its linkage to the supply of ecosystem services (ES). [Note: dashed lines indicate linkages that are expected to play a minor role.]

Fire changes the dynamics of vegetation in the forest. It modifies the vegetation in such a way as to provide particular products and services that benefit those who set the fires, or others who take advantage of the situation. The type and amount of products, in turn, influences the pattern in which fire is applied (e.g. low availability of the products utilised could lead to an increase of the burned area). The fire pattern can also be expected to be a result of the socio-economic context. It can be expected that people only burn the forest if a more attractive income-generation activity is not available to them, and that once they have alternatives for income generation they may reduce the frequency with which they set fires. It may also influence the way fire is applied if the fires are set by the beneficiaries themselves or of others' benefit. This socioeconomic context of fires is also influenced by the product itself. If setting fire facilitates collection of a valuable product (e.g. honey) it may be used by more people in a certain location than if the income would not be attractive. The legal framework and the administration that enforces it are other important factors influencing the occurrence of forest fires. Forest fires are strictly forbidden by law and the grade of enforcement will reduce the impact of fire on the forest and therefore the vegetation dynamics. This again changes the variety and amount of benefits provided. Beside these factors, the socio-economic context is likely to be influenced by the traditional and religious settings. The way fire is perceived and used in daily life could be, to a certain degree, determined through the role fire holds in rites and religious practices.

Most of our existing knowledge about fires is based on a very thin layer of empirical research and scientific certainty. Given the scale at which forest fires occur in India, their

impact on the vegetation, and also given the large gap between the legal framework and the actual practices of local forest management, we think it would be timely to study the matter in greater depth. We need to study the theoretical relations surrounding fires (figure 1) with scientific methodology to discover ways of directing fire application and therefore the supply of ecosystem services. This includes understanding forest vegetation dynamics in relation to the fire regime, the role fire plays in the provision of ecosystem services, and the social background behind fire applications. This will help us to understand the behaviour of local forest dwellers and to plan landscape-level management accordingly.

Fire Regimes and Ecosystems:
An Overview of Fire Ecology in Tropical Ecosystems

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A wide variety of ecosystems in the tropics are affected by land-use activities and vegetation conversion practices that either involve the direct use of fire or increase the probability of uncontrolled fires. Some of these ecosystems are extremely sensitive to fire, but without subsequent ignitions that lead to extensive wildfires, they can recover. As an overall trend, increased ignitions result in dramatic changes in vegetation structure and fuel characteristics which can be observed: fire creates a positive feedback loop that leads to increasing flammability and drier conditions. The excessive use of fire in association with demographic development and land-use changes throughout the tropics may lead to a shift of vegetation types towards more pyrophytic life forms and consequently to an alteration of fire regimes. The impact of these changes depends strongly on the social and ecological effects of contemporary fires. In many biomes throughout the tropics, rural populations have continued to use fire in traditional ways to a relatively small extent, but increasing population pressure leads to land-use changes or migration into formerly untouched areas. As a consequence, increasing ignitions are decreasing tree cover and density, not solely in fire-prone vegetation such as tropical grasslands, savannas, and dry deciduous forests. Even under climatic conditions where fire occurrence has been negligible over evolutionary time scales, anthropogenic grasslands and savannas are developing at the expense of the natural tree cover. On the other hand, burning is an integral part of land-use management in many tropical societies with fire seen as an important tool for people in assuring sustainable livelihoods and land-use practices. Human societies and economies, in general, tend to prefer to keep their environment stable rather than living with a dynamic, changing environment. Whether or not this strategy is successful depends very much on the environmental conditions of an ecosystem and the ability of society to react to ecosystem changes. These measures can be top-down or bottom-up (community approach) initiatives. However, climatic patterns can complicate fire events by further altering the conditions within which ecosystems develop. Some climatic cycles, including El Niño/La Niña and others, are predicted to become more frequent and more extreme with global climate change. These events can contribute to large-scale fires that overwhelm local fire management capacities. For example, in Indonesia and other Southeast Asian nations, El Niño years (such as those in 1997–1998) can result in

severe drought, which, when combined with human ignition, results in huge areas burned by tropical forest fires.

For millions of years, lightning-ignited fires have driven the evolution of fire-adapted traits in plants. The large area occupied by flammable biomes in the tropics and subtropics is often attributed to anthropogenic burning. Yet, the occurrence of natural fires and flammable ecosystems pre-date anthropogenic burning by millions of years. Recently, there has been evidence that the expansion of C4 grasslands during the late Miocene was driven by natural fires rather than by decreasing atmospheric CO2. Unlike in the humid or moist tropics, fire is an ecologically important disturbance factor in the seasonal tropics. Dry deciduous forests and savanna grasslands have co-evolved with fire as a disturbance factor. Most plant life forms of these tropical biomes can cope with fire through various adaptive strategies. On the contrary, over evolutionary time scales, fire has played a less significant role in tropical evergreen forests, as the plants in these forests show no specific adaptations to fire. Meanwhile, natural fire regimes in fire-adapted ecosystems were variable in terms of affected area, frequency, and intensity. The term ‘fire regime’ refers to the pattern of fires that are characteristic for a given ecosystem, and depends on fuel characteristics and climatic conditions. The interplay of the effects of fire type, seasonality, intensity, pattern, and size determines the extent to which a change in any of these factors leads to a change in an ecosystem’s fire regime. Although climatic conditions have been identified as the predominant factor for fire occurrence at the evolutionary time scale, most fire regimes are now anthropogenically driven. Landscape fragmentation and land cover changes are especially significant elements in the changing probability of ignition and the severity of fire occurrence in many tropical ecosystems. But fire regimes can also be modified by successful fire suppression and prevention. A sound understanding of the fire ecology in tropical ecosystems is usually a prerequisite to identifying social and ecological constraints and benefits of fire application in the tropics. Although fire impacts are widely recognized as important disturbance factors in some ecosystems, many ecologists still fail to incorporate the role of fire into their thinking about natural ecosystems especially in the tropics.

Tropical ecosystems can be classified into fire sensitive, fire dependent, and fire independent ecosystems. Ecosystems where most plant life forms do not show specific adaptations to fire are considered fire sensitive, since they have not evolved with fire as a repeated process. Nevertheless, fire could create important habitats and niches. When fire moves the entire ecosystem beyond a certain threshold, or as happens very frequently, it causes severe damages and could lead to a complete loss of the ecosystem. Species composition and vegetation structure in fire independent ecosystems hinder ignitions and fire spread through low flammability. Most species lack abilities to respond to fire and mortality is usually high, especially in fire sensitive ecosystems.

When ecosystem fragmentation results in a greater edge-to-interior ratio, fuels are altered and ignition probability increases, whereas fire occurrence under undisturbed conditions in these ecosystems may be negligible.

Examples of fire-sensitive ecosystems are the wide variety of per humid to moist tropical forests with relatively stable temperatures and high humidity in the interior due to high evapotranspiration rates beneath the canopy. Despite high temperatures and large amounts of potentially burnable biomass, these factors keep tropical rain forests rather immune to fire. As a consequence, these forest ecosystems also can be considered fire independent under undisturbed conditions. Yet, there are a number of ecosystems whose category remains uncertain and where the role of fire as a disturbance force has not been identified. Since tropical rain forests are increasingly being exposed to more and more logging pressures, there is a significant shift of former fire independent ecosystems towards fire influenced and fire sensitive formations by the expansion of adjacent flammable vegetation.

Ecosystems where fire is an essential process to maintain species composition, biodiversity, and structure are considered to be fire dependent. They are also often referred to as ***fire-adapted*** or ***fire-maintained*** ecosystems. When fire is excluded or the fire regime is modified beyond its usual range of heterogeneity and variability, the ecosystem will change to a different stage, resulting in a significant loss of habitats and species. Usually, individual species within fire-dependent ecosystems have evolved in response to specific fire regime characteristics such as frequency, intensity, and season of burn, and to the variability inherent within these characteristics. Examples of fire-dependent ecosystems can be found throughout the tropics. A wide variety of fire dependent pine forests and pine savannas across Central America and the Caribbean, and extensive open pine forests and woodlands in the tropical and subtropical environments of Southeast and South Asia face frequent fires; here fires act as a key ecosystem driver in maintaining stand characteristics. Fire-maintained palm stands and palm savannas are common throughout the tropics.

The vast landscapes of tropical and subtropical fire-prone savannas and woodlands in large parts of Africa have been shaped by the longest history of human-involvement with fire in the world. Other tropical grassland types include the neo-tropical savannas in the Gran Sabana, the llanos of Venezuela and Colombia, and the Brazilian Cerrado, a mosaic of savannah and scrubland shaped by diverse fire regimes. Many ecologists also consider fire as an integral part of tropical alpine formations such as páramo and Afro-montane vegetation.

Ecosystems where fire plays a minor role or no role at all can be described as fire independent. Fire independent systems occur because temperatures, lack of seasonal precipitation patterns with wetting and drying periods, or insufficient fuel loads, do not allow fire. Examples include cloud and rain forests in aseasonal environments (see above), deserts,

or tundra. Fire becomes a threat only if there are significant changes to these ecosystems caused by land use activities, species invasions, or climate change.

Altered fire regimes have been identified as one of the key threats to biodiversity. A fire regime can be modified by human activities, such as excessive or inappropriate burning, by ecosystem conversion or fragmentation of the natural environment, but also by fire suppression and prevention. As a consequence, the resulting altered fire regime may affect the structure of desired ecosystems and the sustainability of goods and services that those ecosystems deliver. To maintain desired structure, composition, and functioning of certain ecosystems, humans have been changing fire regimes for millennia to keep their environment in a stable condition. As a result, an *ecologically appropriate fire regime* is not necessarily a *natural fire regime*. There are various reasons why humans have been burning when inhabiting a fire-prone environment, however, this often resulted in frequent burning. Smaller populations in smaller areas in the past were often able to manage their ecological resources through a bottom-up approach. When a region is small enough, all individuals are often able to observe their immediate impact on the environment and adjust their behaviour accordingly. In ideal cases, people solve these collective ecological problems by cooperation. For larger societies with centralized political organisation there is a lack of reliable ways through which to transfer local people's knowledge to facilitate effective resource management. Ecological resources are generally managed with a top-down approach where rules are set to maintain ecosystem productivity below an appropriate set carrying capacity for the maximum benefit of society. Often these benefits are difficult to quantify and are not seen in the timescale of one generation. Additional confounding factors include corruption and a general lack of good governance in many rural areas of the developing world which can limit the successful implementation of a community-based management approach. Given all these socially and economically limiting factors, communities are in need of fire management strategies that are consistent with their needs and abilities to react to ecosystem changes, while not having detrimental impacts on the environment.

In many tropical ecosystems fire is a severe problem since each year's fire-caused ecosystem degradation accumulates in the future. Fire is gaining momentum as a commonly-used ecosystem management tool, while at the same time, the increasing scale at which it is used means that people are losing their ability to control it in many tropical ecosystems. However, fire's importance is currently underestimated by local populations, policy makers, and ecologists. The key to bridging the gap in understanding is most often the local population's perception of fire and their concept of fire management. Without much needed support for solutions from the people that inhabit the wide variety of tropical ecosystems affected by fire, most measures such as improved education and fire management are likely to show little effect.

The pressing questions now are: Are the contemporary fires that are burning regularly in short-return intervals beneficial or damaging? How do we need to manage natural and human-caused wildfires? To what extent do we need to foster the application of prescribed fire to maintain productivity, carrying capacity, and functioning of ecosystems in the seasonal tropics? What are the goods and services of a given or desired fire-prone ecosystem or vegetation structure and what is the fire regime that will maintain these values?

Given these questions, we need further understanding of these ecosystem processes as well as the human dimensions of natural fires and fire management in the tropics.

The effects of fire and grazing on stability and dynamics of savanna grassland communities in the Kalakad-Mundanthurai Tiger Reserve, South India

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The Kalakad-Mundanthurai Tiger Reserve (KMTR), situated at the southern end of the Western Ghats, a global biodiversity 'hot-spot', is home to a diverse array of plant and animal species including several endangered species such as tigers (Panthera tigris), leopards (Panthera pardus), elephants (Elephas maximus), gaur (Bos gaurus), lion-tailed macaques (Macaca silenus) and Nilgiri tahr (Hermitragus hylocrius). In addition, it is recognized as a center of high plant diversity in India and also represents the southernmost range of the tiger, making it an area of high conservation priority.

In recent years, the reserve has witnessed changes in its plant and animal communities. Of particular concern with respect to the site's designation as a tiger reserve, is the fact that populations of large herbivores and predators in the region are currently low, and that large tracts of the reserve are dominated by unpalatable tall-grass species such as *Cymbopogon flexuosus* or lemongrass. In the Mundanthurai plateau region of KMTR, 22% of the area is covered by *C. flexuosus*-dominated savannas, representing poor quality habitat for herbivores. Although quantitative data are lacking, anecdotal reports suggest that this widespread dominance of unpalatable tall-grasses is a recent phenomenon; large sections of the plateau remained relatively open until the late 1980's-early 1990's, supporting higher herbivore numbers than toda.

The reasons underlying the current widespread dominance of the tall-grass species C. flexuosus in the Mundanthurai Plateau is unknown. What is clear, however, is that there is an urgent need for management interventions to improve forage availability for ungulates and thereby augment herbivore populations in the reserve. Previous research in the park has stressed the need for improving habitat quality for herbivores, with prescribed burning proposed as a means to this end. Although prescribed burning is often used by managers to improve habitat quality and increase forage availability for herbivores in the world's grasslands and rangelands, the efficacy of such a management strategy to suppress unpalatable tall-grass species in KMTR has not been previously assessed. To this end, an experimental study aimed at investigating the individual and interactive effects of fires and mammalian grazing on savanna-grassland plant community composition and diversity was initiated in 1997. A primary objective of the study was to examine the responses of unpalatable tall-grass species to these perturbations, and thereby evaluate the effectiveness of fire as a tool to control tall-grasses and improve herbivore habitat quality in the reserve.

Three different sites, dominated by the unpalatable tall-grass species Cymbopogon flexuosus, were selected for this study. At each site, a 15x15 m area was demarcated consisting of a square grid of nine 4x4m2 plots with a 1m gap between plots and a 50cm walkway around the edge. Each plot was randomly assigned a burning treatment (unburned, burnt once a year, or burnt once, every 2 years) and a grazing treatment (either ungrazed, grazed, or experimentally clipped). All experimental burns were conducted at the start of the dry season in March 1997. A further subset of these was burned again in March 1998. In plots assigned clipping treatments to simulate high-intensity grazing, vegetation was clipped down to about 5 cm every 15 – 30 days depending on growth. Plots were monitored over time and the response of tall-grass species to the treatments evaluated.

None of the burning treatments had any significant effect on the cover of the tall-grass species *C. flexuosus* in plots, suggesting that this species is highly resistant to fire (Fig. 3). Fire, by itself, is therefore unlikely to cause significant changes in the dominance of this species.

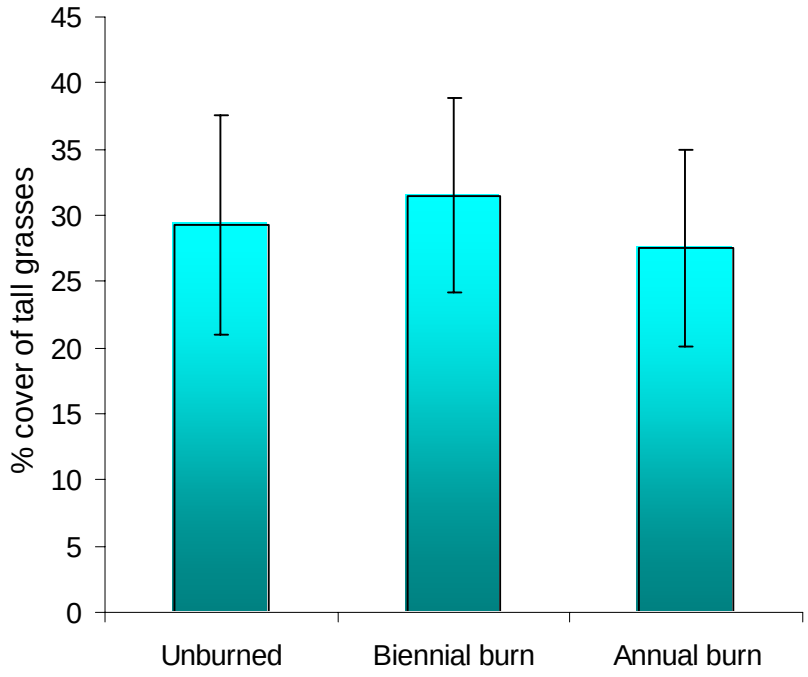

Figure 3. Cover of unpalatable tall-grass *C. flexuosus* in response to different burning treatments. Data are from 2 years following the start of the experiment and indicate that different burning treatments had no effect on the cover of this species.

In contrast, grazing treatments had a disproportionate effect on the cover of the tall-grass *C. flexuosus* (Fig. 4), with *C. flexuosus* individuals faring particularly poorly under sustained levels of grazing. *C. flexuosus* cover increased by 17 percent in fenced plots and decreased by 27 percent in clipped plots, indicating that grazers have the potential to control the dominance of this species.

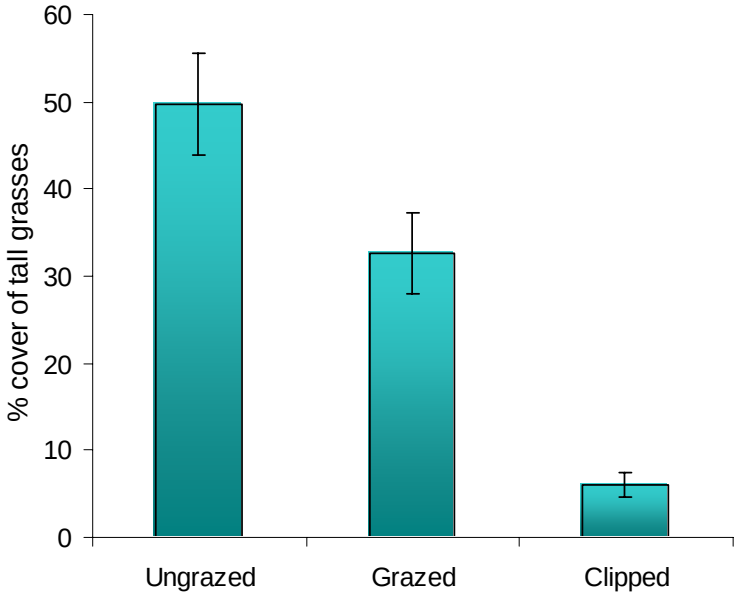

Figure 4. Cover of unpalatable tall-grass *C. flexuosus* in response to different grazing treatments. Data are from 2 years following the start of the experiment and indicate that grazing can significantly reduce the cover of this species.

Although grazers are capable of controlling this species, herbivore usage of *C. flexuosus* savannas tends to be restricted to short periods immediately following burning (Fig. 3). *C. flexuosus* communities are sparingly used by herbivores when mature or unburned since they provide little in terms of palatable forage. Any measure of control that herbivores are capable of exerting on this species, is therefore, likely to occur only during periods immediately following burning.

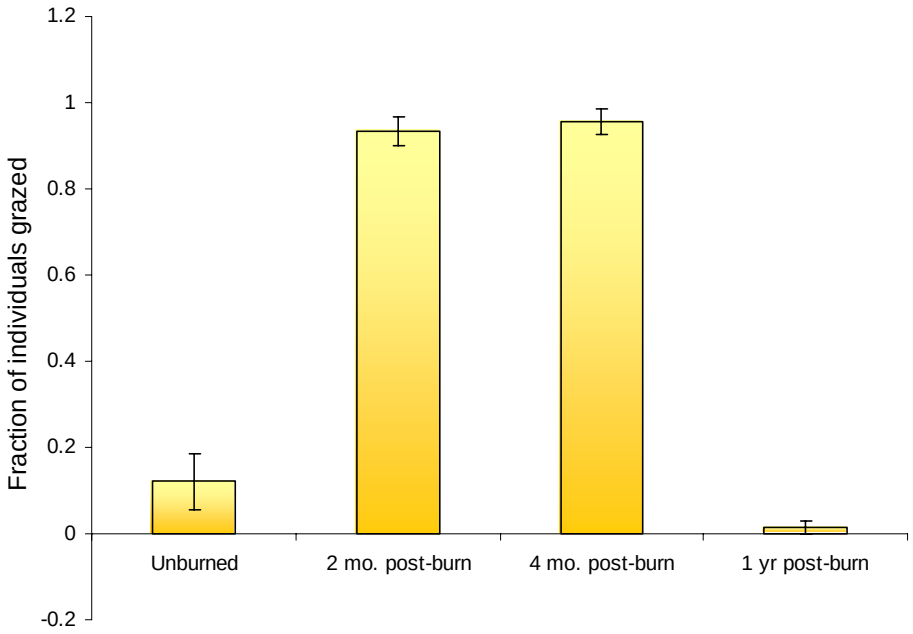

Figure 5. Top: Changes in the use of *C. flexuosus* by herbivores at different times following burning. The data indicate that this species tends to be utlilized by grazers for up to 4 months following burning, but one year following burning its usage declines to very low levels. Further, this species is not consumed in unburned plots.

Although herbivores do feed on *C. flexuosus* individuals following burning, and are theoretically capable of suppressing this species (as evidenced by the results from the clipping treatments in the experiment], it appears that herbivore densities at KMTR are currently too low to exert significant pressure on this species.

In summary, results indicate that tall-grass *C. flexuosus* savannas in KMTR are fairly immune to perturbation by fire, and that prescribed burning on its own is unlikely to be an effective strategy in controlling this species. On the other hand, while the experiments indicate that *C. flexuosus* individuals fare poorly under sustained levels of grazing, it also appears that grazer densities are currently too low to suppress this species. Thus, for prescribed burning to be effective, it must be coupled with other parallel management strategies aimed at augmenting grazer densities in the reserve.

This text is adapted from Sankaran 2005. Fire, grazing and the dynamics of tall-grass savannas in the Kalakad-Mundanthurai Tiger Reserve. ***Conservation & Society*** 3(1): 4 – 25.

Forest fires in India: Extent, justification and policy

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Fire, whether natural or anthropogenic, is a widespread and recurring phenomenon in Indian forests. The Forest Survey of India estimates that as much as half the country's forest area may be affected by fire, annually. Fires in Indian forests are today almost entirely attributed to burning by people. In India, people burn forests for a variety of reasons: to encourage a fresh flush of fodder for grazing livestock, to facilitate the collection of fuelwood and certain non-timber products, to clear the forest understory to improve access, and because of religious beliefs or cultural practices. Fires are also used as a management practice to maintain wildlife habitat. In addition, fires are sometimes set as a form of protest against restrictive forest policies; fires may also spread accidentally from agricultural burning-and-clearing. Past attempts at identifying the causes of fire have attributed most fires to burning by graziers and NTFP collectors, and to a lesser extent, to fire spreading from agricultural fields, or from accidental (and unknown) ignitions. A more recent attempt to identify the causes of fire also highlights the importance of burning by herdsmen and fuelwood collectors, in addition to people's carelessness or other unknown causes.

The occurrence of fires is perceived as detrimental, which may account for the lack of systematic investigation into the causes of fire, as well as into the ecological and socio-economic role that fires play. The principal reason why forest fires are regarded as damaging to forest ecosystems may be due to their perception as being largely human-caused, and therefore 'un-natural'. Additional reasons why fires are regarded as detrimental include the increasing frequency of their occurrence due to demographic pressures coupled with shrinking forest areas, and the breakdown of traditional institutions and systems of fire prevention and control, such as previously existed in the northeast. Nonetheless, India shares a number of bio-physical characteristics with parts of the world where fire is now known to be a recurring natural phenomenon with an important role in ecosystem dynamics. These bio-physical underpinnings of natural fires may include a climate that is conducive to sufficient productivity for the accumulation of fuel, coupled with drying—either seasonally, or during extreme drought years—that allows this fuel to become combustible. Add to this dry-season lightning, which occurs in India as much as it does elsewhere, and one has all the ingredients for natural fires. Yet, the evidence for ecosystems being adapted to fire—a sign of their having experienced fire as a periodic phenomenon over evolutionary and historical time—is scant, at best. However, this may be more for want of investigation, than a true reflection of their fire-adaptedness.

The policy on fires in Indian forests has historically been one of strict suppression. This was first officially articulated in the Indian Forest Act of 1927, which considered the setting of fires a punishable offence. In addition, it made it mandatory for all forest-dependent people to provide assistance in preventing and controlling fires. The extant National Forest Policy (1988) also stresses forest protection against encroachment, grazing, and fire. Furthermore, it advocates the adoption of modern fire management practices for the prevention and control of forest fires. In the wake of this, there have been a series of centrally sponsored forest fire protection and control schemes since 1985, each of which has laid particular emphasis on the adoption of modern techniques and equipment in the prevention and control of forest fires. In addition, a set of national guidelines on forest fires, which was issued to all states in 2000, stressed the importance of community involvement in forest fire prevention and control through the existing joint forest management program.

The annual occurrence of forest fires, and especially, the large extent over which they occur, presents a striking contradiction between fire-policy, and fire-reality. Given that nearly a century of the ban-and-punish approach to fires in Indian forests has not worked, a more effective approach might involve the integration of fire into existing forest management systems. Such an integration would need to take into consideration the management goals of different stakeholders — whether to conserve biodiversity and wildlife habitat, to restore degraded ecosystems, or to ensure a supply of goods and services required by forest-dependent communities.

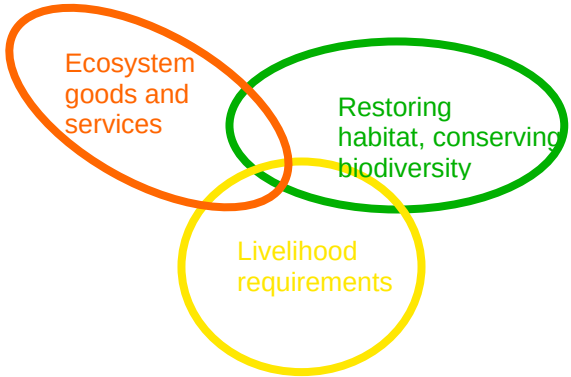

Figure 2. A schematic illustrating the variety of fire management goals, of different stakeholders, that might coexist at the landscape level, thus necessitating an integrated approach to fire management.

Making fire management part of broader land management concerns requires a thorough knowledge of local vegetation dynamics and their interaction with fire, a clear picture of the role fire plays in people's utilization of goods and services from forests, and, importantly, an understanding of local stakeholders' awareness of the potential of forests to

provide ecosystem goods and services under a given fire management regime. We suggest the need for a research program with the multiple objectives of:

- Understanding forest vegetation dynamics in relation to varying fire frequency and intensity in different biogeographic zones of India;
- Understanding the socio-economic and cultural drivers of fire in India; and
- Understanding how fires can be managed to meet the requirements of a variety of stakeholders at the landscape level.

Addressing these objectives would provide the knowledge required to reassess existing perceptions about fires in Indian forests. This knowledge would also enable policy makers to devise fire-management plans that are relevant to the diversity of ecological and socio-economic settings in the country.

Understanding, Perception and Interpretation in Empirical Trans-cultural Research

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Understanding, perception, and interpretation in empirical trans-cultural research, is predominantly a question of comparing theories of different configurations of nature and culture combinations. A methodology that is both appropriate and able to shed light on these groupings is the challenge for investigation and decision-making in the area of managing environments of importance to societies (beyond the local communities which depend on these areas). Socio-cultural driving factors of anthropogenic fires, for instance, vary according to land use typology, composition of user groups, and their status in a society at a given historical period of time. They usually accompany land use management and can occasionally be forms of social protest. Socio-cultural driving factors could be a result of long-standing local knowledge whereby certain actors have a vested interest supported by tradition. Other incentives for using fire could be a result of religious taboos or attempts to supersede the land use patterns of others by using fire. What makes fire use problematic, and sometimes conflicting, in a wider land use policy context is multiple, and often overlapping, use of the landscape. Different land use cultures that are driven by the occupations of certain castes and tribal groups, and their economic interests, lead to distinct patterns of fire management. Shifting cultivation, sedentary intensive agriculture, pasture economy, and hunting and gathering require a respective use or absence of fire at particular phases of time. Forest fires become a social resource in the sense that their use is related to the socio-economic interests and cultural traditions of groups that compete over securing their livelihood.

The meanings and perceptions of natural and socio-cultural phenomena are indispensable in learning about the validity of notions concerning natural or social phenomena in a particular setting. Each natural setting is unique (Greek: *topoi*) as it is located at a distinct point on a geographical network defined by latitude and longitude. There is currently no nature without direct or indirect human interference or landscape. There is very little space on earth where pristine nature is found, as humans have shaped the face of even some of the most remote biospheres of the world. Landscape is defined as nature that is shaped by one or more cultures over a period of time. Flora and fauna make up the cultural characteristics of a region in the way they are used and domesticated. As a generalisation one may assume that space is a cultural construct; the concept of space is always a reflection of the point of view of a particular culture. Strictly speaking, there are no *natural* resources. They are natural in the sense that they are part of a naturally growing and perhaps renewable natural wealth, but from

a perspective of management of natural phenomena it is the social process that determines their use value within the economy of a society. Natural phenomena are appropriated as social resources, because the economic and political reasoning, and the spirit and ethics of a particular time and culture cannot be anything other than socio-cultural appropriations of things that have been declared resources. The social attribution of economic value as a cultural value is a process of converting natural phenomena into a social resource. Moreover, social resources are principally appropriated by the whole society, although they can be owned by social units such as families or individuals. The usage value of certain phenomena can sometimes be larger or smaller than their option value or value of existence. In any case they are esteemed resources that are of principal interest to a society, irrespective of the time of use or harvest. Social resources are established through common cultural consensus whereby people make use of these natural resources, and this very consensus is a representation of the whole of the resource's social and cultural performance. Thus resources are more than just a practical asset; they have a symbolic dimension, and contribute to the particular style of social life of a society and the production and consumption of products and services. Social resources structure communication and exchange between members of the same and different communities.

Based on an ontological theory and a hermeneutic method, nature and culture are investigated as inseparable and making up an all-encompassing life-world, and a comprehensive understanding of this connection is achieved by a scientific introspection that correlates all forms of Being. These relationships are disclosed by hermeneutics, revealing the meaning of cultural phenomena in the overall set-up of Being. In general, research findings have to reveal themselves as relevant topics in order to become the focus of further and more introspective research. A forest in any society, for instance, is reflected in the way by which it is perceived culturally. Over the ages, societies have developed notions of what forests mean to them. The significance of the forest differs between societies whose members' perceptions of it vary and for whom it has a different relevance within the dimensions of their own cultures. The forests of today contain evidence that people have been, and still are, dependent on them, and that these people make use of and interpret their environment keeping in mind survival and/or social advancement. In the Indian context, applied hermeneutics in environmental studies are rare. The Anglo-American legacy of empiricism and positivism has a long-standing tradition of social anthropological research in India. Breaking the methodological barrier represented by quantitative research methods and classical methods of field research, participatory observation and rapid rural appraisals, there is an attempt to test a research method that promised to be more adapted to tribal groups living alongside forests. The necessity to interpret the natural environment and its symbols with a hermeneutic method, natural phenomena such as plant occurrence and animal behaviour, weather and fertility, makes a tribal world an ideal realm for the application of a hermeneutic approach.

Interconnected as all phenomena are within the natural world of the forest where the tribals are exposed to the hardships of life in the wilderness, all natural and social phenomena feed back onto each other. These phenomena are representations of natural and supernatural powers which social and cultural life responds to in order for the people to survive.

The transformation of forest vegetation with the use of fire indicates specific social needs, cultural values, and changing economic and technological processes. Forests represent a legacy; they are a testimony of the evolution of societies and their respective perceptions, needs and appropriations of nature. The significance of trees and forests can only be revealed by understanding these perceptions and the modes of appropriation developed by a particular culture reflecting its needs.

Although it is clear that human activity influences forests, the extent of this impact over space and time is often difficult to assess. Some of the changes are immediate and occur in the short term. Others, and often the more important ones, are indirect and can only be understood over historical timescales. The spatial distribution of forests and the degree of their transformation by human activity are the result of the prevailing physical conditions and varying cultural patterns. This applies to forests that have been intensively used over centuries, e.g. with the help of fire, but also to forests that still appear to be in a ‘natural’ state. They may have been spared from human influence due to physical inaccessibility and economic considerations, or because of a society’s particular spiritual values. The difference between intensively used forests and those showing little or no trace of human interference reflects social rules, economic options and political decisions. In this respect, all forests, including those that we still consider to be natural, are cultural phenomena. We assume that the extent to which the so-called "knowledge of forests" is perceived as globally relevant to all cultures and societies varies in scope and depth. Different world-views and traditions at different stages of economic and technological development reflect what the term "forest" and "knowledge of forests" means to those who share a common culture. This kind of knowledge is more than technical, i.e. botanical knowledge, hunting skills, know-how of wood harvesting or the use of non-timber products.

With this background, the constitution of an indigenous culture is a mode of appropriation of physical and biological elements in a local natural setting and its transformation into cultural livelihood patterns.

Complex configurations, such as people carrying on their activities in their original environments, evolve from complex origins of interrelations. Plants, animals, and human beings’ life cycles are interrelated within a particular habitat. The natural phenomena originate from their being-in-the-world, thus acquiring a social meaning by putting something into an existing social context. This process represents the development of culture.

Fire and Behavior in the Palni Hills

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As a Ph.D Candidate in Human Ecology at the University of California, Davis, I study the co-evolution of biophysical and socio-cultural systems. Since human culture is an evolving phenomenon, socio-ecological systems should be optimized and diverse across space and time. In order to study the nature of human cultural adaptations to the environment, I have designed a project in southern India that investigates the human deployment of fire in landscape management across both social and ecological gradients. The Palni Hills of Tamil Nadu provide a natural experiment which can be used to see how human landscape alteration responds to both the effects of elevation as well as social categories.

Fire gives human populations a decisive control over entire ecosystems, and fire use greatly facilitated the establishment of the Homo genus as having an unprecedented ecologically dominant role. Fire is an important means of environmental control in ecosystems across all inhabited continents. Fire enhanced the survival of native humans by reducing brush and tree encroachment on grasslands, clearing the landscape for more effective hunting and shepherding, and supplying nutrients to new grass that benefited wild and domesticated grazers. The ecosystems of India are no exception to such an extensive land-use pattern, and neither is the grassland-forest mosaic of the Western Ghats. The montane grasslands in the Western Ghats of Tamil Nadu have a strong seasonal anthropogenic fire regime. Just as in similar grassland-forest mosaic ecosystems, this fire regime limits forest expansion at higher elevations and is thought to be responsible for the lands-use mosaic pattern.

Like any fire regime, an anthropogenic fire regime favors certain species, maintaining habitat for species dependent on montane grasslands, while shrinking habitat for species dependent on forest fragments. Currently both native and invading vegetation show signs of fire-adaptation. Many of the dominant native grasses are fire-adapted, including *Chrysopogon zeylanicus*, and *Themeda cymbaria*. The prevalent bracken fern, *Pteridium aquilinum*, is fire-adapted, as are invading shrubs such as *Lantana camara*. Similarly, invasive tree species, such as *Eucalyptus globulus* and *Acacia mearnsii*, are known for their fire adaptations. Endangered endemic species, such as the highly endangered Nilgiri Tahr, *Hemitragus hylocrius*, and the Nilgiri pipit, *Anthus nilghiriensis*, which depend on these grasslands for habitat are, by extension, dependent on a certain fire regime. Thus, in the Palni Hills,

maintaining a diversity of habitats within the grassland-forest mosaic through a controlled fire regime may be the best way to protect biodiversity.

However, others argue that current fire use patterns have become ecologically damaging with increased population pressure. In India, like in North America, there is debate about whether anthropogenic fire can play a role in conservation. The Indian Forest Department holds the view that only forests, as the primary natural stock, deserve protection. In either case, conservation planning with regard to fire cannot progress until the drivers and effects of the anthropogenic fire regime are better understood.

This project serves two aims. First, it will attempt to measure the interacting social and ecological influences on human environmental management, specifically, fire-management practices of pastoralists in the Palni Hills of Tamil Nadu, India. A natural experiment will be conducted allowing villages with similar political, religious and caste makeup to be selected in sets of three across elevations. This permits tests of the effects of ecological factors (elevation, rainfall, temperature, and forage production), social factors (group membership and social distance), and their interaction on fire-use practices. The second aim of this research is to help regional managers understand why and how people burn, and to measure the effect of burning on the landscape, in order to improve conservation strategies for locally threatened endemic species.

Within villages, semi-structured interviews with pastoralists selected with a geographic sampling method will focus on fire-use behavior. Quantitative measurements of social-group affinity will be gained by asking participants to sort stacks of cards bearing political or religious symbols. Social distance between villages will be measured using social network methodology. Two specially selected ‘reference traits’ will also be measured in the main interviews for comparison with fire use. One, choice of winter crop, is chosen to be largely ecologically determined. The other, a largely socially controlled behavior, the traditional kolam designs made on doorsteps, will be documented in a photographic collection. Ecological variables (forage production, grassland composition) will be experimentally determined at three altitudes. At each altitude, multiple plots will be established, half of which will be burnt. After a period of re-growth, the difference between burnt and un-burnt plots will supply measures of the changes in forage production (aboveground biomass in $kg \cdot m^{-2}$) and community composition (nested biodiversity plots, Shannon-Weaver index).

This project introduces a new theoretical tool, which may prove critical to conservation theory: a typology of the overlapping effects of social and ecological selection on individual ecological behavior. This new tool permits predictions about the pressures causing certain behaviors, moving beyond current theory to provide a mechanistic explanation for behavioral distributions, ecological or otherwise.

This work also introduces the ‘reference trait’ method as a means of testing the relative strengths of social and ecological selection between behaviors. This new combination of theory and methodology can be applied to any cultural context, permitting cross-cultural comparisons. Furthermore, this project will use maximum-likelihood procedures to estimate individual-level forces by measuring population-level patterns. These procedures permit researchers to select between competing models. This method of inference is powerful, but rare in anthropology.

This study will provide valuable information about the extent, causes and effects of the human-induced fire regime in the Palni Hills of Tamil Nadu, thus shaping future management decisions about the critical role of fire in the regional grassland-forest mosaic ecosystem.

Culture of Fire in the Forests of India

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Nataraja, the Lord of the Dance – is more than one of Hinduism's favored icons. It is a near-perfect symbol of Indian fire history. The drum represents the rhythm of life; the torch, death; the wheel of flame, the mandala of birth, death, and rebirth that fire epitomizes and makes possible. In this confrontation of opposites, the dance replaces the dialectic; Shiva holds, not reconciles both drum and torch. Considered ecologically, the Nataraja thus expresses in graphic language the great polarity of India, the annual alternation of wet and dry seasons by which the monsoon, with faint transition, imposes its opposing principles on the subcontinent. India's biota, like Shiva, dances to their peculiar rhythm while fire turns the timeless wheel of the world.

For India, the spiritual interacts with the practical and that which organizes society is also thought to govern nature. The installment of Agni and the Vedic fire ceremony, and the way this impacted Hindu society, had its parallel in the way by which Aryan fire worked on the Indian Environment. Fire ordered the landscape as caste did people. The sacrifice to Agni took the form of burning India's forests, or rather of reworking them in somewhat newer ways to support an economy dependent on livestock.

Fire can be said to be the one object upon which society is most dependent for its well-being. It provides warmth on cold nights; it is the means by which people prepare they prepare their food, for they eat nothing raw save a few fruits; it is a possession that has to be constantly guarded, for people have no means of producing it, and must therefore take care to keep it always alight; it is the first people think of carrying with them when they go on a journey by land or sea; it is the centre around which the social life moves, the family hearth being the centre of family life, while the communal cooking place is the centre round which the men often gather after the day's hunt is over.

To the mind of the Andaman Islander, therefore, the social life of which his own life is a fragment, the social well-being which is the source of his own happiness, depends upon the possession of fire, without which his society could not exist. This dependence on fire by society appears in his consciousness as a sense of his own dependence upon fire and a belief that it possesses power to protect him from dangers of all kinds. The belief in the protective power of fire is very strong. A man would never move even a few yards out of camp at night without a fire stick. More than any other object, fire is believed to keep away the spirits that cause disease and death.

Forest fire is also known as wildfire. It may be caused by intentional, accidental or natural factors. It is defined as the result of both constant and variable fire-danger factors, which affect the inception, spread and damage extent of a fire. Forest fires not only damage the biomass of the forest and the ground, but also the cultural, social economic, agricultural and environmental networking of the region.

Forest fires cause enormous damage during April-July every year in several parts of the country depleting precious forest cover and destroying a rich variety of flora and fauna including several species of rare plants and animals. A forest fire is a freely spreading combustion that consumes the natural fuels of a forest, as in, grass, weeds, brush and trees. Forest fires occur in three principal forms, the distinctions depending essentially on their means of spread and their position in relation to the ground surface. Surface fires burn surface litter, other loose debris on the forest floor, and small vegetation. Crown fires advance through the tops of trees or shrubs more or less independently of the surface fire and are the fastest spreading of all forest fires. Ground fires consume the organic material beneath the surface litter of the forest floor. Ground fires are the least spectacular and the slowest-moving, but they are often the most destructive of all forest fires and also the most difficult to control.

Aboriginal fire practices from India's `tribal' peoples shaped the land. Fire was needed for agriculture for clearing, converting, and fertilizing the land. In India, as throughout monsoonal Asia, slash–and-burn agriculture (jhum) became dominant outside of the floodplain areas, ensuring that routine fire would visit even the most remote sites. Where insufficient forest fallow existed, alternatives were found in rab cultivation where wood was carryied to the site for burning, or mixed with other refuse and manure prior to conversion into ash. Some peoples burned the hills `with almost religious fervor', observed one disbelieving Briton, in the hopes that the ash would wash down to waiting fields.

Shifting agriculture, using the jhum system, is a major economic activity of the humid tropics in the north-eastern regions of India. This highly organized agro-ecosystem is based on empirical knowledge accumulated over the centuries. Jhum is in harmony with the environment as long as the jhum cycle is long enough for the forest and soil fertility that was lost during the cropping phase, to recover. This land-use system of north-eastern India, involves slashing the vegetation, burning the dried slash before the onset of the monsoon, raising a mixture of crops on a temporarily nutrient enriched soil for a year or two, and allowing the soil to fallow in the plot with re-growth of natural vegetation.

It was in fact the British who did not understand the Indian forest system. They believed that fire was, by necessity, destructive within the context of India. Enthusiastic forester, Sir David Hutchins, reminded the Indian peoples that they were `soldiers of the State and something more' and attempted to regulate timber harvesting and control traditional forest use by pastoralists and villagers; he attempted to regenerate felled or degraded

woodlands and to suppress fire in the reconstruction of India. The indigenous people however, understood how fire supported jhum cultivation, converting organic residues into fertilizer, maintaining woodlands and prairies as grass, assisted hunting, cleansed the soil of pathogens and supported foraging for flowers, bees, tubers, and herbs. Fire sustained metallurgy. Fire kept tigers away from villages and opened sites that might otherwise hide cobras. Fire structured the intricate ensemble of biomes that was made by and that in turn made possible, Indian society. Alone among the elements, fire illuminated the complex choreography that bound life with death, the human with the natural.

A holistic approach to conservation and development incorporating fire, based on ecological, economic and social considerations needs to be negotiated in India, keeping in mind the spiritual belief and rational knowledge of the local peoples. With a variety of ecological situations, socio-economic conditions and socio-cultural variations in the humid tropics, development strategies necessarily have to be location specific. The continued use of fire is more pertinent than the extinction of fire in Indian society.

Ecological Impacts of Forest Fire in the Indian Central Himalaya

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In the central Himalayan region, every year forest fires leave a devastating impact on the regional landscape affecting flora, fauna, human livelihoods, and the local climate. Although fire may be both of natural and anthropogenic origin, the limited studies on this subject suggest that in this region fire is entirely of anthropogenic origin. In this region fire is used as a tool to meet several objectives, both by the local inhabitants and the Forest Department. On the one hand, the local people harvest good growth of fodder grasses after fire, and on the other the Forest Department uses fire as a tool (by controlled burning or to "fight fire with fire") to reduce the severity of fire during the summer season. In a study in the Garhwal hills by Semwal it was reported that 63% of the total fire incidents were intentionally man-made and the remaining 37% were accidental. The Chir Pine (Pinus roxburghii) forests are more prone to forest fire as they shed their resin-containing leaves during summer. These forests are mostly spread over the middle altitudinal zone of the region (1000-2000 masl), the fire cycle is repeated every 2-5 years, and about 11% forest area of the region faces fire every year. The main reasons for intentional forest fire were: the amusement of livestock herders and children, to hide the realities of forest operations by some interest groups/individuals, driving game animals, and driving away honey bees. Among the reasons for accidental fires were: clearing weeds from the crop fields for crop cultivation, the spread of intentional fires to nearby forests during road repairs, carelessness by travellers (e.g., discarding an ignited cigarette butt), camp fires, etc.

Among the three types of forest fires (i.e., ground fire, surface fire and crown fire) it is mainly surface fires that are found in the region, though these sometimes turn into crown fires due to the prevailing terrain conditions. Mild surface fires are the most rewarding as litter is turned into ash which contains the bulk of nutrients that become available for uptake by the growing annual herbs and grasses. In this way, the fuel load in the forests is also kept in check to prevent any devastating fire subsequently. However, the negative impacts of fire generally seem to grossly override the benefits accrued through its use as a management tool. Fire has been the single most detrimental factor acting against the massive conservation efforts of the Forest Department, institutions, communities and others. The impacts are not confined to the local landscape level but sometimes are also perceptible in the adjoining lowlands connected to this region through streams and rivers. Erosion of nutrient-containing ash, on one side, leaves the site effectively poorer in soil nutrient capital, and on the other side, the subsequent

flushing of nutrients to adjacent water bodies causes eutrophication. The burnt sites / micro-watersheds are also left with reduced capacity of water retention due to eroded soil layer that lower the “sponge function” of the soil-vegetation pool, results in low rainwater percolation to recharge the water table, and consequently diminishes the discharge of springs. In many areas the shortage of water arising from such practices has compelled people to seek out alternative practices of crop cultivation, household water consumption, and coping mechanisms. Facilitation of spread of Chir pine trees and invasion of weeds, such as lantana, eupatorium, parthenium etc. in the once thick forests of oak (*Quercus* spp., a socially valued species known for its fodder, fuel-wood, soil and water conservation etc.) is another major concern that is augmented by fire.

Literature reviews reveal that despite fire’s importance in relation to people’s livelihoods, this subject has been dealt with only sporadically, and detailed studies are required to come up with management suggestions to protect the forests of the central Himalayan region so that the continued supply of the required ecosystem goods and services can be ensured. It is also pertinent to review the fire-fighting strategies employed presently on the regional, national and international level by a range of stakeholders in the light of newer scientific knowledge generated on this subject. A need for research and development in the area of understanding fire dynamics in these ecosystems can be clearly seen and it is timely to make efforts in planning and implementing respective cooperative programmes with relevant research institutes and the local forest authorities.

Understanding local perceptions of landscapes and natural resources: An interdisciplinary approach with possible application to fire management

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Multidisciplinary Landscape Assessment (MLA) is an interdisciplinary set of methods and tools that were developed in East Kalimantan, Indonesia in 1999 by Douglas Sheil and his team as a collaborative effort among different partners from several disciplines (the Indonesian government, universities, NGOs). MLA is able to produce clear and quantified information about the landscape and perceptions of the local people. We believe that people's perceptions make landscape information more meaningful for decision makers. I present the MLA approach, its tools and examples, lessons learned from several tests and adaptations, as well as preliminary suggestions on its adaptation for fire management in the Indian context. The approach could be a potentially helpful tool in developing fire management, especially in assessing ecosystems and the perceptions of local people.

Originally, the MLA was created in order to assess local people's perceptions more effectively than can be done using the traditional survey approach. A usual baseline/biodiversity survey normally assesses only what occurs where, e.g. species, habitats or sites. We believe that information resulting from this kind of survey does not help to improve landscape or resource management decisions. People's perspectives have to be included in order for this information about landscapes or resources to be meaningful, for example, by asking them why and how the landscape or resource in question matters to them. We also try to identify the threats to land types (e.g. forest) or biodiversity and the implications these threats have for stakeholders. Based on this, recommendations are made for improving landscape/resource management decisions.

MLA combines methods of natural and social science into an interdisciplinary assessment. These methods include botany, ethnobotany, ecology, forestry, pedology, anthropology as well as socio- -economic aspects. These methods seen individually are not novel, but their combination into one survey integrates biophysical information and people's perspectives in a manner which has seldom been attempted previously. Moreover, MLA enables the linkage of community based ('traditional') and scientific priorities and knowledge to improve decision making in landscape management.

The main characteristics of the MLA approach are as follows: it is diagnostic in nature and takes a broad overview of people and the landscape, avoiding assumptions and allowing for surprises. MLA also has the ability to integrate scientific information with local perceptions to produce meaningful data for decision-making. It is a very flexible approach (in terms of who can apply it and for how long), in addition to being adaptable (in terms of where and for what purpose). Using the MLA approach, scientific experts can learn from experiences together with local people, who are key collaborators and experts in their own environment.

The various activities of the MLA approach can be grouped into village activities and field-based activities, which are simultaneously done both by natural and social scientists, and by local experts. Success in applying the overall methods to reflect accurate and reliable information greatly depends on building trust with the local people through various meetings, and by working together during the research period (e.g. through community meeting, mapping, and field sampling observation). It is very important to build a shared reference with the local people from the beginning.

Community meetings are held during the course of the research conducted in order to introduce research activities to the local people, to create work schedules, to collect basic information on relations between people and the landscape, to crosscheck and collect feedback on results. Participatory mapping is aimed at creating a common understanding between researchers and local people about the important features of the local landscape. Interviews and discussions with informants and representative groups are important to understand local people's perceptions – both personal and collective – of their surrounding landscape.

Samples of important local landscapes and resources are taken to discover key information including the site's history and description, vegetation, soil, trees, as well as local perceptions and preferences. Questionnaires and datasheets are tailored for interviewing key informants and households, as well as for recording results of observations and measurements on a local-level landscape mosaic. Scoring exercises are also deployed to capture people's ranks, preferences and insights on various lists of local landscape features.

This approach has been tested as well as adapted to other countries in order to fit various objectives. In Indonesia local people's perceptions, demonstrated by the MLA approach, have been considered in land-use planning and environmental management. In Bolivia the approach has been simplified to provide communities with useful tools and information to negotiate for land rights with the government, and to develop Brazil nut management plans. These are two among various lessons learned on the impacts of the application of the MLA approach.

The MLA approach has not been used previously to study fire and fire management, and will require adaptation. Some initial suggestions have been made as ideas for further discussion. The following questions could be the main starting points to consider in fire management: What is important to local people? (Who? where?); Why do people use fire and/or burning the way they do? What are the consequences for the landscape and the values (and negative aspects) associated with it (from the perspectives of the various local stakeholders)? What are their concerns? What is the local process of burning and what are the local views about these activities and processes?

The need for an integrated approach to the management of tropical forest landscapes

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Conversion of tropical forest landscapes to agriculture and industrial landscapes is a major cause for the decline of forest cover and biodiversity worldwide. In addition, forest landscapes continue to degrade because of excessive exploitation of natural resources by humans and the agents of disturbance leave in their wake. Nevertheless, large tracts of tropical forest have been managed for long periods of time, either by the state or by communities of forest-dependent people, to provide natural resources. Many such management practices have involved the use of fire as a tool to maintain forest structure, composition, and productivity of certain components such as grasses, particularly in seasonally dry and dry tropical forests. Although people have most likely used fire as a management tool for a long time, the detailed histories of the use of fire have rarely been documented for any tropical forest. The lack of reliable fire histories have led to often acrimonious debates on whether fire in most tropical forests is an agent of human-caused disturbance that is damaging to ecosystem structure and function, or whether current tropical forests have evolved with fire as an ecological and evolutionary stress factor for a long period of time; with fire as a longstanding stress factor, the ability to cope with it without suffering species and functional losses or even the creation of a dependency on it for the operation of some ecological processes make it a potentially positive process. There is evidence for both points of view from different tropical forests, but huge gaps remain in our understanding of how fire impacts the structural and functional integrity of tropical forest ecosystems. We do not know whether the use of fire as a tool to manage forest ecosystems to yield specific natural resources can be sustained while not seriously undermining species diversity and degrading the services rendered by these ecosystems.

While detailed studies are needed to bring clarity to this debate, the role of fire as a factor in tropical forest ecosystems cannot be viewed in isolation. Today's tropical forests have to be managed keeping several imperatives in mind – conservation of biodiversity, retention of ecological services, and the sustained provisioning of natural resources to forest-dependent communities. Typically these imperatives have been addressed at the population level, but it is becoming increasingly apparent that the landscape level is the more meaningful and useful level for this kind of planning. I focus here on landscapes that have substantial forest cover but a mixture of land uses. The long-term goal is to maintain the range of forest structures over time in the landscape so as to ensure the diversity of forest values (e.g.,

habitats, water, soils, wood products, non-timber products, and recreation). I intend to explore analytical approaches to study land-use dynamics and develop a framework that allows us to examine scenarios for planning and intervention. Integrating socioeconomic factors with biophysical ecological factors poses difficult challenges. Analytical models of the kind already developed offer a promising approach to study the factors driving land-use dynamics, although such models need to be expanded to incorporate socioeconomic factors more explicitly.

This model involves capturing various land-use transformations and the rates of these transformations in a clearly defined landscape as a series of coupled differential equations. Equilibrium and transient dynamics of such a system offer useful insights on the qualitative importance of the various factors and their interactions in driving land-use dynamics and determining landscape composition at any given point in time. Such a model also lends itself to incorporating population-level processes and patterns to examine the landscape-level outcomes. However, we need to devise appropriate scaling rules to ensure that as we move from the population to the landscape level, we carry the only relevant detail forward. Because most ecological studies on natural resource management, impacts of fire on ecosystems, and so on have been and are carried out at the population level, an analytical framework that can incorporate population-level processes to study landscape dynamics would offer a powerful tool to study land-use dynamics. Scenarios on natural resource management, the ecology and management of fire, ecological restoration of degraded forest lands,etc., can then be examined at the landscape scale—the most meaningful scale for planning and management of forest ecosystems within a mosaic of other land-use types.

Summary and the way forward

The final day of the workshop was spent discussing ways in which the process begun in the workshop could be carried forward. The participants agreed that wild land fires in India are an important issue in the context of sustainable management of forests, biodiversity, and ecosystem services that society derives from forests. The group had a structured, constructive, and creative discussion on the aims of a research initiative in this field, the methodologies that would have to be applied, and the steps for its implementation. There was consensus that the overall aims of such an initiative would be:

- *To generate an information base about wild land fires in India*

It was felt that the factors determining the biotic and abiotic environmental drivers of fire have to be identified in conjunction with the socio-cultural, economic, and institutional context of fire occurrence. An objective, therefore, is:

- *To understand the environmental, socio-cultural and economic drivers of wild land fire*

Fires in India, for the most part, are associated with the utilisation of forest products or other needs of local forest dwellers. In addition, fires influence forest structure, composition and dynamics, which, in turn, have an impact on ecosystems services such as carbon sequestration, biodiversity, and water regulation. A second objective, therefore, is:

- *To assess the role of fires in ecosystem processes and the supply of ecosystem services in different forest types of India*

It was felt that in order to meet the national-level aims of such an initiative, we would need to select representative sites from different parts of the country. The primary criterion for site selection would be based on some pre-existing (and accepted) classification, for example, that of biogeographic zones (and sub-zones). Within this broad site classification, it would be necessary to identify well replicated sites (e.g., n=3, for a total of about 30 sites) where fires have occurred and continue to occur. The group identified various potential sources of information for site selection, including satellite imagery, state government records, and records of non-governmental and community-based organizations. These criteria for site selection and coarse-scale assessment are a limitation of the proposed initiative, and reflect

the scant knowledge about fires in India as well as the paucity of information available. The method for site selection could be refined as more information becomes available.

Once sites are selected based on information about fire, it would also be necessary to compile information regarding soil types, census data, land use, population, cattle densities, etc., so as to capture the range of variability within potential drivers. The group discussed considering watersheds as the unit of study, within which specific detailed information could also be obtained at the plot level.

In the absence of existing information on prevailing fire regimes, the group discussed the need to determine the frequency, intensity, extent, and seasonality of fire occurrence. It was also mentioned that there may be existing methods developed elsewhere, and sources of information (e.g., the National Remote Sensing Agency, interviews, and measurements of fire-relevant parameters such as fuel loads) that could better enable the characterization of prevailing fire regimes in the selected sites.

The group also recognized the need for a rapid survey method to define the factors affecting the type of fires, which could be replicated across sites. Such a method could comprise collation of existing information, interviews, and focused discussion.

The potential environmental drivers of fire were identified as:

- Rainfall, mean, variation, seasonality
- Length of dry season
- Temperature
- Wind speeds, relative humidity
- Vegetation type
- Soil type
- Topography
- Potential evapotranspiration

Correspondingly, the potential socioeconomic drivers of fire were identified as:

- Social and demographic factors (population, livelihoods, poverty levels)
- Agricultural crops cultivated
- Distance from habitation
- Access to renewable and non-renewable natural resources, and patterns of resource use
- Cultural practices
- Institutional drivers/context
- Land tenure and land cover type (e.g., reserve forest, village common land, protected area, etc.)

This initial, coarse-scale assessment would involve attempting to determine the degree of influence that these different drivers have on fire, as well as the interplay or synergy among them. Moreover, we would seek, in the initial assessment, to determine the impact of varying fire regimes on ecosystem processes and the supply of ecosystem services. Information on

ecosystem services—whether supporting, provisioning, regulating, or cultural (sensu MEA)—could be obtained through interviewing stakeholders and through measurements, where possible (e.g., amount of fuel wood utilised, water yield, carbon stock). It was also stressed that indicators developed to assess various parameters should be understandable to local people, thereby providing a way of informing communities.

To complement the extensive and coarse-scale assessment proposed, it was also suggested that there could be intensive studies—both ecological and socio-cultural—conducted in a subset of sites. Sites selected for intensive study would need more extensive (easily replicable) measurements, and would also need to be stratified based on existing ecological, socio-cultural, and economic information.

The group agreed that the multidisciplinary landscape assessment (MLA) approach from CIFOR is a viable option to obtain people's perspectives on fire and its effects on ecosystem services at the local level. At larger levels it would be necessary to assess fire behaviour and its effects using a mixture of remote sensing data, interviews and measurements. The need to understand the role that fire has played, historically, in evaluating the present-day effects of fire on ecological processes and ecosystem services was also highlighted.

There was agreement that such a national-level initiative could only be undertaken with the involvement of governmental and non-governmental agencies and civil society at the local, regional, and national level. The expected outcomes of such an initiative include the generation of a database and monitoring protocol on wildland fires (their frequency and extent, drivers, and effects); creation of materials for education and training; and initiation of a policy discussion on wildland fires. The workshop ended with the formation of a steering committee, which is charged with the responsibility of seeking partners and funds. We aim to have a draft proposal prepared by end-July 2007, and hope that the proposed initiative can begin in the first quarter of 2008.