Geospatial- Scenario Planning Framework for Assessing Risks and Impacts of Forest Fire in Eastern Himalaya

SERVIR HIMALAYA Program: NASA, USAID & ICIMOD

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South Asian Forum for Environment

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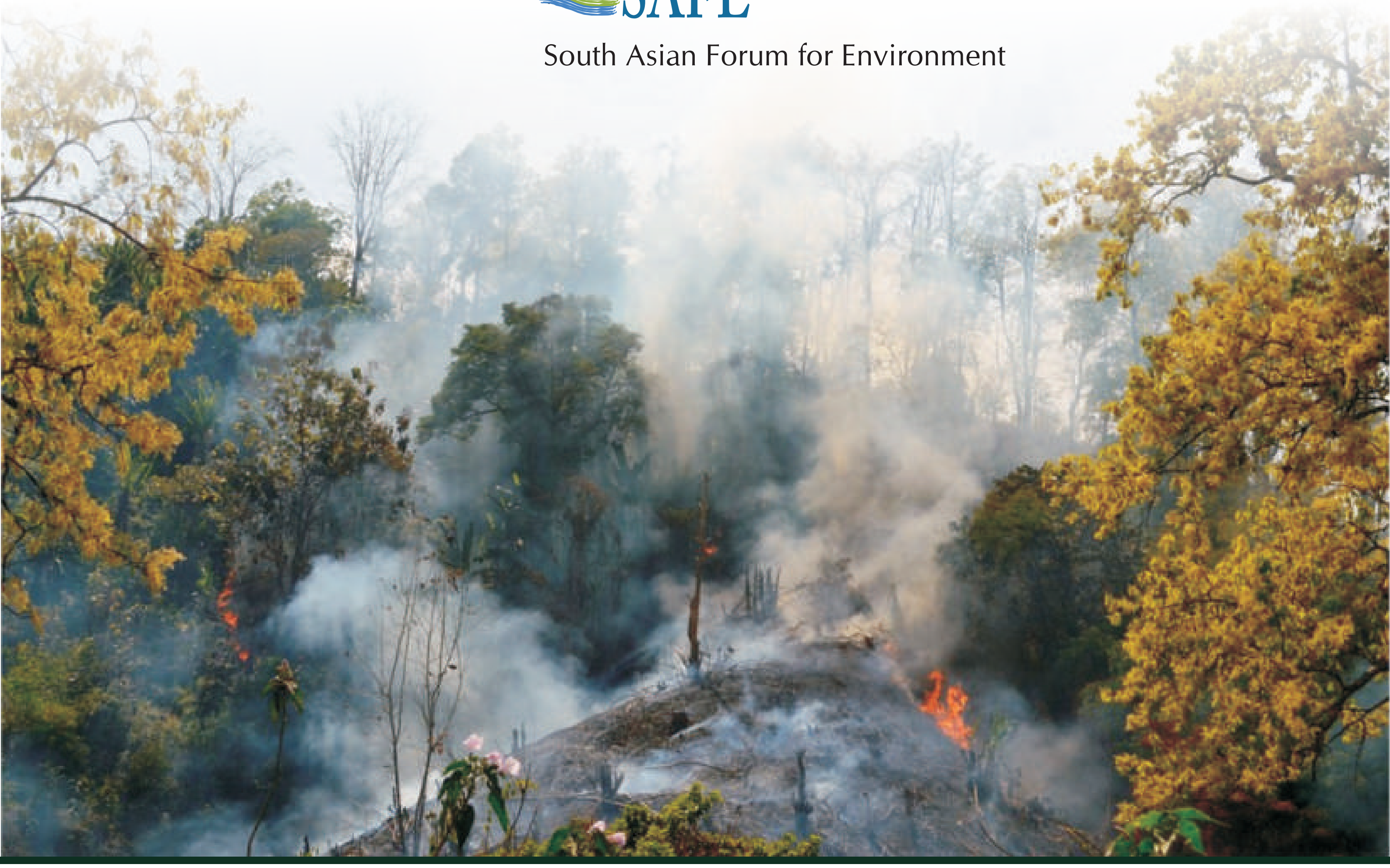

Geospatial- Scenario Planning Framework for Assessing Risks and Impacts of Forest Fire in Eastern Himalaya

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Foreword...

Dr. R. Gopichandran
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It is a matter of great pleasure and privilege to forward this publication of SAFE, entitled "Geospatial-scenario Planning Framework for Assessing Risks and Impacts of Forest Fire in Eastern Himalayas" based on the geospatial studies and field interventions undertaken in the aegis of SERVIR Himalaya Small Grant Program of ICIMOD supported by NASA and USAID for peer review.

There is no iota of doubt in mentioning that it is indeed a very innovative and challenging work given the paucity of background knowledge on the climate-terrain dynamics of forest fire and the rough landscape of eastern Himalayas. SAFE team has once more delivered a genuine and meticulously sculpted work at its best.

I must say, this work would improve forecasting skill through scenario framework analysis and mend the knowledge gaps in assessing of fire events and its socio-ecological contrivances. However, this also leads to a newer horizon of research and neo-technological intervention for prevention of environmental hazards, prescription of climate adaptive human centric mitigation strategies to combat climate impacts and policy planning in community preparedness.

I look forward to this new prospect and wish the SAFE team all success in its future endeavor.

Acknowledgement

Dr. Dipayan Dey
Chair
South Asian Forum for Environment

Geospatial science has ever been a very essential and loyal tool in decision support research, though its usage at science-society interface for community based interventions in the development sector has been limited. The intervention entitled "Geospatial-scenario Planning Framework for Assessing Risks and Impacts of Forest Fire in Eastern Himalayas" based on the geospatial studies and field interventions undertaken in the aegis of SERVIR Himalaya Small Grant Program of ICIMOD supported by NASA and USAID has been a unique learning experience in using geospatial tools in a very significant ecological event – forest fire. As a team leader I express my gratitude to ICIMOD, NASA and USAID for this opportunity to use and learn the science of remote sensing for acquiring community preparedness to combat ecological hazard and more so work together towards inclusive development of mountain people in eastern Bhutan and Arunachal in the milieu of climate change.

I am sincerely thankful to the Department of Forest in Bhutan and Arunachal Pradesh, who's support has been very crucial for the success of this project along with other institutional partners namely State Forest Research Institute, Arunachal Pradesh, Bhutan Trust Fund for Environmental Conservation, Rajiv Gandhi University, Jadavpur University and CEPT University in India. I sincerely thank the ICIMOD team specially for guiding us extensively throughout the project period that has helped us to keep our commitments.

Last but not the least, I thank my research and intervention team members, who have been meticulously working towards a goal and through all odds and eventualities, have extended their sincere support for this project.

Thanks and Regards

Content

Executive Summary

Can Forest Fires be prescribed? This is a critical argument from the perspectives of mountain people's livelihood and safety or conservation and physiognomy of the mountain forest. Geospatial- scenario planning framework for assessing risks and impacts of forest fire is therefore important for developing an inclusive and holistic conservation paradigm in the eastern part of the Hindukush Himalayas. Forest fires are really catastrophic necessities in the pristine ecology of eastern terrains in Hindukush Himalayas (HKH), both from environmental, societal and economic perspectives. While 60% of the events are reportedly intentional and anthropogenic, losses incurred every year are epical too that crosses 1.5 to 1.7 billion rupees. Again from ecological perception, though emission potentials and heat radiations from forest fires multifold climate impacts, it supports pyroecological dynamics of growth in forest vegetation and reportedly helps in speciation. It is therefore a pressing need to define decision support mechanism for the stakeholders and inhabitants in wild fire prescription, forecast and management. Present program delineates a strategic multi-criteria action research using geospatial tools to deliver decision support inputs for developing a pro-conservation management plan for forest fire events in the milieu of climate change.

The study area of the present project consists of six districts of Eastern Bhutan, six districts of Western Arunachal Pradesh, five districts of Meghalaya and two districts of Northern Assam where forest fires are regular phenomena. Bhutan places high priority on forest fire prevention programs since most of the forest fires are anthropogenic in nature. The people have rights on harvesting lemon grass (Cymbopogon flexuosus) for lemon oil extraction and grazing. Therefore, there exists widespread practice of burning forested areas to promote new grass growth for oil and also as cattle feed, whereas, in Arunachal Pradesh, Jhum burning is considered responsible for sneaking fire into the nearby forest. The practice of jhumming is deeply rooted into their culture, customs, myths & folklores. The neglected ember which escapes from the burning jhum readily transforms hectares of rich forest cover into ash. This project has attempted in preparing a scenario analysis framework for conservation and management of fire-prone landscape in these areas, augmenting community resilience to respond to wildfire towards downscaling impacts of fire through adaptive mitigation. Customizing one cost trade-off quantification tool for strategic impact evaluation of fire events on natural and social capital will be an integral part of this study in future. The program, for now, has attempted to review the following sectors in such fire events related to community based forest management, habitat conservation and risk avoidance towards a climate adaptive practice. These are as follows :

- Mapping of fire events and its socio-ecological contrivances for understanding its character and assessing the impacts. This has improved forecasting skill through scenario framework analysis.
- Identifying the 'drivers of occurrence' through participatory vulnerability analysis and change detection studies that can supplement to fire-prescription decisions of the stakeholders.
- Developing community based participatory plans for adaptive change management based on the previous set of findings and as well comment on the cost trade-off towards policy implications

The intervention has been framed over a time series action plan followed by adaptive management, participatory planning and stakeholder partnership to provide a logical risk assessment frame based on a multi-criteria data-matrices elucidating fire prone areas, burnt areas, vegetation dynamics pattern, geo-morphological attributes, meteorological factors, support services and accessibility options for community interface creation. It has also been able to provide a scenario planning framework for projection analysis, simulation and impact assessment studies that can help design a community based adaptive mitigation strategy. Excerpts from the final report of the project has been outlined below.

Trends Analysis Study Briefs:

1. Fire events have distinct correlations with slope elevation and aspects of the terrain and as well are driven by three meteorological factors viz. Temperature, Humidity and Air current.
2. Cluster and outlier analysis of fire spots shows distinct differences in fire event patterns in Bhutan and Arunachal Pradesh that hints about anthropogenic and natural fire causes. Decadal studies show that in both cases event frequencies have decreased but extent has increased.
3. Canopy density dependence of fire events are observed that has strong spell on secondary succession in vegetation dynamics. This makes the mid-story canopy more vulnerable to fire.
4. Post fire impacts on soil nutrients are marked in N,P,K & Total Organic Carbon but demands intensive study.
5. Societal vulnerability of inhabitants depends on acquired mitigation potentials those are mainly driven by accessibility, water resources and capacity building towards risk management. Bhutanese villagers are comparatively less vulnerable to fire events.
6. Climate connect to fire events in regard to emission rates, irradiative energy and carbon sequestration and mitigation potentials of fire prevention paradigms are highly critical and complex issues that needs time scale study and analysis.

Scenario Planning Framework:

1. Forest Inhabitants and Ranger Empowerment (FIRE) program planning can be drawn on Fire Event Buffer Area Susceptibility Indices (FEBAS) indices.
2. Spatial Decision Support Tool (SDST) for planning Emergency Response Systems (ERS) can be developed on Accessibility (Road), Extinguish ability (Water & Drainage) and Support System (Resource)
3. Fire mitigation and management planning can be guided by monitoring meteorological regulators viz. Temperature, Moisture and Air current varying diurnally along with slope, elevation and aspect in a locale.
4. In areas of greater anthropocentric activities agro-farming planning and regulation of vegetation patterns (or dynamics) can decrease risk potentials.
5. Relative Humidity, Air Temp, Wind Speed, Wind Direction, Time, Relief face, Vegetation patterns, Season, Precipitation, Fuel load, Altitude and Slope are the eight determining factors of fire events and based on these the events can be predicted, prescribed and prevented.

Questions to lead the 'Way Forward'

(a) How do vegetation patterns and dynamics regulate the spread and intensity of fire? Can there be geospatial trekkers for this?

(b) Are there anthropogenic links to fire - like changes in agro-farming and LUP or migration and displacements in the hills?

(c) Fire economics would necessarily need carbon estimates. How can the carbon estimations be guided with geospatial tools?

(d) What can be the easier ways and means for FIRE (Forest Inhabitants and Ranger Empowerment) programmes?

SAFE being working at the science society interface has the onus to provide lead for community development in the area especially for those who are sustaining their livelihood through Jhooming. SAFE is also designing a pro-community jhoom intervention that can prevent forest fire in collaboration with National Bank for Agricultural and Rural Development of India. Direct policy implications have brought back the 'Shillong Declaration' of ICIMOD to discussion table following ban on Jhooming in Arunachal. While local impacts have brought-in beneficiaries and stakeholders together to address the fire situations in hills, talks continue for Public-Private-Partnerships in fire mitigation and safety. Global impacts are expected from communities concerned with climate change. Asia Pacific Network for Global Change Research will consider for supporting capacity building program on innovative jhooming to prevent forest fire.

The project is supported by NASA and USAID and is mentored by International Center for Mountain Development (ICIMOD) Nepal. Farmer's intervention and forest fire management regime is being partnered with local community based organizations and Department of Forest and Environment in Arunachal & Bhutan.

Introduction

Forest fire events in the pristine ecology of eastern Himalayan terrains have both advantages and disadvantages from environmental, societal and economic perspectives. While 60% of the events are intentional and anthropogenic, losses incurred every year are in billions of dollars in terms of natural capital, lives and livestock, crops and assets etc. From ecological perception, significance of forest fire on vegetation dynamics, growth and biomass accrual and nutrient recycling is immense, though emission potentials and heat radiations multifold climate impacts. It is therefore a pressing need to define decision support mechanism for the stakeholders and inhabitants in wild fire prescription, forecast and management. Present program delineates a strategic multi-criteria action research using geospatial tools to deliver decision support inputs for developing a pro-conservation management plan for forest fire events in the milieu of climate change.

The program would attempt to review the following sectors in such fire events related to community based forest management, habitat conservation and risk avoidance towards a climate adaptive practice through

- Mapping of fire events and its socio-ecological contrivances for understanding its character and assessing the impacts. This would improve forecasting skill through scenario framework analysis.
- Identify the 'drivers of occurrence' through participatory vulnerability analysis and change detection studies that can supplement to fire-prescription decisions of the stakeholders.
- Develop community based participatory plans for climate adaptive change management based on the previous set of findings and as well estimate the cost trade-off towards policy implications

Forest fire has been the dominant disturbance regime in Himalayan forests since long, and is the primary process which organizes the physical and biological attributes of the mountain forest biome over most of its range, shaping landscape diversity and influencing energy flows and biogeochemical cycles, particularly the global carbon cycle. The physiognomy of the mountain forest is therefore largely dependent, at any given time, on the frequency, size and severity of forest fires. The overpowering impact of wildfires on ecosystem development and forest composition in the Himalayas is readily apparent and understandable. Large contiguous expanses of even-aged stands of oak and pine dominate the landscape in an irregular patchwork mosaic, the result of periodic severe wildfire years and a testimony to the adaptation of Himalayan forest species to natural fire over millennia. The result is a classic example of a fire dependent ecosystem, capable, during periods of extreme fire weather, of sustaining the very large, high intensity wildfires which are responsible for its existence.

For a number of reasons, Himalayan forests fires have taken on an added significance in a wide range of global change science issues in recent years. Climate change is expected to be most significant in this fragile ecology and the distribution of ecosystems in this region will change dramatically in response to climate change. This will have serious economic implications for many indigeneous races, countries and anthropocentric activities relying on forest ecosystem services, timber and non-timber forest products and Himalayan biodiversity. In addition, forest fire activity is expected to increase significantly with climate change, acting as a catalyst to a wide range of ecosystem processes controlling carbon storage in mountain forests, and likely resulting in a loss of terrestrial carbon to the atmosphere.

Trashigang, a district in Eastern Bhutan with 16 gewogs, has a population of 51,134 people and a forest cover of 180,272 hectares. The district has 79% of the land under forest cover, which has been under constant threat of fires, with 64 forest fires reported between 2001 and 2009. The forest fires, caused largely by human activities, have changed the forest ecosystems of Trashigang endangering its rich biodiversity. 67% of the forest fires in the country were reportedly due to intentional burning, whereas 21% were accidental and 12% unknown, consuming a total of 154,692 hectares of pristine forest. A study by Renewable Natural Resource Research Center revealed that most of the fires that occurred due to the aforementioned reasons were related to agricultural activity. The majority of fire incidences which are termed 'unknown' are speculated to be actually anthropogenic in nature. Management of forest fires in Bhutan Himalayas needs to be intertwined with community awareness. Public knowledge of the forest fire situation in the district is important to generate this awareness. District-level fire management systems and their operation as well as constraints faced by the District Forest Officers need to be discussed for recommending better forest fire management. Forest fire issues have been extensively discussed in various sessions of the National Assembly since 1960s. The rugged topographic conditions combined with high ground fuel loads, erratic wind conditions, constrained by lack of trained manpower, increases risk of fire incidents.

Forests play a vital role in sustaining rural livelihoods and food subsistence for the Himalayan tribal people, who are semi-nomadic highlanders of eastern Bhutan, and as well constitute the most important natural wealth of the country. Further, forests in Bhutan are vital for maintaining the sustainability of hydropower industry, which is at present the main source of national revenue and also maintains the geologically fragile mountain ecosystem. There is high national concern on forest protection, conservation and its management by reducing forest fires and improving methods of fire prevention and suppression. Bhutan places high priority on forest fire prevention programs since most of the forest fires are anthropogenic in nature. The people have rights on harvesting lemon grass (Cymbopogon flexuosus) for lemon oil extraction and grazing rights within Government Reserved Forests. Therefore, there exists widespread practice of burning forested areas to promote new grass growth for oil and also as cattle feed. Fires result from such practices including burning of agriculture debris, the timing of which unfortunately coincides with the fire season. Evidence from incidence records show that one of the main causes of fires is escapes from agricultural debris burning. Setting forests on fire, accidentally or as an act of arson is against the law in Bhutan and hence carries severe penalties too. To prevent forest fire and support sustainable management of the country's forest, different level of organization has their area of responsibility, who are the stakeholders too, and consists of Government agencies (national level) are involved in designing and implementing a nationally coordinated forest fire awareness programme and enhancing people's awareness about forest fire, develop training modules and technical manuals to backstop the district (dzongkhag) forestry sectors etc. Further, liaising with media in informing and educating the public about forest fire prevention, training the field staff and community in fire prevention and suppression is also done by these stakeholders. Currently the program is delegating forest fire management to grassroots level through formation of village level fire management groups.

At District level community education addresses basics in forest fire prevention and suppression and remains responsible for coordination of firefighting. Members of local communities, businesses, students, and private organization actively participate in forest fire suppression. During fire incidents or in large fire situations the Department of Forests plays the lead role and arranges and coordinates the suppression activities. A large part of the manpower includes volunteers from the armed forces; Royal Bhutan Army, Royal Bhutan Police, Royal Body Guards and nearby communities, who would greatly benefit from this action research. All fire incidences are reported to Social Forestry Division (National level coordination office) of the Department of Forests, through District Forest Office or the Divisional Forest Office. In line with the decentralized forestry policy, the District Forest officers have the lead role in forest fire management at local level in close collaboration with local communities.

In Arunachal Pradesh, Jhum burning is considered responsible for sneaking fire into the nearby forest, but at present there is no alternative to jhum in general and Kurung Kumey district in particular. The practice of jhumming is deeply rooted into the sustenance, culture, customs, festivals, myths, folklores, and cultural tastes of the people. The jhum provides varieties of food items food and vegetables preferred by the people throughout the length of growing season. The traditional variety of crops grown in the jhum can hardly sustain in other system. The products of the jhum are used for the preparation of traditional items. Moreover, the difficult terrain, inadequate transportation facilities and other circumstantial factors have made jhum farming convenient for the Arunachalee farmers. The main advantage for farmers is that it permits more than one crop to be harvested from the same piece of land in one season, ensuring more self-sufficiency in meeting the requirements of multiple products. Forest burning for jhum is viewed as to increase soil fertility and destroy harmful weeds and pests. It is perhaps because of all these reasons that official efforts during over 20 years have failed to dissuade people from resorting to jhum. A seeming lack of coordination among the various departments tackling the problem has been compounded by dearth of accurate statistics on how far jhum cultivation has been contained and how much forest land has been laid bare because of this method.

The initiative should be taken to improve jhum more on scientific basis instead of alternative methods. People should be encouraged to adopt more environment friendly methods and techniques. The protective and conservative measures are also needed in order to check the recurring forest fire. In some parts of the Arunachal Pradesh, especially in the Adi, Galo and Tangsa belts people clean up the margins of jhum before setting fire in order to check fire-spread. Strict vigilance is kept to check the sneaking of ember into the forest. In case of the forest fire incidence the defaulter is given appropriate punishment by the community institutions. Such practices can be emulated all over. The stringent laws must have to press into action for the effective result. The degraded forests should be restocked through social forestry advocating Community Forest Area. The state Government must be equipped with Farmers friendly plans and programmes. The government should also encourage through subsidies or loan for a non-timber forest produce (NTFP) cultivation, livestock and poultry farming, fisheries, sericulture and bee keeping etc. for the sustainable and economic growth. Such farmer's friendly policy will inculcate them towards attainment of self-sufficiency thereby allowing better environment and ecosystem services.

- **Socio-ecological dilemma in fire prescription :** Forest and wild land fire are considered vital natural processes initiating natural exercises of vegetation succession. However uncontrolled and misuse of fire can cause tremendous adverse impacts on the environment and the human society, especially indigenous highlanders who are directly dependant on mountain ecology. The vast majority of wild fires are intentional for timber harvesting, land conversion, slash and burn agriculture and socio-economic conflicts over question of property and land use rights, though most of these back-fires and leads to huge economic loss. In the absence of a place-based quantitative cost-tradeoff analysis, no fire events can be prescribed as beneficial, either for ecological or socioeconomic advantage.
- **Gap analysis in impact assessment studies :** In recent years extended droughts (prolonged dry weather), together with rapidly expanding exploitation of tropical forest and the demand for conversion of forest to other land uses, have resulted in significant increase in wild fire size, frequency and related environmental impacts. Though knowledge of the geographical and temporal distribution of burning is critical for assessing the emissions of gases and particulates to the atmosphere, statistical data on fire loss are meager and strategic environmental impact assessment studies are very sporadic.
- **Knowledge gaps in real-time fire ecology :** A critical combination of edaphic, climatic and human activities account for the majority of wild land fires, the dynamics of which is least understood yet, making fire incidences in diverse ecosystems differ widely in the production of gaseous and particulate emissions, fire frequency, fire intensity and impact on soil and vegetation dynamics. Comprehensive studies are essential on real time scenarios for designing decision support paraphernalia for conservation and management. The inability to detect wild land fires during initial

stages and take rapid aggressive action on new fires is perhaps the most limiting factor in controlling wild land fires, especially in areas with limited access. Providing an effective response to wild land fires requires few essential stages of analysis and assessment including factors determining fire potential risk, efficient tools for detecting fire start threshold limits and monitoring active fires and frameworks that are conducive for conducting post-ante assessments of fire events.

- **Under-usage of geospatial information in climate connect :** Though technological advancement in usage of geospatial data sets and tools has been widely experimented in last three decades to obtain the desired pyroecological information, decision support application models for fire management are still weak. Further, convergence of climate related research inputs from atmospheric cartography or horizontal and vertical mapping of GHGs during fire events etc for developing climate resilient application paradigms needs to be worked out yet.

Based on geospatial data analysis, it has been attempted in the project perimeter to provide a logical risk assessment and analysis framework based on a multi-criteria data-matrices elucidating fire prone areas, burnt areas, vegetation dynamics pattern, geomorphological attributes and accessibility options for community interface creation. It has also been able to provide a scenario planning framework for prediction and prescription analysis, simulation and impact assessment studies that can help design a community based adaptive mitigation strategy. The main outcome of the intervention has been as highlighted below :

1. Improved forecasting skill in fire prone zones of eastern Himalayas for risk avoidance and enhanced preparedness for both community and the stakeholder agencies.
2. Scientifically validated decision support tool for fire prescription that can facilitate the local community to harness benefits of the fire-event and as well regulate the anthropogenic impact on forests deteriorating its ecosystem services.
3. Climate adaptive participatory guidelines for monitoring and management of forest fire regime that can significantly bring in policy implications in conservation of fragile Himalayan ecology
4. Assessment of cost trade-off in implementing the suggested management paradigm towards conservation of natural capital as a place-based intervention in Eastern Himalayas.
5. Augmentation of social capital in capacity building of stakeholder, awareness and preparedness in community beneficiaries enhancing disaster resilience, resource enrichment through knowledge economy in identifying economic mechanism for recompensing opportunity costs.

The intervention directly relates to disaster response and change management towards sustainable environment development by innovatively using geospatial tools, which is the main objective of SERVIR Himalaya program. Further, it tries to accomplish a knowledge economy for bridging the information gaps in pyroecological studies with reference to climate change and adaptive mitigation in alignment with the prime focus of the SERVIR program. Being a decision support action research, the project outputs would also help in carrying out the mission of SERVIR for creating a network of data sharing and strategy planning involving stakeholders, wherein the community participation and partnership would be binding.

The presented work at science-society interface is relevant from the climate adaptive conservation perspective, ensuring that technology cooperation and capacity building can augment place-based climate resilience by developing a community-ecosystem framework for adaptive management across time and space. This would in future enable the stakeholders in accomplishing sustainability to a large extent, as it addresses one of the critical and catastrophic events of a fragile ecosystem like Eastern Himalayas, which is a climate vulnerable biological hotspot. Information banking and sharing the same for knowledge economy would be integral to all action research elements of the proposal, in accordance with the SERVIR program guidelines. Additionally, this would fetch the empowerment of information and reduce technological paucity among the partners of change, supplementing the sustainability coefficient. Further, this would not only enrich the scientific strategy maneuver in fire regime management but would essentially delineate a economic feasibility study to support community based policy designing and implementation planning so as to endow with a single-window solution to one of the least understood cataclysmic phenomenon in the Eastern Himalayas.

Literature Review

Except for Antarctica, practically no region of the world is entirely free from fires in an open environment (Luke and McArthur 1977). Fire is one of the forces of nature that has shaped our world over millions of years. It may be creative or destructive, or both at the same time in its environmental impacts. The occurrence, frequency and intensity of fire, either natural or human caused, or its exclusion either through natural or human intervention are determining forces for maintaining, enhancing, or reducing the health and sustainability of ecosystems (Hamilton et al. 2003). At the turn of the century, many nations initiated policies and programs to protect resources from fire. The negative effects of fires greatly overshadowed their benefits, and thus initial policies were largely centered on fire exclusion. According to Keane et al. (2002), "Fire exclusion' is the defacto policy of trying to eliminate fires from the landscape using fire suppression techniques." In U.S., The Use Book, published in 1905 for administration and management of Forest Service lands advocated total fire exclusion on both public and private lands (Biswell 1989). The first national fire policy came after several years of severe fires between 1910 and 1935, in line with accepted theories of the time, fire exclusion was believed to promote ecological stability and in addition reduce commodity damages and economic losses (NWCG 2001). Over several decades, the Forest Service led a multiagency, paramilitary-type program to eliminate forest fires. By 1960s, rapidly expanding knowledge in the young science of ecology revealed that fire plays an important role in natural forests (Amo and Fiedler 2005).

In the years that followed, fire policy in the U.S. saw many changes. By 1977 the Forest Service encouraged fire by prescription. The 1988 Yellowstone fires sparked much debate on such fire policies in the wilderness and national parks. During the season, a total of 248 separate fires raged in the Greater Yellowstone Area; 31 of which were initially designated and allowed to bum as prescribed natural fires under U.S. Departments of Interior and Agriculture policies (Wakimoto 1990). The 1989 review of the 1988 Yellowstone fires affirmed the positive benefits of fire and continued the evolution of fire policy. The 1995 Federal Wildland Fire Management Policy review recognizes the need for landscape-level resource management, the integration of fire into land management planning and implementation, and the involvement of all affected landowners and stakeholders (NWCG 2001).

In the Rocky Mountains, after more than a century of fire suppression, it is now widely accepted that the health of the ecosystems is now in decline because of fire exclusion. According to Keane et al. (2002), at first glance the effects of fire exclusion may seem beneficial to society (for example, preservation of timber resources and watershed protection), but on closer scrutiny, there seems little doubt this policy has created many unhealthy features on the Rocky Mountain landscape.

In Bhutan, in tune with nationalization of the forests with the enactment of the Forest Act in 1969, the Royal Government commenced on a policy of strict fire exclusion from all state owned forests. According to Ura (2002), although forest fire is prohibited, a Royal Edict issued in 1981 makes exception to yak herdsmen who are permitted to bum alpine pastures under the supervision of the DoF and Animal Husbandry. This indicates that provisions on forest fire in the 1969 Act had obvious conflicts with interests of pastoral communities' dependant on yak herding.

The National Assembly of Bhutan, the highest legislative body in the country, has deliberated much on the issue of forest fires in the country. Resolutions on prevention and control of forest fires were passed as early as 1963 at the 19"* session of the Assembly. Subsequent sessions dwelt extensively on the subject, which culminated into enactment of provisions on forest fires in the Forest and Nature Conservation Act (FNCA) of 1995. The 11*^ session held in June 1999 voiced much concern on the destruction of trees and unprecedented accumulation of smog as a result of forest fires during that past season. The legislation of the FNCA (1995) brought dramatic changes to legal provisions on forest fires. Section lO(ii) of the Act prohibits, "setting of fire, except controlled campfires, or leaving any fire including a campfire burning in such manner as to destroy, damage or endanger trees, any forest produce or wildlife" (RGoB 1995). It also spells out that it is the duty of every citizen to help in suppression efforts and in identifying offenders. Wherever the culprit cannot be identified, it is the responsibility of the nearest community to replant and maintain the burnt area under supervision of the department. In addition, the Revised Forest and Nature Conservation Rules of 2003 further details, "for causing or contributing to the causation of a forest fire, a penalty of imprisonment of not more than 5 years, or a fine, minimum of which shall be Nu.300 and may extend upto Nu. 1,000 per acre" (RGoB DoF 2003). Unlike in the Rocky Mountains, there is hardly any study on effects of fire exclusion on the Bhutanese landscape. Limited research on fire effects on grazing lands indicate that, since the ban of fires in early 1970s, encroachment of unpalatable shrub species have increased in high altitude grazing lands of western Bhutan (Gyamtsho 2002). Others offer similar views that, certain species of plants and animals whose habitats depend on periodic fires for clearing are dying out due to cessation of burning (Ura 2002). According to the author, in alpine region, there is a well-founded suspicion that diminutive annuals - floral and medicinal plants - are becoming less abundant due to colonization of the meadows by coniferous forest. Despite a cautious policy on fires, the Act (1995) and Revised Rules (2003) mentions specific provisions for the Ministry (RGoB 1995) or the Department (RGoB DoF 2003) to issue rules and adopt regulations governing the use of fire in GRFs. In recent years the Department is making use of this provision to try out prescribed bums for management of forest stands and NWFPs. A few prescribed bums have already been carried out on trial basis in Chirpine (*Pinus roxburghii*) forests in eastern Bhutan.

Fire Effects on Ecosystem

Fire affects entire ecosystems - their flora, fauna, the atmosphere, soil and water. Ecosystems have evolved with, and adapted to, specific fire regimes and therefore, it is imperative to define and understand 'fire regimes' when we talk about fire effects on the ecosystem. "Fire regime is defined as pattems of fire occurrences, frequency, size, severity, and sometimes vegetation and fire effects as well, in a given area or ecosystem" (NWCG 2005). The inherent abilities of plants to respond to fire depend partially on the fire regime to which plant community has adapted. According to Agee (1993), fire has played and will continue to play a significant role in determining vegetation physiognomy, structure, and species composition in the

world's temperate and boreal ecosystems. He asserts fire has variable but predictable effects on individual plants; and that translating these from the physical to the physiological helps understanding of how fire affects vegetation not only at the level of the individual plant, but also at levels of plant community and the landscape. Fire effects on plants cannot be understood unless their survival and reproductive strategies with respect to fire are understood. Some plants resist fire by characteristics such as thick bark or buds that can withstand scorching temperatures, whereas some plants are almost always killed by fire (Miller and Findley 1994). In many cases fire is a major cause of plant mortality since it preferentially kills trees of short stature or thin bark. Likewise, fire creates gaps that new individuals colonize (Brown and Smith eds. 2000). Anderson (1994) maintains that generalizations regarding fire effects on vegetation can be misleading. Species such as bitterbrush (*Purshia tridentatd*) are frequently credited with being so severely harmed by fire, that they should be given complete protection. However, many of them are dependent on fire or some similar disturbance. Effects of fire on fauna show almost infinite variety. In North America, faunal communities have evolved in the context of particular regimes and show patterns of response to fire itself and changes in vegetation composition and structure that follow fire. Fires affect animals mainly through effects on their habitat. There is often short term increase in productivity, availability and nutrient content of forage and browse. These changes can contribute to substantial increases in herbivore populations. Such increases may be moderated by animals' ability to thrive in the altered, often simplified, structure of the post fire environment (Lyon et al. eds. 2000). Similarly, fire has different effects on populations of different animal species depending on their habitat, predation habits and home range. The following effects of wild land fire on wildlife are reproduced from Agee (1993):

1. Fire is not detrimental to many species of wildlife; conversely, it is not always beneficial to wildlife or of equal effect on all species.
2. Death of large animals directly due to fire is rare. Death is usually due to suffocation and primarily affects species with small home ranges.
3. Many species ignore the presence of fire, while others are attracted to it because of the availability of prey.
4. The major effect of fire is on animal habitat: food, cover, and water.
5. Fire may have different effects over time on an individual species, with immediate beneficial or detrimental effects and later offsetting effects.

Fire, either in the wild or prescribed, may have a large range of effects on the soils, water, and watershed resources of forestlands, shrub lands, grasslands and wetlands. The wide range of effects is due to the inherent pre-bum variability in these resources, and to fire behavior characteristics, season of burning, and pre-fire and post-fire environmental conditions such as timing, amount, and duration of rainfall (Clark 1994). Agee (1993) points out that, much of the rigorous research on soil and water impacts from fire has been conducted on the scale of soil sample, whereas much of the relevant geomorphic and hydrologic impact of fire occurs at the scale of the sub-basin or watershed. At this scale there are a variety of confounding impacts associated with weather variation, other aspects of management (logging, roads, salvage operations), and variation in fire severity. In most watersheds of fire dependent or dominated ecosystems, fire impacts to soils and water are significant components and variable backgrounds of cumulative watershed effects (Neary et al. eds. 2005).

The effects of fire on soil resources are induced by soil heating, by removal of protective cover of vegetation, litter and duff, or by concentration of plant material substances in the soil (Clark 1994). Burning and resulting post fire environmental conditions can alter the functioning of soils physically (e.g. aggregate stability, pore size, distribution, water repellency and runoff response), chemically (e.g. nutrient availability, mineralogy, pH and C:N ratios) and biologically (e.g. biomass productivity, microbial composition and carbon sequestration) (Doerr and Cerda 2005). As a physical event, fires may influence soil temperature, soil structure, and the ability of the soil to absorb and store water. All of these properties are related and depend on how thoroughly the duff and litter are burned. Fire rarely consumes the duff layer completely and almost always some duff remains to protect the soil against raindrop impact and erosion by wind or water (Pyne et al. 1996). One very important effect of fires on soil in the context of this paper is erosion. Observations suggest that various erosion processes may be accelerated by moderate to high severity fires (Agee 1993). Pyne et al. (1996) suggest that areas normally subject to erosion experience erosion rates accelerated temporarily by fire, and those areas with little erosion under normal conditions show little increase as a consequence of fire.

The effects of a fire on a water regime may be physical, relating to movement of water and sediment; chemical, pertaining to array of chemicals and nutrients released by the fire; or biological, relating to changes in aquatic habitat as a result of fire (Pyne et al. 1996). Fires may affect both water quality and water quantity.

Annual water yield can be significantly increased after fire due to the reduction of interception loss and transpiring vegetation, compared to generally lower increases in evaporation. This effect is proportional to the amount of watershed area burned and to annual precipitation (Agee 1993). Fire decreases water quality, by increasing sedimentation and turbidity, increased stream temperatures, and increased concentrations of nutrients resulting from surface runoff (Clark 1994). Wild land or manager ignited fires emit huge quantities of smoke which contributes to pollution of the atmosphere. In the U.S., the 1977 Clean Air Act (CAA) mandates the protection of human health and the prevention of deterioration of air quality, and establishes acceptable levels of emissions. Amendments to the CAA specify that individual states must consider smoke from wild land fires in their state plans. In addition, states can also establish stringent requirements on prescribed fires (Mahaffey and Miller 1994). Smoke impacts during episodic fire events can threaten public health, cause smoke damage to buildings and materials, and disrupt community activities. Although particulate concentrations in ambient air rarely reach health-threatening levels, particulate matter concentrations from wildfire smoke sometimes exceed accepted levels. Wildfire smoke can also be the dominant cause of visibility reduction in adjoining areas during episodic events like the 1988 Yellowstone fire (Sandberg et al. eds. 2002).

The effect of smoke on air quality has become a critical limitation to use of fire in the wild land and alternatively a basis for suppression of fires. When a fire occurs, about 90% of fire emissions consist of carbon dioxide and water vapor. The portion of carbon in smoke not converted to carbon dioxide (CO_2) is particulate matter, carbon monoxide (CO), and volatile organic matter (Agee 1993). These other gaseous components of smoke are considered pollutants. CO is the most abundant and poses major risk to human health. While CO_2 is technically not considered a pollutant, it contributes to global warming. According to Glick (2004), computer models predict that CO_2-induced warming could eventually raise the incidence of fires by more than half and northern coniferous forests, which become fire prone in hot weather, could be hit hard.

In addition, wildfires have serious social and economic implications. In the U.S., fires in the wildland-urban interface pose serious threat to communities. Large fire episodes in 1910 in northern Idaho and northwestern Montana burnt 1.2 million hectares and resulted in the deaths of 85 people (Agee 1993). Devastating wildfires in western U.S. in 2002 burned more than 3 million acres, and more than 600 homes (Amo and Bunnell 2003). Studies on the economic impacts of the 1988 Yellowstone fires show that there was a big drop in total tourist visitation. Only 1.7 million tourist visits were recorded in 1988, as opposed to the projected 2.3 million based on past figures. Expenditures based on tourism were down about US$ 21 million in 1988, US$ 13 million in 1989, and US$ 26 million in 1990 (Polzin et al. 1993). In Bhutan, there is little documented research and literature on effects of fire on the ecosystem. Forest fires are perceived as a big threat to national conservation efforts. The effects of forest fires are more pronounced given the highly sensitive nature of the mountainous ecosystem and the time it takes to rejuvenate completely from such incidents. According to Chettri (1994), forest fire is one of the biggest threats to Bhutan's natural resources. Broad leaf and conifer forests which constitute the bulk of Bhutanese forests are most susceptible to frequent wildfires. In addition, scientific forest management plans with high cost inputs can be made quickly obsolete by the occurrence of large fires.

Types of Forest Fire : There are two types of forest fire i) Surface Fire and ii) Crown Fire

- **Surface Fire :** A forest fire may burn primarily as a surface fire, spreading along the ground as the surface litter (senescent leaves and twigs and dry grasses etc) on the forest floor and is engulfed by the spreading flames.
- **Crown Fire :** The other type of forest fire is a crown fire in which the crown of trees and shrubs burn, often sustained by a surface fire. A crown fire is particularly very dangerous in a coniferous forest because resinous material given off burning logs burn furiously. On hill slopes, if the fire starts downhill, it spreads up fast as heated air adjacent to a slope tends to flow up the slope spreading flames along with it. If the fire starts uphill, there is less likelihood of it spreading downwards.

Forest fire in Arunachal Pradesh

Arunachal Pradesh, which forms part of Eastern Himalaya bio-diversity hotspot, is characterized by wide range of physico-climatic conditions varying from tropical foothills in the south to alpine grasslands in the north stretching within narrow width of the entire forest cover of the North-east, a total forest cover of 68019 square kilometer (39.25%) lies in the state of Arunachal Pradesh. The state of Arunachal Pradesh has more than 80 percent of forest cover. Of the entire forest cover of the North-east, 39.25% of forest covers lies in the state of Arunachal Pradesh. However, in the recent, the loss in forest cover was registered as being highest among the north-eastern states by 26 sq km in the year between 2001 and 2003. One of the factors behind such loss in forest cover could be the unprecedented forest fires, which is very frequent in the state. Undoubtedly, the repeated annual forest fires in the state may increase further depletion of forest. The forests of the state of Arunachal Pradesh are legally classified and notified as reserved forests, protected forests, anchal and village forests reserves, national parks and wild life sanctuaries under the relevant provisions of Assam Forest regulation 1891, Anchal and Village Forest Reserve Act 1978 and 1981 and the Wild life (Protection) Act 1972.It is required to be mentioned here that four different types of forests which are prone to forest fires. These are:

1.	Tirap district	Tropical wet evergreen forest - 80.14 percent
2.	Lower Subansiri district	Sub tropical and pine forest - 91.49 percent
3.	Papum pare district	Tropical semi evergreen forest - 94.95 percent
4.	East and West Kameng district	Temperate forest - 88.59 percent

Causes of forest fire in Arunachal Pradesh:

The forest fire in the state is purely anthropogenic in nature. Almost all tribes living in the hilly parts of the state practice traditional slash-and-burn method of agriculture along the hill slopes, which is known as jhum cultivation. The new jhum plot is selected and slashed generally in the months of December, January or February. The slashed biomass is set ablaze as soon as it dries up adequately to turn into ash by the fire. The neglected ember which escapes from the burning jhum readily transforms hectares of rich forest cover into ash within no time. It is a tough job to contend or manage forest fire in the hilly terrains. Due to gradient, the fire creep upslope readily; steeper the slope more aggressive is the fire because of the easy reach of fuel to slither through. Moreover, the mountain or valley breezes also act as catalyst for its rapid spread. The distant and difficult terrains are not reached by the available fire brigades and other services.

The forest fires in some pockets of Arunachal Pradesh are intentional to meet certain specific requirement of the ethnic groups. Intended burning of the forest fulfills the objectives of rejuvenating the forest cover by burning down the dried up leaves and grasses during the lean season (Mid November to March) to allow regeneration of tender vegetation which serves as fodder for the livestock. There are other communities who collect green vegetables from the forest, have been practicing forest burning to help grow the selective plants used as vegetables. The burning of forest also regenerates thatch-grass used for roofing and other important activities. Such forest burning is in practice in Ziro, Tawang, Bomdila, Anini and Hawai areas. Further, the forest burning helps native hunters to allure browsing animals. Sometimes the encroachers also set fire to forest in order to clear the land for agricultural purposes.

Recent history of forest fire in Arunachal Pradesh:

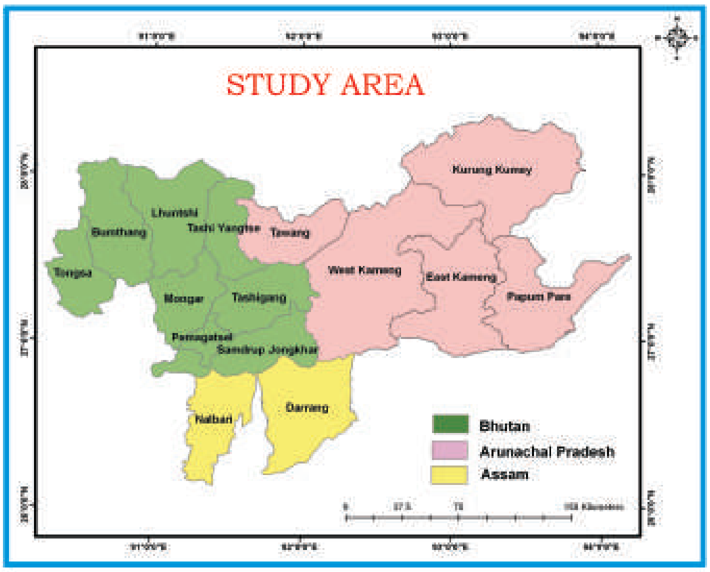
The recent history of incidence of forest fires in the state of Arunachal Pradesh has been studied between 1985 to 2005. It is clear that the incidence of forest fire has increased by more than threefold after 1995. In fact as many as twenty seven fire accidents are recorded between 2001 to 2005 where as there were only six incidences traced between 1985 to 1990. At the regional level maximum fire incidence (numbering thirty nine) are recorded in the lower temperate forest type of West Kameng district traced into Bomdila Forest Division. Of these thirty nine as many as thirty incidence of forest fire in this Division has been recorded in the last 10 years. All the rest three Forest Divisions in the districts of Tirap, Papum pare and Lower Subansiri also have shown increasing incidences of forest fires in recent times. Therefore, it can be concluded that incidences of forest fire is related to increasing interference of human activities inside natural forest covers. The human activities can be traced into general categories of grazing, jhumming, hunting and poaching and tea cultivation (Palit, G. 2010).

Effect of forest fire in soil erosion and ecosystem:

The jhum clearing and forest fires are immediately followed by the onset of the monsoon rain. Unfortunately, high concentration of erosive energy of rainfall is found during monsoon (June to September) followed by summer (March to May).Thus, the rainfall is not only consistent during summer and monsoon but its energy also is more concentrated. The high intensity storms during monsoon causes heavy damage to soil mainly from the naked and unprotected earth surface because of the jhuming activities, degraded forest due to fire and secondary forest areas (which is the cumulative result of the jhumming and forest fire). The shortening of the jhum cycle and increase in the number of jhuming families is also causing concern. In 1974, around 81,000 families were jhum cultivators in Arunachal Pradesh; by 1984 their number had shot up to 107,000 and it was estimated to reach up to 1, 55,000 families by 2000 (Roychowdhury 1992). Further, according to a 1989 survey, the forest area affected by shifting cultivation in Arunahal Pradesh has increased from 7.94 lakh ha in 1975 to 8.52 lakh hac in 1984, a 7.3% increase.

The number of escaped fires can be reduced by adapting appropriate controlled burning techniques in agricultural land and orchards. Uncontrolled use of fire as a tool to improve pasture land should not be considered in any part of the country. If it is a necessity for the survival of livestock, appropriate techniques for burning of pasture land should be developed so as to insure the protection of surrounding vegetation. Similarly, the number of fires escaping from camp fires, cooking fires etc. can be reduced by adopting more restrictions through rules and regulations. Appropriate prevention modules for different types of target groups, such as agriculturists, orchard owners, herders etc. should be designed. Various target groups should be made aware of the value of the forests. Only then would we be going in the right direction towards achieving good-will of the people. Prevention is better than cure. Therefore every effort should be made to prevent forest fires. If there is honour with our people in preventing forest fires, then the fire incidence could be avoided.

Study Area



The study area consists of six districts of Eastern Bhutan, six districts of Western Arunachal Pradesh and two districts of Northern Assam (table no. 1). The study area has been selected on the basis of frequency of forest fire.

Table 1 : Study Area

Country	State	Districts
Bhutan		Trashigang(27°19'48?N 91°34'12?E) Mongar(27°15'N 91°12'E) Samdrup(26° 49' 0" N / 91° 34' 0" E) Luntse(27°28, N, 89°39'E) Bumthang(27°36'N 90°49' E) Tongsa(27°36'N 90°31″59″E)
India	Arunachal Pradesh	Tawang, West Kameng, East Kameng, Papum Pare, KurungKumey
	Assam	Nalbari, Darrang

A brief description of the study area :

Bhutan

Bhutan (26°45' and 28°0'N and 88°45' and 92°10'E) occupies about 38,394 km^2 area and is located in the eastern Himalaya region. Bhutan is recognized as one of the 10th global biodiversity hotspots. Bhutan's forest covers 72.5 percent of the total area of the country.

Uncontrolled forest fire directly impacts the environment; damages resources, damage wildlife habitat and population, and more importantly damage property and threaten lives. In a span of 13 years from 1993- 2005, 868 cases of wildfires have affected 128,368 ha of pristine forest area. Most of the forest fires are anthropogenic in nature. The people have right to harvest lemon grass for lemon oil extraction. Therefore, there exists widespread practice of burning forested areas to promote new grass growth for oil and also as cattle feed. Fires result from such practices including burning of agricultural debris, the timing of which unfortunately coincide with the fire season.

Forest fire usually occurs when the vegetation is dry and ground fuels are abundant during the winter months, it also differs based on the geographical locations such as tropical, sub- tropical, temperate and climatic conditions like length of dry season and frequency of rainfall. In eastern Bhutan the fire season is between January to June and in west between November to May.

Trashigang, Mongar, samdrup, Luntse, Bumthang, Tongsa are the districts of eastern Bhutan which are frequently affected by the forest fire. The following table shows the frequency of forest fire in the study area.

District in eastern Bhutan	Forest Fire Years	Avg. No. of Forest Fire events / year (Frequency)
Bumthang	1978, 80, 81, 83, 86, 87, 2005	4
Trongsa	1979, 80, 81, 82, 83, 84, 85, 86, 87, 2006	3
Luntse	1986, 87, 88, 90, 91	8
Mongar	1980, 81, 82, 83, 84, 88, 89, 90, 91, 92, 2011, 2013	8
Trashigang	1982, 83, 84, 86, 87, 88, 89, 90, 91, 92, 2006	11
Samdrup Jongkher	1979, 80, 83	10

Arunachal Pradesh

The state of Arunachal Pradesh has more than 80 percent of forest cover. Of the entire forest cover of the North-east, a total forest cover of 68019 square kilometer (39.25%) lies in the state of Arunachal Pradesh.Arunachal Pradesh with a geographical area of 83743 square kilometer accounts for about 2.55 percent of the total land of the country. Of the total geographical area 68019 square kilometer is covered by forest amounting to 81.22 percent of the total land area of the state.

Table No-4. Geographical area under forest cover in Arunachal Pradesh (FSI-2003).

Districts	Geographical Area (Sq.Kms)	Very Dense Forest (Sq.Km)	Moderately Dense Forest (Sq.Km)	Open Forest (Sq.Km)	Total Forest (Sq.Km)	Percentage of Forest
Changlang	4662	1879	1539	888	4306	92.36
Tirap	2362	459	1042	392	1893	80.14
Dibang Valley	13029	851	5836	2736	9423	72.32
East Siang	3655	448	1944	480	2872	78.58
Lohit	11402	1955	4224	1615	7794	68.36
Lower Subansiri	9548	2286	4745	1704	8735	91.49
Papum pare	3462	754	1699	834	3287	94.95
Upper Siang	7050	736	3676	1198	5610	79.57
Upper Subansiri	7032	849	3803	1155	5807	82.58
West Siang	7813	997	4884	946	6827	87.38
East & West Kameng	11556	2583	5548	2107	10238	88.59
Tawang	2172	110	664	453	1227	56.49
Arunachal Pradesh	**83743**	**13907**	**39604**	**14508**	**68019**	**81.22**

*Districts marked red are intervention sites of SAFE

The forests of the state of Arunachal Pradesh are legally classified and notified as reserved forests, protected forests, anchal and village forests reserves and are prone to forest fire. The recent history of incidence of forest fires in the state of Arunachal Pradesh has been studied between 1985 to 2005. It is clear that the incidence of forest fire has increased by more than threefold after 1995. In fact as many as twenty seven fire accidents are recorded between 2001 to 2005 where as there were only six incidences traced between 1985 to 1990. At the regional level maximum fire incidence (numbering thirty nine) are recorded in the lower temperate forest type of West Kameng district traced into Bomdila Forest Division. Of these thirty nine as many as thirty incidence of forest fire in this Division has been recorded in the last 10 years. All the rest three Forest Divisions in the districts of Tirap, Papum pare and Lower Subansiri also have shown increasing incidences of forest fires in recent times. Therefore, it can be concluded that incidences of forest fire is related to increasing interference of human activities inside natural forest covers. The human activities can be traced into general categories of grazing, jhumming, hunting and poaching and tea cultivation.

Table:No-5. Recent history of forest fire in Arunachal Pradesh

Types of forest/ Districts	1985-90	1991-95	1995-2000	2001-2005	Total
Tropical wet evergreen forest of Tirap district	2	1	5	2	10
Tropical Semi evergreen forest of Papumpare district	1	0	2	3	6
Sub-tropical and Pine forest of Lower Subansiri district	0	0	1	9	10
Lower temperate forest of West Kameng district	3	6	17	13	39
Total	6	7	25	27	65

Spatial and Causal aspects of forest fire in Arunachal Pradesh

The spatial and causal aspects of forest fire in Arunachal Pradesh has been studied through primary sources covering the four Forest Divisions namely Deomali, Bandardewa, Hapoli and Bomdila in the districts of Tirap, Papum pare, Lower Subansiri and West Kameng, respectively. All the causes traced are recorded to be anthropogenic by nature. These manmade causes are divided into two clear cut categories.

These are : (i) Intentional. (ii) Accidental.

It is understood that fire caused by human interaction with forest is categorized into activities like jhumming, grazing, encroachment, hunting, tea cultivation and road construction in that order. Of these activities jhumming is related to controlled fire which is not considered as fire incidence within the jhumming land. However, a fire escape from the jhumming land and creates forest fires more often than not. These kinds of forest fires are categorized into anthropogenic accidental as their causes. Sometimes road construction also leads to cause of forest fire (one case recorded). Under the category of anthropogenic intentional causes, several human activities can be identified.

In case of Arunachal Pradesh burning natural forest for development of tea cultivation, for developing grazing land are traced to the Deomali Forest Division (Tirap district) and Bomdila Forest Division (West Kameng

District), respectively. The other intentional causes for forest fire created by human beings are burning of bamboo flowering, hunting and poaching and sometimes for land encroachment which are wide spread in all over Arunachal Pradesh.

Types of Forest	Name of Forest Division	Anthropogenic Causes		Total Area Affected (In Hectare)
		Intentional	Accidental	
Tropical wet evergreen forest of Tirap district	Deomali	For tea cultivation(1). Burning bamboo flowering (1)	Jhumcultivation(8)	109.50
Tropical Semi evergreen forest of Papumpare district	Bandardewa	Burning bamboo flowering(1). For hunting & poaching(1)	Jhumcultivation(4)	655.20
Sub-tropical and Pine forest of Lower Subansiri district	Hapoli	For hunting & poaching(1).	Jhumcultivation(9).	850.0
Lower temperate forest of West Kameng district	Bomdila	For land encroachment(2). For grazing land (8)	Jhum cultivation(28) From combustible (petroleum) product(1)	1486.12
Total area effected (In Hectare)				3100.82

It is found that large areas are affected in the western district of West Kamengwhereas the tropical wet ever green forest of Tirap district is least affected. This is how ever more of approximation as far as the intensity of fire is concerned because the grazing land development in the western Arunachal Pradesh (West Kameng district) covers large tracts of grazing land development which is of intentional and beneficial to the people in that area who rear large herds of cattle. Therefore, it can be deduced that forest fire study has a region specific aspect to its cause and consequences.

Assam : (Nalbari District)

Nalbari District is situated between 26N and 26.51°N latitude and 91°E and 91.47°E longitude. The north and west side of the district is bounded by Baksa and Barpeta districts respectively .The south and east side of the district is bounded by Kamrup district. The entire area of the District is situated at the plains of the Brahmaputra Valley. The tributaries of the Brahmaputra, Nona, Buradia, Pagaldia, Borolia and Tihu which originate from the foothills of the Himalayan Range are wild in nature and have enormous contribution towards the agrarian economy of the district. The Soil condition of the District is a heterogenous one. The Soil of the northern part of the district is clayey and loamy, the middle part is loamy and sandy. The Soil of the southern part of the district is composed of predominantly sandy soil. The District has a sub-tropical climate with semi dry hot summer and cold winter. During summer, generally during the months from May to August, heavy rainfall occurs for which the district experiences flood. The District experiences annual (average) rainfall 1500 mm and its humidity hovers around 80%.

Goals & Objectives

A. **Goal 1 : Ecological Perspective : Preparing scenario analysis framework for conservation and management of fire-prone landscape in eastern Himalayas.**

Objectives

1. Develop decision tools for fire prediction and prescription, where multiple benefits can be achieved
2. Assess the extent of ecosystem dependence on fire-events and evaluate its contrivances as a disturbance process in the given scenario
3. Determine anthro-ecological drivers of fire-events and prepare participatory plan for place-based impact abatement

B. **Goal 2 : Societal Perspective : Augmenting community resilience to respond to wildfire towards downscaling impacts through adaptive mitigation**

Objectives

4. Define directives, to guide adaptive community activities, to improve initial response capacity and enhance community preparedness
5. Provide decision inputs to perk up organizational efficacy in mitigating fire-events by the community stakeholders through shared response capacity
6. Prepare ecosystem management framework for compensating burnt loss through participatory range recovery programme

C. **Goal 3 : Economic Perspective : Customizing cost trade-off quantification tool for impact evaluation of fire events on natural and social capital.**

Objectives

7. Develop cost analysis template for valuing tangible and elusive losses in fire-events.
8. Develop cost analysis templates for valuing benefits in prescribed fire scenario
9. Assess changes in ecosystem services in pre and post-ante fire and value economic implications, with specific reference to the study area.

The intervention would be framed over a time series action plan followed by adaptive management, participatory planning, stakeholder partnership and scenario framework analysis. The chronological activities would include

1. **Acquiring Geospatial Resources :** Various geospatial data sets, maps and satellite imagery (details given in methodology) shall be acquired from open sources access, following which an inventory shall be created for facilitating the study and further analysis.
2. **Identifying Intervention Sites :** A specific study area in the laps of Eastern Himalayan terrain that is prone to forest fire incidents shall be identified, which would expectedly encompass six districts each in eastern Bhutan and western Arunachal Pradesh and 2-3 districts in Assam foothills. Two field survey sites shall be identified based on event significance, occurrence, accessibility, proneness etc.
3. **Developing Research Partnership :** Upon fixation of study locations and field sites, partnership with local stakeholders and agencies will be built for participatory planning exercises, vulnerability analysis, community approach, logistic support and permission for accessibility etc. These stakeholder agencies would include the District Forest Management Team, Department of agriculture, Department of forest, Royal Bhutan army, Indian army, Disaster management groups, District administration etc. Community members, local village beneficiaries, farmers and community foresters shall be briefed on the abridged concept and purpose of study to seek their partnership and participation.
4. **Defining Research Designs :** After an initial overview of the geospatial data sets acquired, specific experimental designs will be prepared for field survey and sampling in the designate study sites. The same would then be shared with the stakeholders for further optimization and feasibility assessment. Field trips would be planned accordingly. This would attempt to bridge the knowledge gaps from field data inputs, community feedback review and ocular diligence.
5. Field Truthing, Survey & Sampling: This field exercise would include GPS supported field truthing, physical assessment, ecological survey and sampling and also socio-economic survey of the community in the near vicinity who would be directly affected by a fire event.
6. **Community Meet, Awareness Workshop :** Community events will be organized in the study area for two specific aspects:
    - Awareness building and preparedness to augment community resilience to fire incidences.
    - Undertake PVA, Attitude Scaling, Peer interaction etc. and identify TEK inputs for facilitating the study discussion support method.
7. **Data Compilation and Analysis :** All data will be compiled and analyzed for scientific interpretation, assessment studies and comparative analysis.
8. **Feedback and Adaptive Management :** In the process of data compilation and analysis, the information gaps and input supplementation needs shall be assessed and accordingly actions shall be planed to mitigate through adaptive management. Further, feedbacks from stakeholders and community members shall be sought if needed for facilitating the review work.
9. **Data Interpretation, Interpolation, Inferences :** Data accrued shall be statistically interpreted, interpolated in various software environment and inferences thereto shall be derived for developing inputs for achieving the target objectives of the study.
10. **Report Preparation, Publication and Dissemination Workshop :** Reports and deliverables (maps, photographs, videos, images, graphical analysis matrices etc) shall be prepared and published. The publication shall be disseminated through a workshop as advised by the funding agency. The final report shall be shared with the stakeholder partners and translated in local languages as handout-briefings for the community members. An exhibition of deliverables can be held for visual impacts, if possible, during the dissemination workshop.

Methodology

Forest fire detection for the last 10 years :

Methodology & Data to be used **:** MODIS thermal band derived fire locations data MODIS-FIRMS (Fire Information for Resource Management System). Full archive data (2001-current) will be downloaded from the portal.

Vulnerability analysis, zonation and repetition :

Fire Intensity monitoring :

Methodology : Relative Fire intensity can be estimated from a parameter in the MODIS fire location data product called FRP (Fire Radiative Power) which depicts the pixel-integrated fire radiative power in MW (Mega Watts). FRP provides information on the measured radiant heat output of detected fires. The amount of radiant heat energy liberated per unit time (the Fire Radiative Power) is thought to be related to the rate at which fuel is being consumed Wooster et al. (2005).

Vulnerability zonation / repetition analysis :

Methodology : Forest fire vulnerability zone maps are prepared with the inputs from land use/land cover (with vegetation type information),Digital Elevation Model(DEM),slope, direction of slope (aspect), proximity to settlement, water-bodies, road approach to the fire location or road connectivity, weather inputs like wind speed, wind direction and relative humidity from IMD/ Automated Weather Station (AWS) data established by ISRO/IMD or any other sources (Methodological flowchart is given below).

Data to be used : LULC/Forest type/cover: LANDSAT TM/ OLIDEM/;slope/aspect: ASTER/ Carto-DEM. Fire repetition analysis or in other words the Jhum/shifting cultivation cycle period can be derived by burned area analysis. Burned area product from MODIS/LPDAAC website can be used as a proxy to determine the area subjected to fire and hence shifting cultivation.

Fire Duration Monitoring :

Methodology : Duration of a fire can be somewhat monitored by analyzing data from multiple passes of MODIS (Aqua/Terra).

Fire data Analysis and Interpretation

Cluster and Outlier Analysis

Basic Definition : Given a set of features (Input Feature Class) and an analysis field (Input Field), the Cluster and Outlier Analysis tool identifies spatial clusters of features with high or low values. The tool also identifies spatial outliers. To do this, the tool calculates a local Moran's I value, a z-score, a p-value, and a code representing the cluster type for each feature. The z-scores and p-values represent the statistical significance of the computed index values.

Interpretation : A positive value for I indicate that a feature has neighboring features with similarly high or low attributes values; this feature is part of a cluster. A negative value for I indicates that a feature has neighboring features with dissimilar values; this feature is an outlier. In either instance, the p-value for the feature must be small enough for the cluster or outlier to be considered statistically significant. Note that the local Moran's I index (I) is a relative measure and can only be interpreted within the context of its computed z-score or p-value.

The output field, cluster/outlier type (COType), distinguishes between a statistically significant (0.05 level) cluster of high values (HH), cluster of low values (LL), outlier in which a high value is surrounded primarily by low values (HL), and outlier in which a low value is surrounded primarily by high values (LH).

Hot Spot Analysis

Basic Definition : The Hot Spot Analysis tool calculates the Getis-Ord Gi* statistic (pronounced G-i-star) for each feature in a dataset. The resultant z-scores and p-values tell you where features with either high or low values cluster spatially. This tool works by looking at each feature within the context of neighboring features. A feature with a high value is interesting but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is very different from the expected local sum, and that difference is too large to be the result of random chance, a statistically significant z-score results.

Interpretation : The Gi* statistic returned for each feature in the dataset is a z-score. For statistically significant positive z-scores, the larger the z-score is, the more intense the clustering of high values (hot spot). For statistically significant negative z-scores, the smaller the z-score is, the more intense the clustering of low values (cold spot).

Series Trend Analysis

This method is used to run trend procedures, both parametric and non-parametric, to explore the correlation of the image time series with a linear trend.

Linear trend : It calculates the intercept and slope of the least square correlation of the series with a linear trend. The linear trend (Ordinary Least Square-OLS) option maps out the slope coefficient of an ordinary least squares regression between the values of each pixel over time and a perfectly linear series. The result is an expression of the rate of change per time step. Thus, if your data are monthly, it expresses the rate of gain/loss per month.

Mann-Kendall : Mann-Kendall significance calculates the z and p values of the significance of the monotonic trend. The monotonic trend (Mann-Kendall) option provides a non-linear trend indicator that measures the degree to which a trend is consistently increasing or decreasing. It has a range from –1 to +1. A value of +1 indicates a trend that continuously increases and never decreases. The opposite is true when it has a value of -1. A value of 0 indicates no consistent trend. All pair-wise combinations of values over time are evaluated at each pixel and a tally is made of the number that is increasing or is decreasing with time. The Mann-Kendall statistic is simply the relative frequency of increases minus the relative frequency of decreases.

With a Mann-Kendall statistic, the data series is the dependent variable and time is the independent variable. The Mann-Kendall significance option produces a pair of images – a significance image expressed as Z scores and a second image that expresses the probability that the observed trend could have occurred by chance. Strictly speaking, this option is expressing the significance of a Mann-Kendall trend.

Meteorological data collection and correlation

Rainfall pattern of the study area :

Data to be used : TRMM (Tropical Rainfall Measuring Mission) Satellite Imageries

Methodology : Monthly average rainfall data will be downloaded and using geospatial and statistical analysis decadal rainfall pattern of the study area will be assessed.

Land Surface Temperature pattern :

Data to be used : MODIS (Moderate Resolution Imaging Spectro-radiometer) Terra land surface temperature data.

Methodology : 8 day composite Land Surface Temperature imageries of MOD11A2 will be downloaded and using geospatial and statistical analysis decadal land surface temperature pattern of the study area will be assessed.

Relative Humidity (RH) :

Relative humidity of the study area will be collected from the Indian Meteorological Department of the available stations within the study area. These data will be incorporated within GIS environment and by spatial interpolation techniques the relative humidity of the total study area will be plotted. Finally using geospatial and statistical analysis decadal relative humidity pattern of the study area will be assessed.

Land-Use & Land-Cover Change Detection Studies :

Data to be used : LANDSAT-TM &LANDSAT 8-OLI

Methodology : After radiometric and Atmospheric correction supervised classification will be applied which will be followed by ground truthing and Knowledge based classification and accuracy assessment. Finally change detection study will be done to assess the changes in Land use land Cover.Using CA-Markov chain Modelling future prediction of the land cover types of the study area will be done.

Differentiation of characteristic between a forest fire affected soil and a non-affected soil :

Methodology : It is a well-established fact that the hydrophobicity of a soil increases after a forest fire session and the strength of soil hydrophobicity is dependent on several factors like burn severity, vegetation type, soil texture, soil moisture, and time since burning (Huffman et al. 2001).The heat of a fire vaporizes the hydrophobic compounds present in the litter, humus, and soil organic matter (DeBanoet al., 1967). These compounds generally have two fates. Firstly it can escape into the atmosphere, or it might move into the soil atmosphere and condense on cooler soil particles at or below the soil surface (DeBano 1981; Crockford et al., 1991; Doerr et al.,1996). The condensation of these compounds forms a hydrophobic coating on the soil particles (DeBano and Krammes, 1966; Savage, 1974).In normal forested areas the natural hydrophobicity is too weak and it is commonly associated with fungal mycelia (Savage et al., 1969). Fire-induced soil hydrophobicity is believed to be the primary cause of the observed increases in runoff and erosion from forested watersheds after wildfires (DeBano and Krammes, 1966; DeBano, 1981; Wohlgemuthet al., 1996). In order to study the present status of a forest fire affected soil surface certain parameters are measured throughout the globe namely

1. Fire-induced soil hydrophobicity would be calculated by measuring water drop penetration time (WDPT) and critical surface tension (CST).
2. Soil temperature and moisture would be measured at varying depths.
3. The soil texture (i.e sand, silt and clay content) along with particle size analysis would be done.
4. Soil electrical conductivity (EC), pH, organic and inorganic carbon would be estimated.
5. All the above mentioned parameters would be measured in the fire affected and non-affected soils (as control setup) and these would be incorporated in geo-spatial modelling.

Building Spatial Decision Support System (SDSS) for forest fire :

The above stated goals will deliver the following data :

1. Forest fire vulnerability zonation (With maximum, Moderate, minimum and non-vulnerable zones)
2. Manmade forest fire area zonation over the decades
3. Rainfall pattern zonation of the study area
4. Land Surface temperature zonation of the study area
5. Soil type scenarios of forest affected and forest fire non-effected soils
6. Relative Humidity zonation of the study area
7. Elevation, slope, aspect of the study area
8. Land covers types of the study area
9. Local practice and traditional knowledge and mind sets of the local stakeholders regarding forest fire
10. Socio economic factors regarding forest fire.

Using all those spatial and non spatial data a Spatial Decision Support System (SDSS) will be developed in a software environment, where using quarry analysis in GIS environment along with probable forest fire zones a total forest fire management system will be developed in which some suggestions will be provided to the stake holders identifying the zones where they might practice a real-time manmade forest fire which will be beneficial but not harmful and also where not to practice manmade forest fire.

Ecological Survey and Sampling :

Ecological survey and sampling for soil, meteorological data and vegetation analysis shall be done following standard methods in at least three study replicas in each site of intervention. Weather stations will be set up in each place.

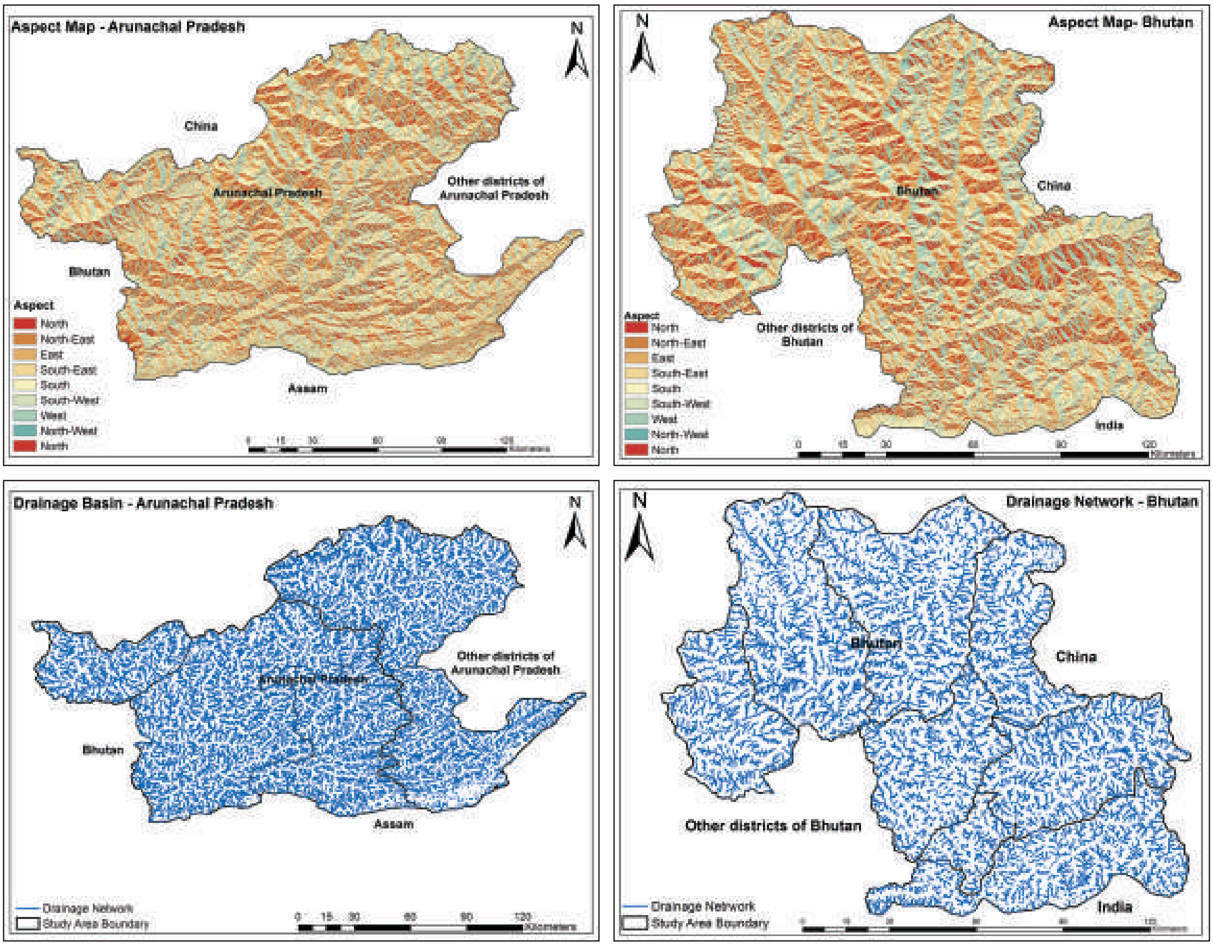
Cost Trade-off analysis :

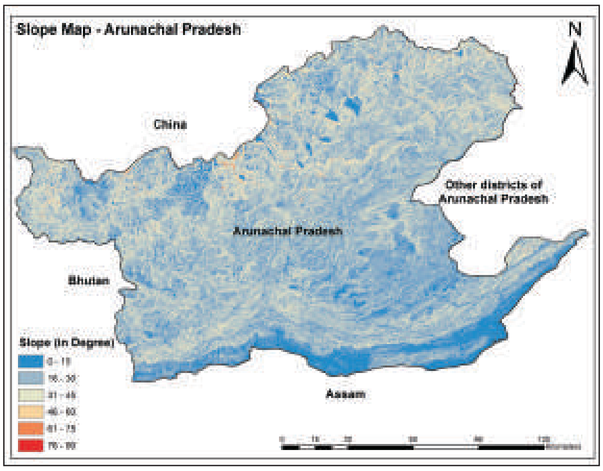
A complete cost-benefit analysis will be made with respect to the available standard methods of assessments.

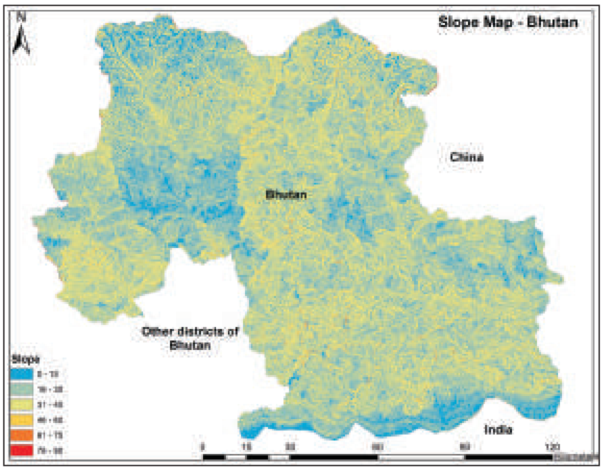
Results and Observations

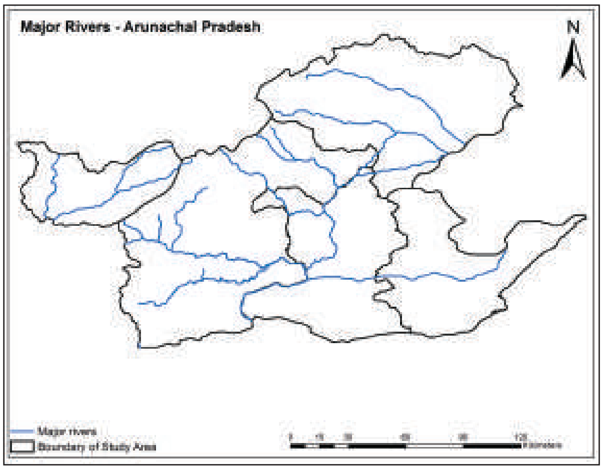
Geospatial Studies

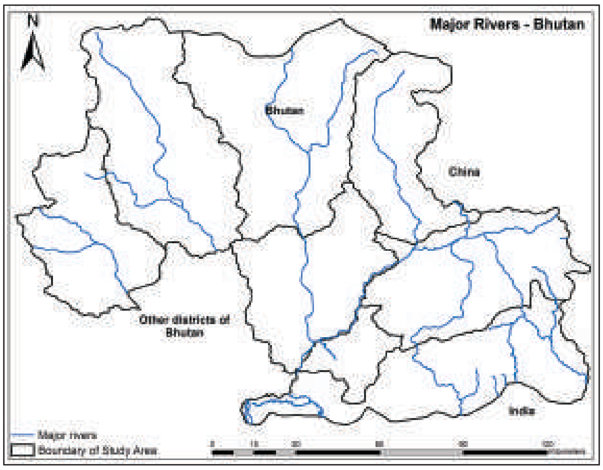
Physiographic Attributes





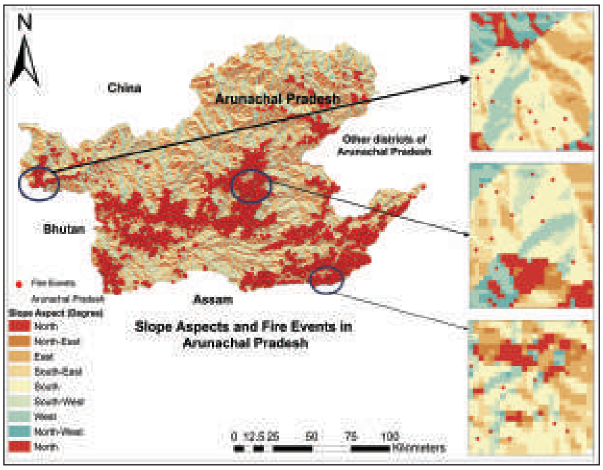


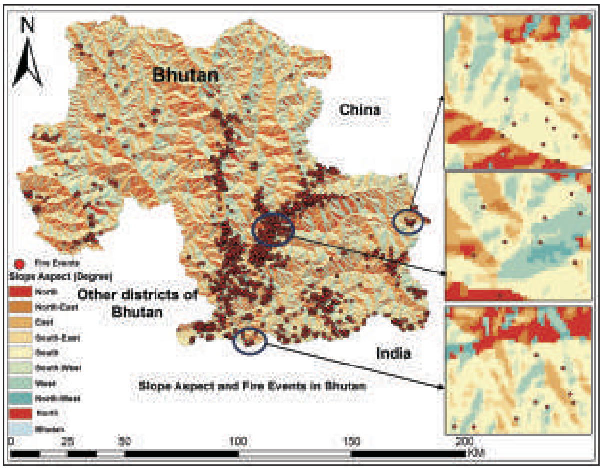


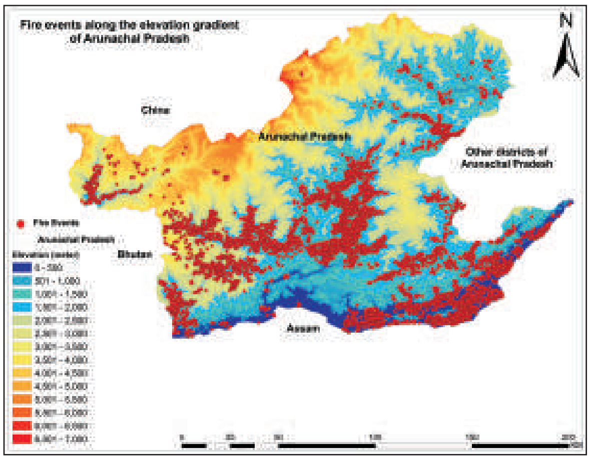


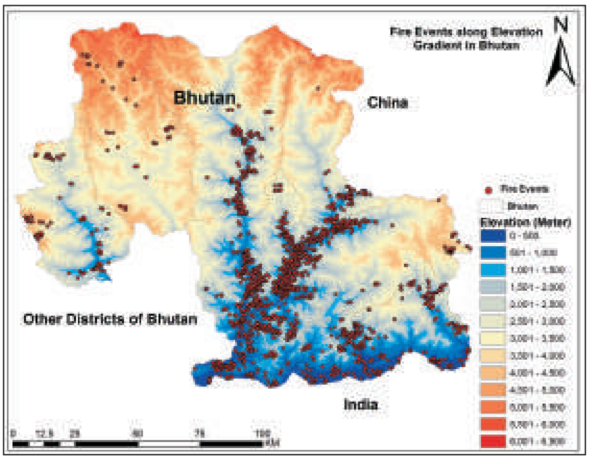
Geospatial Studies

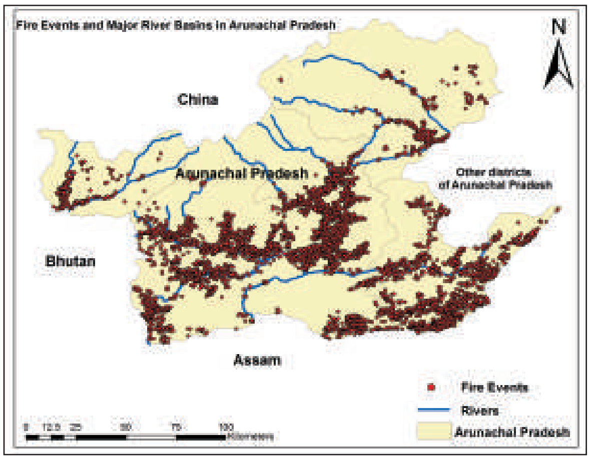
Fire events and attributes

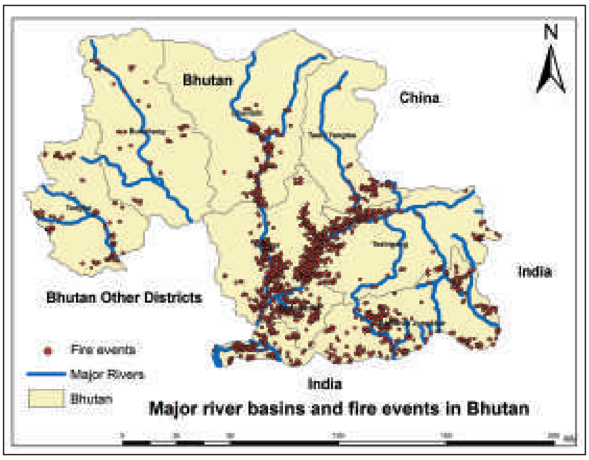


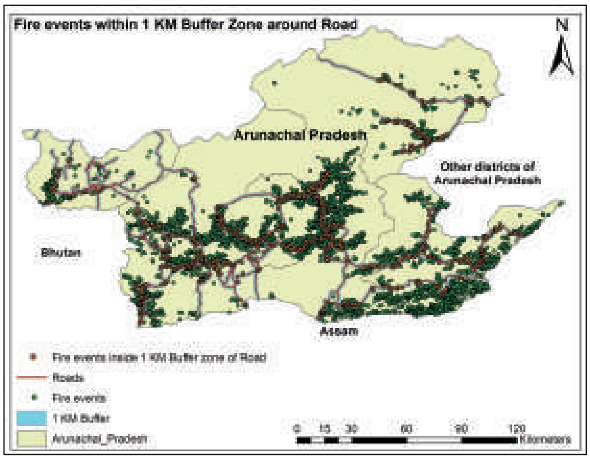


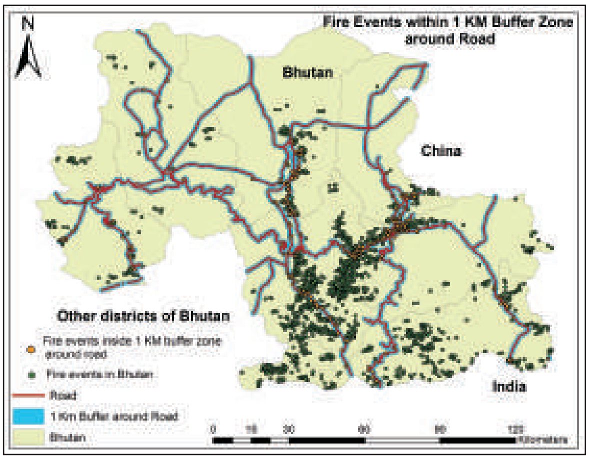

Fire events along the elevation gradient
of Arunachal Pradesh
N
China
Arunachal Pradesh
Other districts of
Arunachal Pradesh
Fire Events
Arunachal Pradesh
Bhutan
Assam

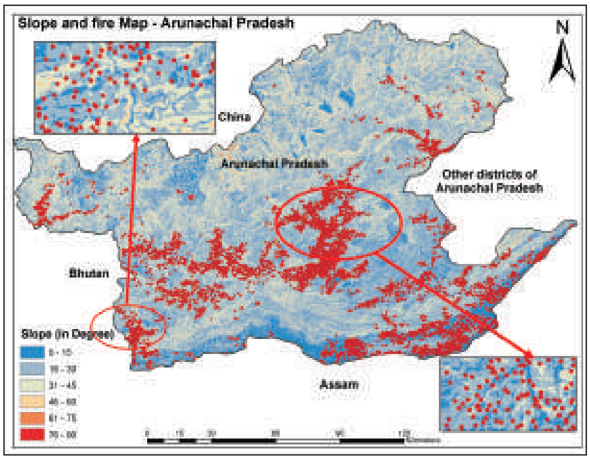

Fire Events along Elevation
Gradient in Bhutan
N
Bhutan
China
Other Districts of Bhutan
India
Fire Events
Bhutan
Elevation (Meter)

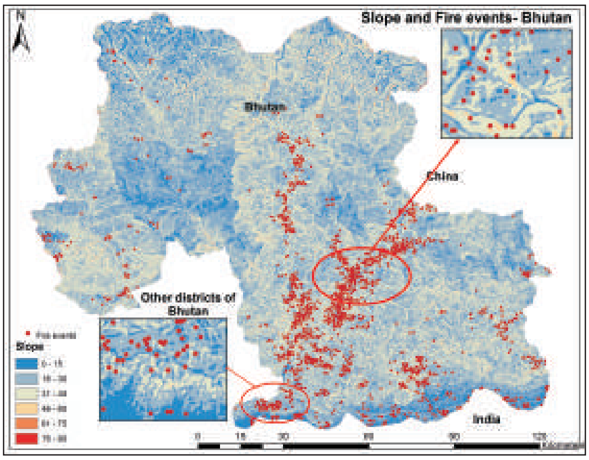

Fire Events and Major River Basins in Arunachal Pradesh
N
China
Arunachal Pradesh
Other districts
of Arunachal Pradesh
Bhutan
Assam
Fire Events
Rivers
Arunachal Pradesh

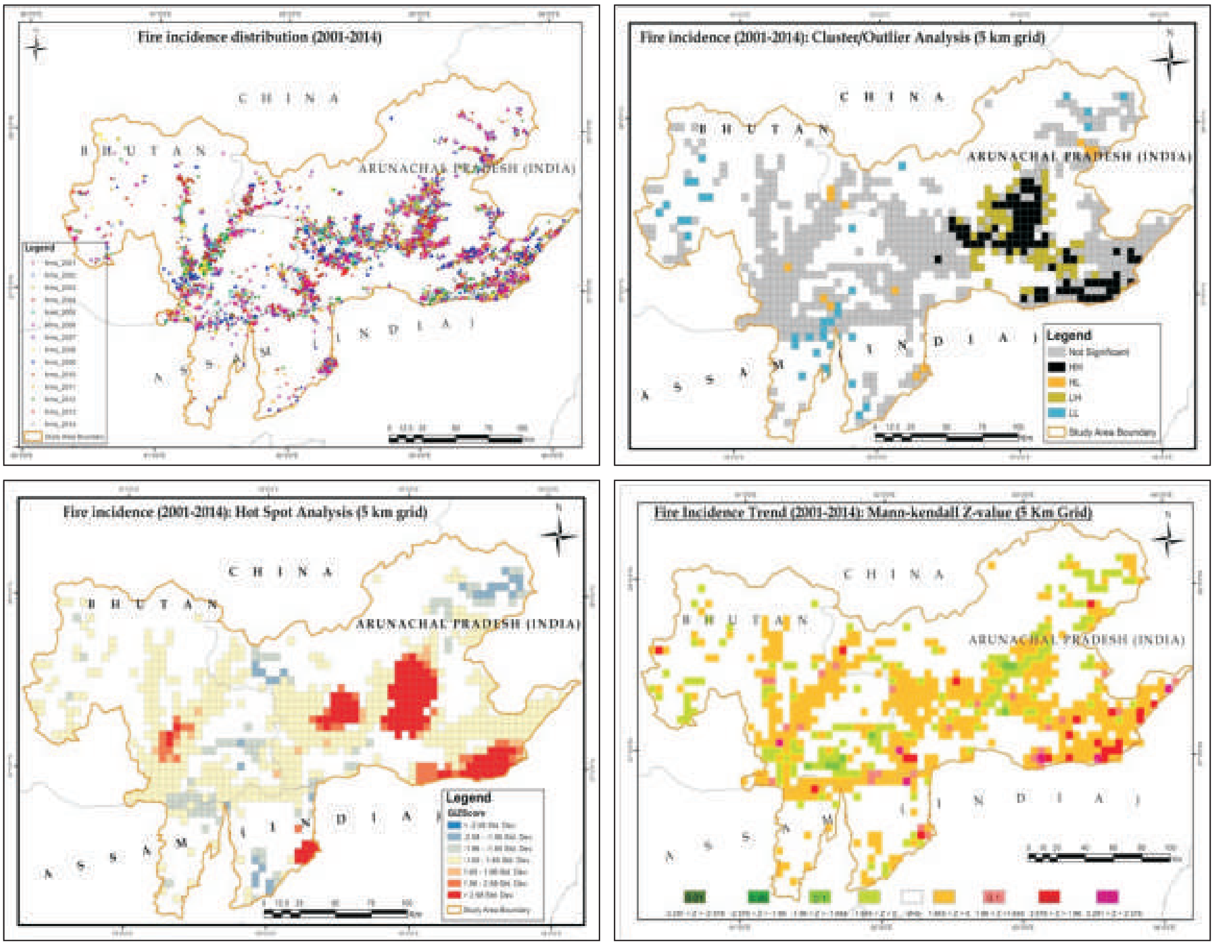

N
Bhutan
China
India
Bhutan Other Districts
Fire events
Major Rivers
Bhutan
India
Major river basins and fire events in Bhutan


Fire events within 1 KM Buffer Zone around Road
N
Arunachal Pradesh
Other districts of
Arunachal Pradesh
Bhutan
Assam
Fire events inside 1 KM Buffer zone of Road
Roads
Fire events
1 KM Buffer
Arunachal_Pradesh
Kilometers


N
Fire Events within 1 KM Buffer Zone
around Road
Bhutan
China
Other districts of Bhutan
Fire events inside 1 KM buffer zone
around road
Fire events in Bhutan
Road
1 Km Buffer around Road
Bhutan
India
Kilometers


Slope and fire Map - Arunachal Pradesh
N
China
Arunachal Pradesh
Other districts of
Arunachal Pradesh
Bhutan
Slope (in Degree)
Assam


N
Slope and Fire events- Bhutan
Bhutan
China
Other districts of
Bhutan
Slope
India

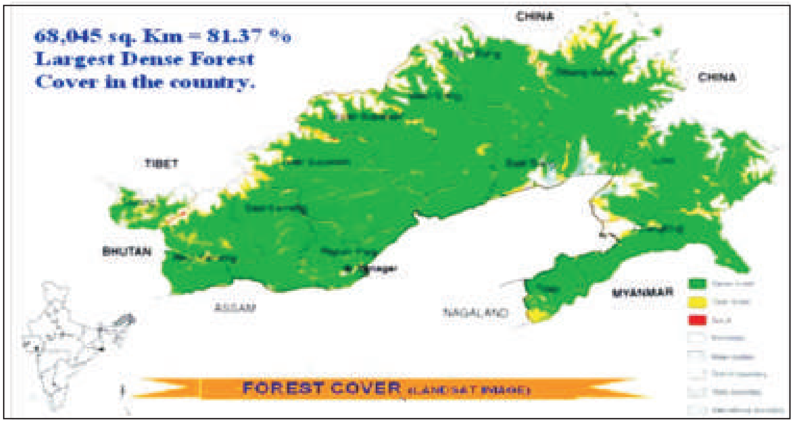


Ecological Studies

Impact of Forest Fire on Vegetation Dynamics

FOREST: ARUNACHAL PRADESH

Situated on the northeastern tip of the country, the state of Arunachal Pradesh is a part of Eastern Himalayan Ranges located between 26° 28' to 29°30, N latitudes and 91° 30' to 97°30' E longitudes. Arunachal Pradesh occupies the largest area (83.743 Sq. Km) in the northeastern region of India, and consists of mountainous ranges sloping to the plains of Assam. The diversity of topographical and climatic condition has favoured the growth of luxuriant forests, which are home to myriad plant and animal forms, adding beauty to the landscape. Living in this incredible cradle of nature are the colorful and vibrant tribes of Arunachal Pradesh for whom the forests and wildlife are of special significance. However, with increasing population, development activities, large number of wood-based industries and unsustainable land use practices like jhuming, the pressure on forest resources is consistently increasing leading to their degradation affecting regeneration and productivity.



Arunachal Pradesh with a geographical area of 83743 square kilometer accounts for about 2.55 percent of the total land of the country. While this is significant in terms of purely land availability what is more significant is that 68019 square kilometer of the land area is covered by forest amounting to 81.22 percent of the total land area of the state. It is essential here to know the actual legal status of the vast forest land of this low population density state (13 person / sq. km).

Forests are the mainstay for the people of Arunachal Pradesh and are the richest biogeographical province in eastern Himalayan zone. The State has 20% species of country's fauna, 4500 species of flowering plants, 400 species of pteridophytes, 23 species of conifers, 35 species of bamboos, 20 species of canes, 52 Rhododendron species & more than 500 species of orchids and is considered as one of the 12 mega diversity "Hot Spots" in the world. Forests generate the largest employment and are the single largest source of revenue for the State. However, of late, forests have been adversely affected by several factors, which include rapid increase in human & livestock population, insufficient infrastructure, and diversion of forest areas for development activities. Several other problems unique to forestry sectors are inadequate public awareness about multiple roles of forests, low investments in forestry, inadequate people's participation, technological weakness and insufficient funds and facilities.

Un-surveyed forests where status of right and ownership is not settled are classified as Un-classed State Forest (USF). The USF is an ambiguous term and there is not much departmental control over these lands. It is found from the field experience that all kind of forest mentioned above are not distinct by their identity and all of them are prone to forest fires of different nature in different regional context.

As far as the forest covers at the district level are concerned all the districts except Tawang show more than 70 percent of their land area covered by vegetation. In fact the 56.49 percent forest cover of Tawang is among the healthiest considering its high altitude. It is required to be mentioned here that four different types of forests which are prone to forest fires are covered which has significant coverage as per the recent data available through the survey of Forest Survey of India (FSI) 2003. These are:

i.	Tirap district	Tropical wet evergreen forest - 80.14 percent
ii.	Lower Subansiri district	Sub tropical and pine forest - 91.49 percent
iii.	Papum pare district	Tropical semi evergreen forest - 94.95 percent
iv.	East and West Kameng district	Temperate forest - 88.59 percent

All these districts have varied forest types of eastern Himalaya and exhibit an enormous floristic diversity. Apart from large number of timber species, there are innumerable varieties and kinds of orchids, medicinal plants, ferns, bamboos, canes, wild relatives of large number of our cultivated plants and even plants of biological curiosities, such as parasites, saprophytes, etc. are found. Other important groups of plants are Rhododendrons, Hedychiums and oaks etc. Orchids form a dominant group of plants with their attractive and unique blooms. There are more than 600 species of orchids, 52 species of rhododendron, 18 species of Hedychium, 16 species of oak, 18 species of canes, 45 species of bamboo in addition to large number of medicinal and aromatic plants.

A district wise break up as available from the department of forest, Govt. of Arunachal Pradesh is presented herewith for a comparative study.

Districts of Arunachal Pradesh	Geographical Area (Sq. Kms.)	Very Dense Forest (Sq. Kms.)	Moderately Dense Forest (Sq. Kms.)	Open Forest (Sq. Kms.)	Total Forest (Sq. Kms.)	% Forest Cover
Changlang	4662	1879	1539	888	4306	92.36
Tirap	2362	459	1042	392	1893	80.14
Dibang Valley	13029	851	5836	2736	9423	72.32
East Siang	3655	448	1944	480	2872	78.58
Lohit	11402	1955	4224	1615	7794	68.36
Lower Subansiri	9548	2286	4745	1704	8735	91.49
Papum pare	3462	754	1699	834	3287	94.95
Upper Siang	7050	736	3676	1198	5610	79.57
Upper Subansiri	7032	849	3803	1155	5807	82.58
West Siang	7813	997	4884	946	6827	87.38
E&W Kameng	11556	2583	5548	2107	10238	88.59
Tawang	2172	110	664	453	1227	56.49
TOTAL	83743	13907	39604	14508	68019	81.22

(NB: The shaded rows are the districts under this project intervention)

Arunachal Pradesh has many species of endangered, endemic, primitive, and relict flora, Magnolia Pterocarpa pterocarpa is one such primitive angiosperm, which occurs in the foot-hills. Some rare and endangered flora that occur in Arunachal Pradesh are: Amentotazus assamica in Lohit District . Rhododendron arunachalense found in Subansiri District, Rhododendron dalhousie, and Tetracentron sinense, occurring in Kameng District, Rhododendron santapaul recorded in Subansiri District.

Gomphogyne macrocarpa found in Tirap and Kameng Districts, Gymnocladus assamicus and Lithocarpus Kamengensis available in Kameng district. Rhynchoglossum lasulinum in kameng and Subansiri District. Dendrocalamus sahni in Subansiri District. Hypericum griffitthii in Kameng District, Coptis teeta of Dibang Valley Districts, etc. The State harbours about 52 species of *Rhododendrons*, 18 species of *Hedychium*, 16 species of *Qaks*, 33 species of *Conifers* and a large number of ferns and lichens. About 500 species of orchids occur in Arunachal Pradesh. These include about 140 species of terrestrial orchids with 15 saprophytes and about 340 epiphytes found in the different forest types. The prominent species are : *Cymbidium ansifolium , C, grandiflorum, Coelogyne corymbosa. Dendroblum aphylla, D. fimbriatum var occulatum, D. densiflorum, Calanthe masuca, Phaius flavus, Paphiopedilum. Tairriearum, venustum renanthera imschootiana, vanda coenulea*, etc. *Rhynchostylis refusa* is the state flower of Arunachal Pradesh

The forests of Arunachal Pradesh possess a phenomenal range of biological diversity, both in flor and fauna. The forests are also home to sizeable tribal population which continues to live in close association with nature and utilises a wide variety of forest resources for sustenance and livelihood. Nature has been exceedingly kind and has endowed this beautiful State of Arunachal Pradesh with diverse forests and magnificent wildlife. The richness of life forms i.e. the flora & fauna that occur in these forests presents a panorama of biological diversity with over 5000 plants, about 85 terrestrial mammals, over 500 birds and a large number of butterflies, insects and reptiles. The vegetation of Arunachal Pradesh falls under four broad climatic categories and can be classified in five broad forest types with a sixth type of secondary forests. These are tropical forests, sub-tropical forests, pine forests, temperate forests and alpine forests.

Tropical Forests : These forests occur up to an elevation of 900 metres above MSL . They are persent in all the districts along the foothills. These forests can further be classified into two main types viz. tropical evergreen forests and tropical semi evergreen forests

Subtropical Forests : These types of forests occur in districts between altitudes 800m to 1900m. These are essentially evergreen and dense in nature. The trees attain large dimensions (25-40m high). The forests are rich in species diversity and dominated by *Fagaceae* members. *Castaniopsis lidica, C. armata, Quercus lamellose, Q. griffithili, Q. spicata, Q. Semiserrata, Q. fenestrala, Michelia oblonga, Manglietia insignis, Ostodes paniculata, Ulmus lancifolium, Engelhardia spicata, Ficus spp. Acer oblongum, Schima wallichji,* *S.khasiana*, etc. are the dominant tree species. Luxurious growth of climbers, orchids & ferns, occurs in these forests.

Pine Forests : These forests extend both in the subtropical and temperate belt in between 1000 m to 1800 m elevation. These are generally met with in rain shadow area and are represented by three different species viz. *Pinus roxburghii, P. wallichiana and P.merkusii*, is found in Rupa and Dirang valley of Kameng district and forms either pure stands or occasionally mixed with *P. wallichiana, Quercus spp, Prunus sp. Etc. P. wallichiana* is widely distributed in Rupa, Dirang valley (Kameng district), Hapoli (Lower Subansiri district), Mechuka (West Siang district), Anini (Dibang valley district). and Melinja (Lohit district). In Kameng, Siang and Lower Subansiri district it is found in nearly pure stands or less frequently mixed with P. roxburghii, Quercus spp. Lyonia sp. Etc. In Dibang valley they are found in association with Betula alnoides, Alnus nepalensis, Lyona ovalifolia, etc. In Lohit district it is less extensive and is associated with Tsuga dimosa, Pinus merkusii, occurs in Lohit district along the Lohit valley extending from Kharang (Hawal) to Dichu.

Temperate Forests : This occur in all districts as a continuous belt and can be divided into two subtypes viz. Temperate broad leaved forests and Temperate conifer forests.

Alpine Forests : This type of vegetation occurs on the peaks of higher hills above an altitude of 4000 m upto 5500m above timber line. For major part of the year, the area is covered by snow and plant activity is restricted to a few months when snow melts. As a rule there are no tall trees but dwarf branches and shrubs and mainly herbs with deep roots and cushioned leaves and branches. The profusion of bright coloured flowers which is purely seasonal for a brief period makes the area highly attractive. Plans like *Rhododendron nivale., R. anthopogon, R. thomsonii, Sedum sp, Festuca sp, Rhodiola sp, Saxifraga sp. Saussaurea sp,. Arenaria sp,. Rheum sp.* etc. form the major constituent of this peculiar vegetation.

Degraded Forests : The common trees seen are *Machranga denticulate, Mallotus tetracoccus, Callicarpa arbnorea, C. vestita, Bauhinia sp,. Glochidion spp,* and shrubs like *Clerodendrum spp. Randia sp. Rubus sp,. Viburnum sp. Croton caudatus, Capparis spp., Eurya acuminata, Dalbergia sp.* etc. and also obnoxious weeds like *Mikania micrantha, Eupatorium odoratum*, etc.

Bamboo Forests : These are seen as bambaoo breakes up to 2000m altitude throughout the State, Bamboos grow mostly in pure stands with very less of associated species. Normally bamboos appear in areas abandoned after shifting cultivation, where they colonise fast. Bamboos of Arunachal Pradesh are *Bambusa tulda, B. pallida, Dendrocalamus hamiltonii, D. hookerii, Pseudostachyum polymorphum, Chimonobambusa sp. Cephalostachyum sp. and Arundinaria spp., Phyllostachys sp.* (both single stem bamboos) occsur in higher elevation 1000-2000m.

Grasslands : Grasslands form a main feature of vegetation in reverine plains and at higher elevations. This seral type is maintained through recurring annual fires at higher elevation and excessive grazing at lower elevations. In lower elevation, *Saccharum spontaneum, S. arundinaceum, Neyraudia reynaudiana, Chrysopogon aciculatus, Chrysopogon aciculatus, Imperate Cylindrica*, etc. associated with a few sedges like *Cyperus sp., Scirpus sp., Fimbristylies sp.*, etc. are seen commonly in grasslands. A few trees scattered at lower elevations, like *Macranga denticulate, Bombax ceiba, Duabanga grandiflora* make the grassland are prominent in pine belt. Such grasslands support gregarious tall grasses viz., *Thysanolaena maxima, Imperata cylindrical. Sporobolus sp., Paspalum sp.*,

FORESTS IN BHUTAN

The Himalayan kingdom of Bhutan lies in the biotic province of the eastern Himalayas with an intact forests stand of 72.5% of the total land area. In this fragile mountain environment forest farming system plays a crucial role in providing the needs of the local population as well ensuring proper management of land, water and natural resources. Bhutan is endowed with more than 902,000 hectare of operable forest containing an estimated standing volume of 184 million cu. Mt. above 10 cm diameter at breast height. The classified data on kind and quantity of forests are displayed in the following table

Forest resource of Bhutan, known as **Dzong Gyel Khab** (den of medicinal plants) in the past, is self sufficient for the rural communities in non-timber products. Important medicinal plants include Cordyceps sinensis (a fungus growing over *Leptropteris butterfly larva*), *Panax, Taxus baccata, Belledona, Aconitum, Swertia, Herachlium, Zanthoxylum* etc. Reportedly there are 141 species of orchids available in Bhutan Himalayas of which atleast 25 are in the IUCN red list. Forests of Bhutan also hosts many endemic plant species like the Blue Poppy (*Meconopsis grandis*) *Primula sp. Ceropegia dorjei*, and animals like Golden languor (*Panthera uncia*), Black necked crane (*Grus nigricollis*). Many Gondowana flora and flora of African origin (*Lobelia nubigiana*) can also be spotted here. Out of 52 species of Rhododendron, one known as *R. kesangii* is also endemic to Bhutan Himalayas. Bhutan has a predominantly biomass dependant economy with agriculture being the main subsistence occupation of 87% of Bhutanese people. The total arable land in Bhutan is approximately 3146 Sq. Km, which accounts for 7.7% land of the entire kingdom, out of which 31.1% is under dry land cultivation and 38.1% is Tseri (shifting cultivation) land. Wetland and irrigated cultivable land is only 12.3% of the total arable land and the remaining of it has mixed cultivation practices (Gyamtsho 1998).Survey suggests that 87% of the area under rice cultivation is cropped with local or indigenous varieties; rural inhabitants collect as much as 172 species of plants of varied ethno-botanical importance from the forests for their livelihood. The National Institute of Traditional Medicines alone use more than 300 plant species. Hand made paper industry, lemon grass oil extraction units, resin tapping, turpentine oil and cane products are some of the most common small scale industries of rural Bhutan. Land use patterns in the main districts other than forests are tabulated below in Table 2.

Table 2: Land use patterns in few main districts of Bhutan.

LAND TYPES→	Chhuzing Wetland		Kamzhing Dryland		Tseri Shifting Cultivation		Tsamdo Pasture		Seshing Horticulture		Dung Settlement	
DISTRICTS↓	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Lhuntse	994	0.3	8879	2.9	3289	1.1	9452	3.3	Nil	Nil	35	0.1
Monger	627	0.3	12485	6.4	5904	0.1	1551	0.8	Nil	Nil	91	0.1
Trashigang	1659	0.7	21319	9.3	9414	4.1	10992	4.8	Nil	Nil	135	0.1
Yangtse	2021	1.4	8042	5.6	1169	0.8	4732	3.3	Nil	Nil	40	0.1
Pemagatshel	Nil	00	6489	6.8	19938	38.5	22	0.1	12	0.1	12	0.1
S. Jongkher	2187	0.9	20671	9.0	19239	8.3	781	0.3	101	0.1	275	0.1

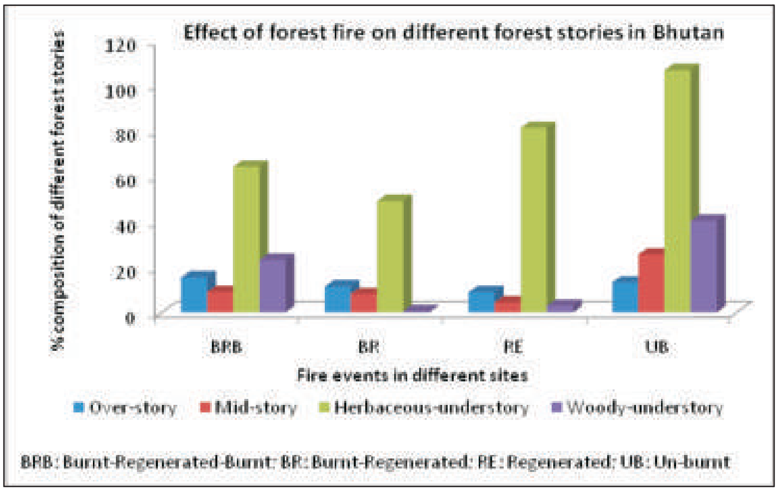
NB: Shaded rows are districts of interventions in this project.

Analysis of results from field observations in Bhutan & Arunachal Pradesh :

The field investigations were done in 4 types of areas where forest fire has occurred in 2 events separated by a span of 2-3 years, 2 events separated by a span of 7-8 years, recent fire incidence and in places where fire incidences have taken place at least before 3 years. Depending on these 3 categories of quadrate sampling were done.

i. Burnt-Regenerated-Burnt (BRB)
ii. Burnt-Regenerated (BR) – fire event cycle of 2-3 years
iii. Regenerated (RE) – fire event cycle over 7-8 years
iv. Un-burnt

The results were compared with un-burnt (UB) plots to understand the impacts of fire events on the vegetation dynamics of secondary succession. The perusal of results shows that impact of fire events on the vegetation pattern is distinct but highly complicated. Though a trend analysis could be done within the short period of supervision of the present project, we assume that more numbers of sampling, field investigations and vegetation analysis across a wider span of time and space would help us to understand the dynamics in a better way. Some of the observations are noted here below.



i. The mid-story catches fire from the woody-understory and spreads it up to the over-story. Presence of a thick herbaceous-understory or very high litter load diminishes the progress rate of fire and its intensity.

ii. In a climax vegetation the over-story with a clear forest floor is least vulnerable to fire. However, mixing of broadleaf forest in the climax vegetation increases fire vulnerability.

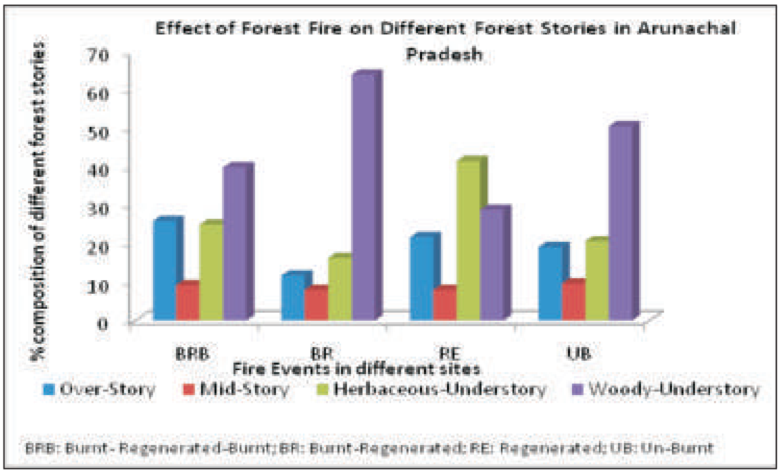
iii. In the secondary succession pattern the process begins with the regeneration of herbaceous understory, during which an equitable species competition is observed that paves the way of new species introduction in the same habitat.

iv. Certain plants with fire stress resistance like Pinus bhutanica or Cymbopogon sp and Rumex sp show better vigor of growth in post fire event and therefore may over-dominate the herbaceous-understory reducing the species density in the habitat. Such cases are found to be making the vegetation more vulnerable to fire events.

v. Twig diameter and over growth of cork in the woody-understory are factors for determining the vulnerability of fire. Lesser twig diameter and thicker cork density increases fire vulnerability as this adds to the fuel load. However, in case of thicker bark the fire-damage is comparatively less.

vi. Mixed vegetation with sparse distribution or random scatter in the distribution of established vegetation are always less vulnerable to fire as intermediate spaces acts as natural fire barriers.

A comparative analysis on the effects of forest fire on different forest stories in Bhutan and Arunachal Pradesh reveals the following inferences:



i. Herbaceous-understory growth is maximum in un-burnt patches of Bhutan while in Arunachal Pradesh it is maximum in patches those have regenerated after a fire event.

ii. Similarly woody-understory in Bhutan shows a feeble growth and the maximum of it are found in un-burnt patches. However, results from Arunachal Pradesh shows that fire events promote growth in woody understory and the species regenerates faster than in Bhutan.

iii. Mid-story growth in both Bhutan and Arunachal Pradesh shows minimum impact of forest fire and provides a steady growth rate.

iv. Over-story growth is comparatively better in Arunachal Pradesh though impacts of fire events are not marked on it.

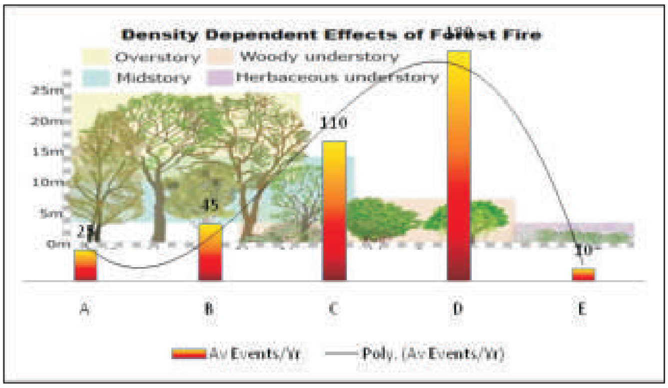
v. Fire is desirable to forest ecosystem to enrich the adoptability and habitation of wild life.

Therefore, the desirability of forest fire, in the ecosystems, where climatic conditions support fire, the plants seem to possess not only fire survival traits but also fire enhancing traits. Vegetation belts of Pine, Grassland and shrubs are examples of fire adopted ecosystems, since their continued existence depends on periodic occurrence of fire.

In any terrestrial forest landscape, the origin of fire can be either natural or anthropogenic, depending upon weather, topography and fuel type, commonly known as the fire triangle.

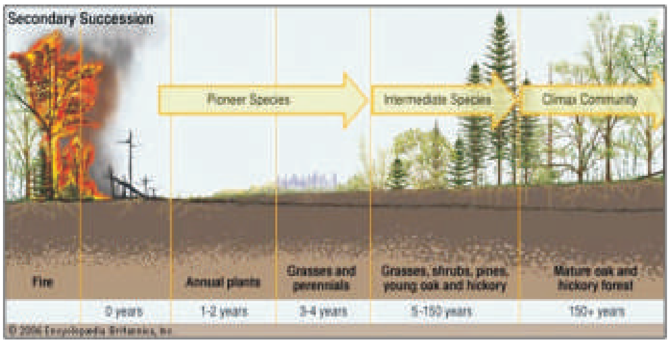
Density Dependence Effects of Forest Fire

Perusal of field results shows that woody understory spanning a height of 4-6 mts are the most vulnerable fire zones. This has the most compact density and easily catches fire in conducive situation. The mid story either catches up from the woody understory or else can be fire initiator too if the twig diameters are less or the vegetation density is more or both. Proneness to fire is least in over stories those have sparse density in canopy and as well in herbaceous understory, where less aerobic conditions prevail owing to very high density of vegetation distribution.



In both Bhutan and Arunachal Pradesh similar trends of fire intensity and break depending on the vegetation density has been marked. A Computer Aided Model is developed to explain the same as it influence the secondary succession strongly.

Forest fire leads to secondary succession, a process of gradual change in species structure of an ecological community over a spatio-temporal scale. Secondary succession is pretty much faster than primary succession. Low intensity fires churn up the nutrients inside soil thus making the soil more favourable for growth of vegetation. Fire also favours the germination of coniferous seeds by providing suitable conditions. The onset of secondary succession is a mesic structure with more species richness. The shade tolerant herbaceous under-story may experience changed species composition pattern leading to their resistance of fire susceptibility. The root system grows inside the soil. This phase is followed by mid-story formation and is more vulnerable to forest fire events as at this phase fuel load is higher. The succession process gets disrupted on occurrence of another fire and the cycle of succession resumes again. If not affected by fire, then the plant community proceeds towards climax community creating a forest over-story. We have noticed that regeneration process of oak trees is less in comparison to coniferous trees, hence, coniferous forest dominates the over-story of forest, and climax community is less susceptible to forest fire.



Ecological Studies

Fire Site Soil Analysis Report

Developing a Decision Support System

A. Excerpts from the Analysis Report

i. Fire is beneficial and as well harmful to the soil component of forest depending upon its intensity.

ii. Low intensity fire increases availability of plant nutrients and thereby promotes secondary succession faster

iii. High intensity fire damages soil quality by thermal decomposition of essential organo-chemical componants, microbial vegetation and vaporization of a number of thermo labile componants.

iv. Forest fire decreases water holding capacity of soil, but our result shows highest water holding capacity in the soil type with 2 fire events intermitted by a regeneration phase.

v. Perusal of field observations and results from our intervention sites show that low intensity fire does not affect the nitrogen content of soil.

vi. Generally, soil potassium and phosphorus content are not affected by forest fire. Our data sets of soil potassium and phosphorus content show significant site specific variability. This needs more extensive studies.

vii. Variability of phosphorus content affects the woody understory of forest which is the most inflammable layer among all. If fire events destroy the phosphorus contents of soil, there can be impacts on vegetation dynamics.

viii. Though total organic carbon in soil varies non-significantly among different study sites, the amount of total organic carbon shows a direct correlation with percentage of woody understory of forest. Vegetation analysis shows a direct impact of forest fire on woody understory. Needs detailed study analysis to establish the missing links.

ix. In our study sites, Soil is rich in nitrogen which indicates higher rate of decomposition and higher rate of nutrient recycling preferable for regeneration. However, the impact of heat in nitrogen cycle needs to be traced and amount of vaporization of oxides of nitrogen during fire events are crucial data sets for estimating the climate impacts of forest fires.

B. Scope of the Study

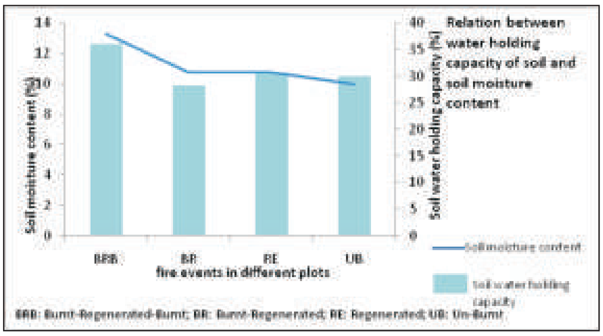
- Organized change detection studies on soil properties would essentially support the decision system for assessing the impact of various degrees of fire events in the milieu of forest conservation in Himalayan terrain.
- Soil carbon sequestration potentials, soil emission data and thermal vaporization of GHGs in post ante fire event and as well during the event would be substantially important for assessing the climate impacts.

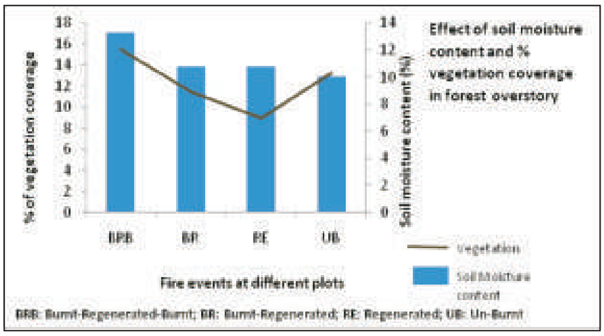
C. Analysis of Results

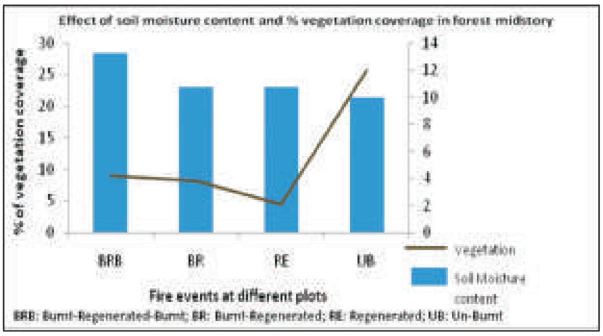
Physiography of a site, wind direction and litter-load together play crucial role in controlling the intensity of forest fire which in turn is responsible for modifying the soil properties. Growth of plant is dependent on the soil properties and increasing growth is responsible for generating heavy fuel load and the cycle of fire repeats itself.

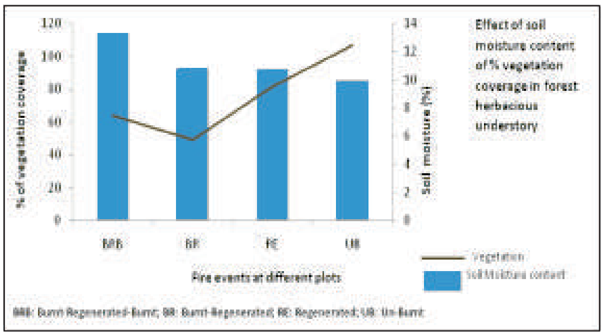
The impact of fire on forest soil depends on various factors such as intensity of fire, fuel load and soil moisture. Fire is beneficial as well as harmful for the forest soil depending on its intensity and fire return interval. In low intensity fires, consumption of litter and soil organic matter increase available nutrients, which results in rapid growth of herbaceous plants.

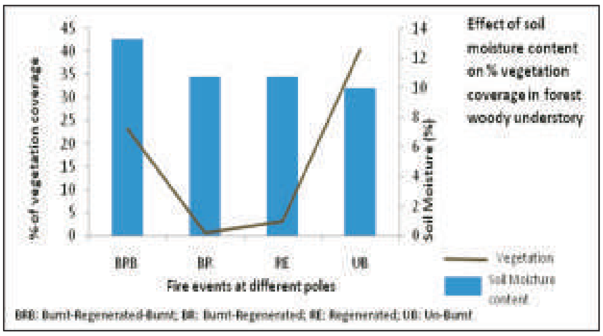
Forest fire results into formation of some organic compounds with hydrophobic properties, which reduces the water holding capacity of soil. Burning of organic matters create a fume and vapour that condense on soil particles reducing the porosity thus a reduction of water holding capacity occurs. Highly variable water repellant soil conditions have been reported after fires (Robichaud & Hungerford, 2000; McDonald & Huffman, 2004). Our study sites are categorized into 4 groups depending on the fire events and regeneration process such as burnt-regenerated-burnt, burnt-regenerated, regenerated (no recent fire events) and a group of controlled un-burnt sites. One way ANOVA shows that moisture content in these different types of sites does not vary significantly though each type of sites have different fire event history (P Value=0.2) whereas water holding capacity of the soil vary significantly with frequency of fire events in different sites (P Value=0.0006). Variability in moisture content does not affect the over-story (correlation, P Value=0.46), mid-story (correlation, P Value=0.53), herbaceous-understory (correlation, P Value=0.59) and woody-understory (correlation, P Value=0.59).



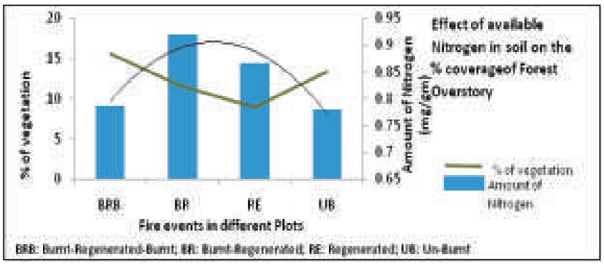


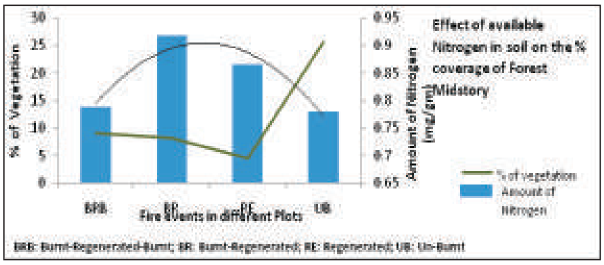


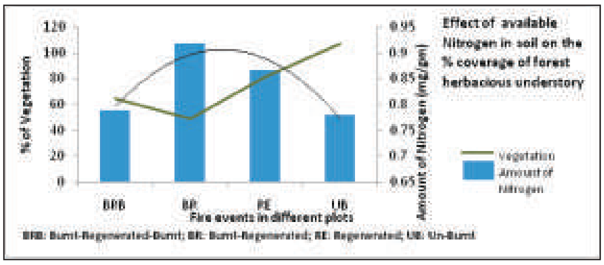


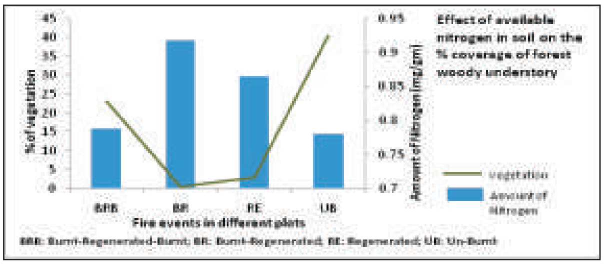


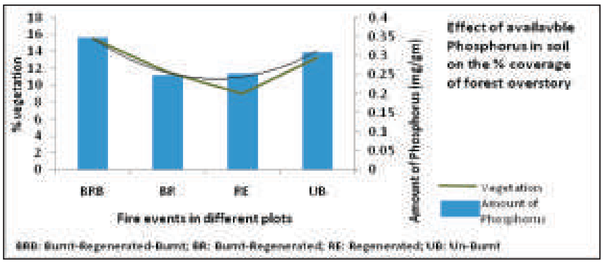
After forest fire soil nutrient decreases but their plant-available forms increases (Kutiel & Naveh, 1987). Severely burnt soil shows lower Nitrogen than un-burnt soil. Burnt soil shows nearly unchanged Potassium and Phosphorus content (Neff et al., 2005). Our study shows that Nitrogen content is non-significantly different in different study sites (one way ANOVA, P value= 0.11) which indicates low intensity fire events in the study sites though more ground troothed data are needed to support the statement. On the other hand, Potassium (one way ANOVA, P value= 0.03) and Phosphorus (one way ANOVA, P value= 0.03) content vary among study sites significantly. Change of Phosphorus content of soil does not affect the forest over-story (correlation, P Value=0.08), forest mid-story (correlation, P Value=0.59), forest herbaceous understory (correlation, P Value=0.28), on the contrary change in Phosphorus content of soil affect the forest woody-understory (correlation, P Value = 0.001). We have noticed that the woody-understory is the most inflammable layer of forest. Change of Potassium content of soil does not affect the forest over-story (correlation, P Value = 0.53), forest mid-story (correlation, P Value = 0.05), forest herbaceous understory (correlation, P Value = 0.14), forest woody-understory (correlation, P Value = 0.03).

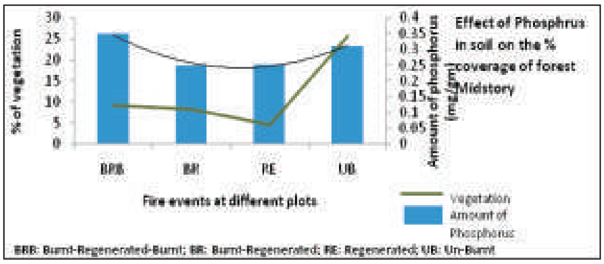


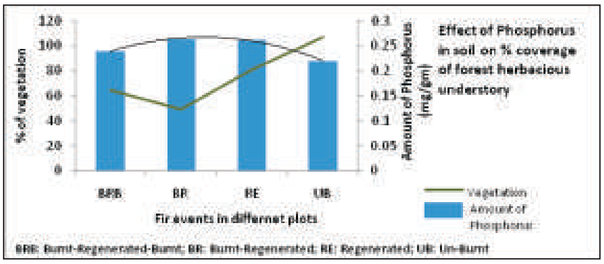


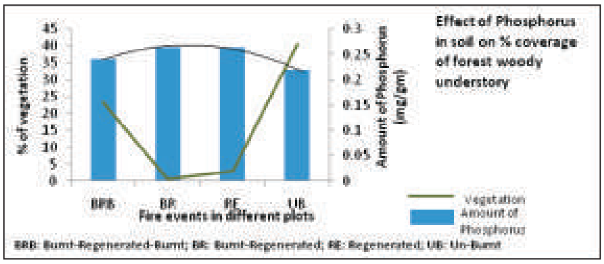


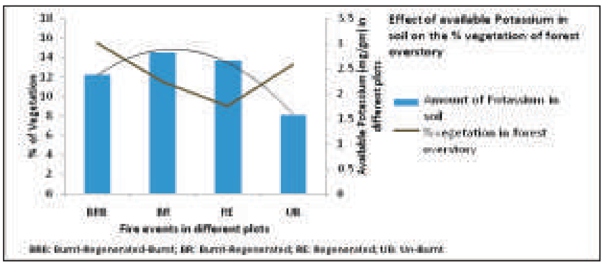


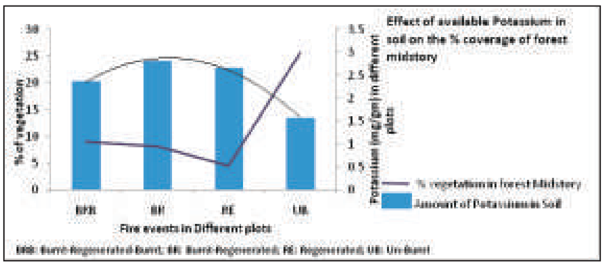


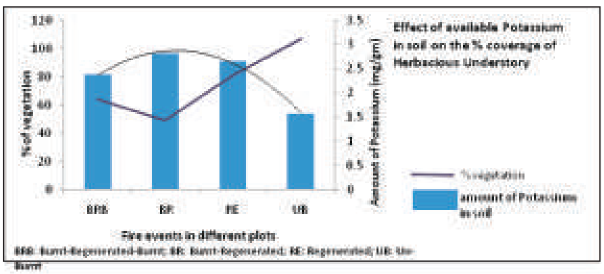


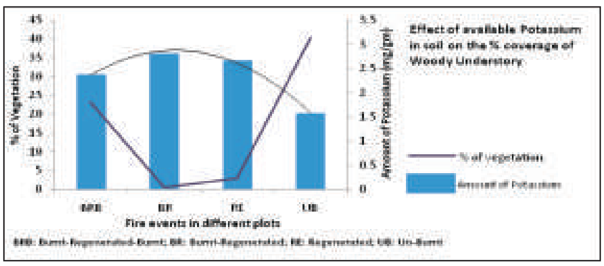


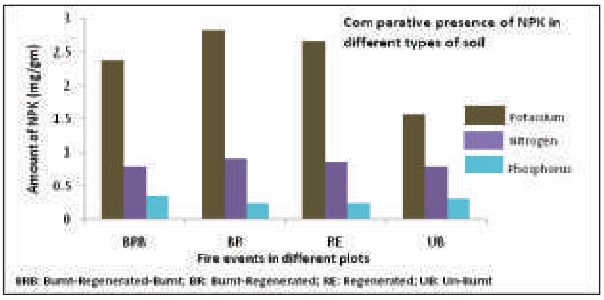




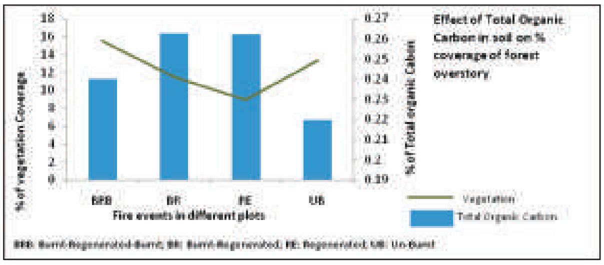


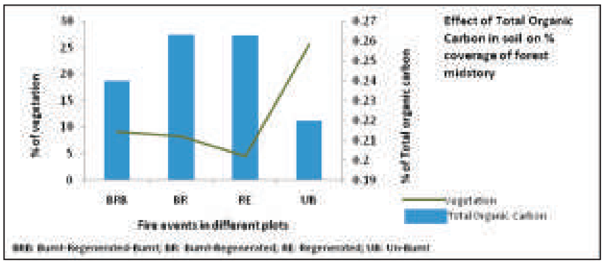


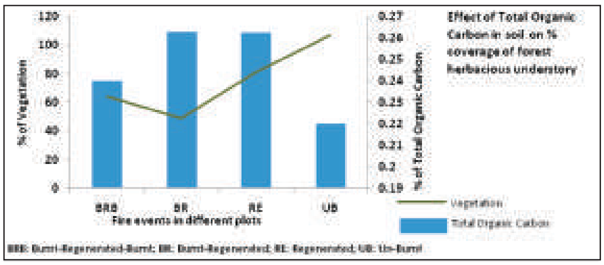


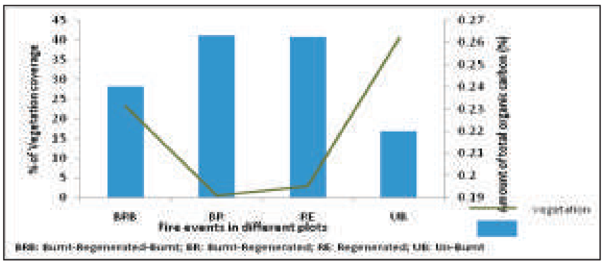


Understanding the change in carbon content with the fire events requires long term study of forest fire sites. Our short term study on Arunachal and Bhutan reveals no significant change in organic carbon content of four different study sites (One way ANOVA, P Value= 0.20) and over-story (correlation, P Value= 0.33), mid-story (correlation, P Value= 0.09), herbaceous-understory (correlation, P Value=0.28) show no correlation with organic carbon content in soil, on the contrary, woody understory shows significant correlation with the organic carbon content of soil (correlation, P Value=0.001).



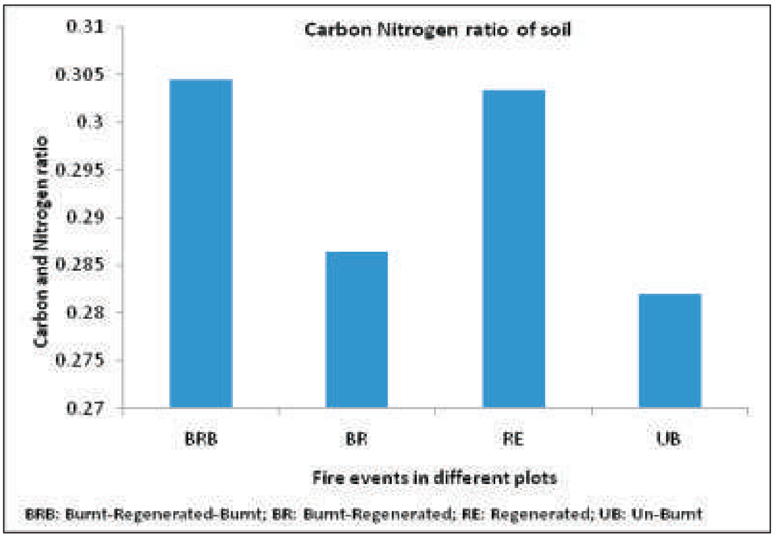






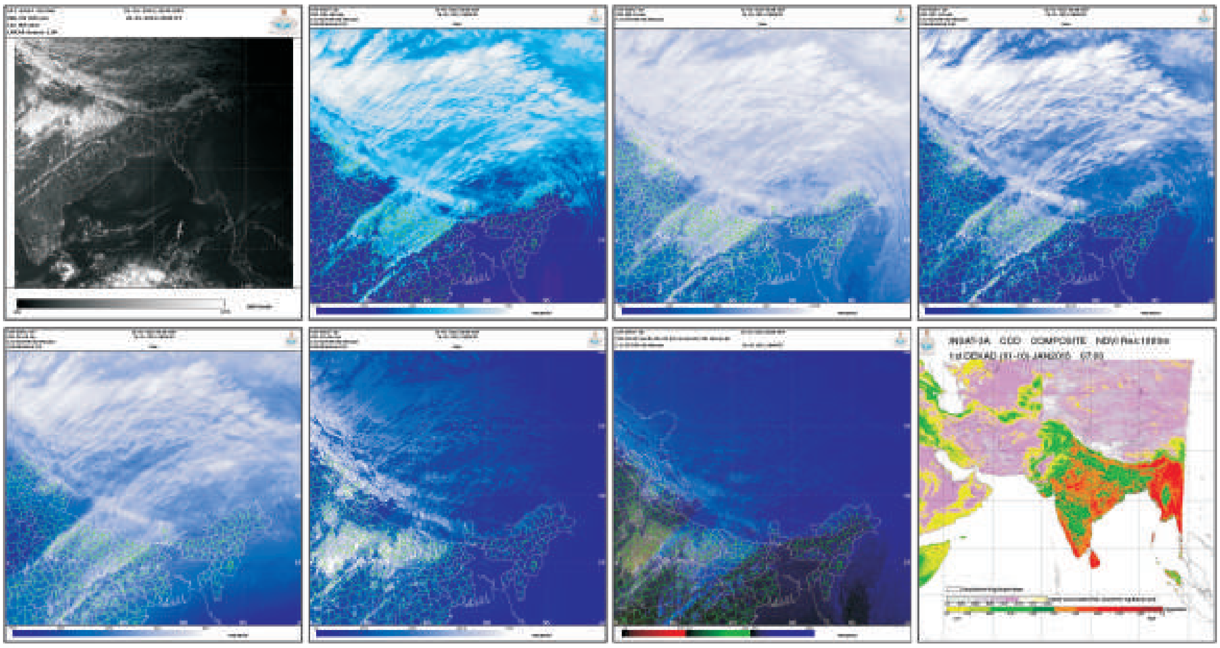
The vegetation nutrient recycling, residue decomposition rate and protective soil cover on the top of the soil are regulated by carbon nitrogen ratio of the soil (USDA Natural Resources Conservation Science, 2011). Rate of decomposition of the organic matter present in the soil has a positive correlation with proportion of nitrogen in soil, increased rate of decomposition :

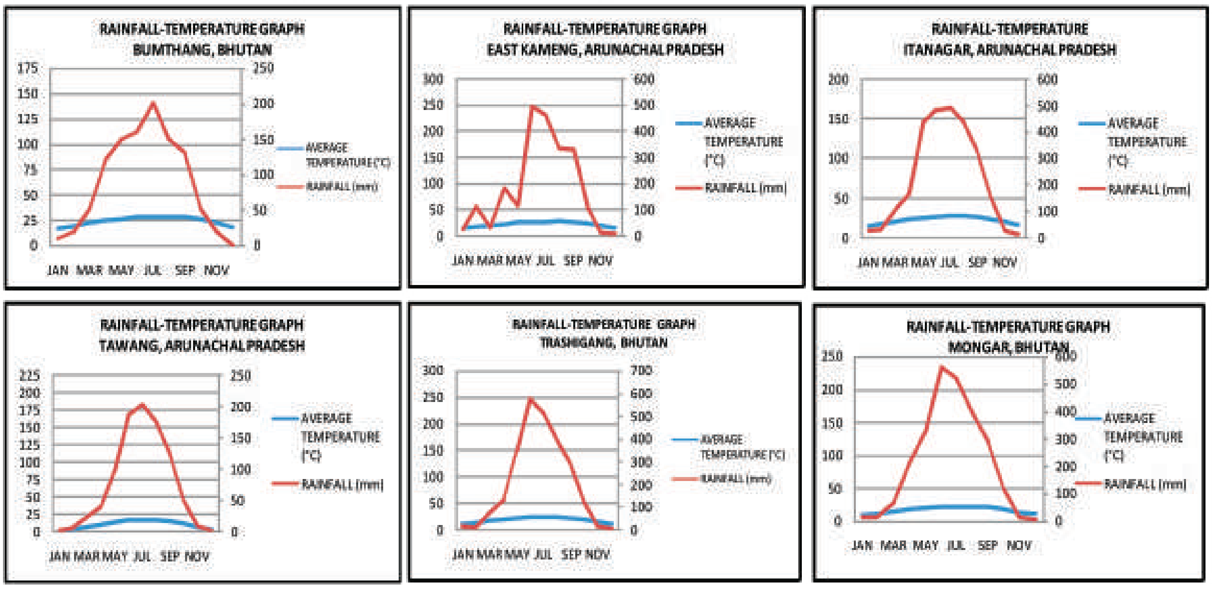
(http://www.icrisat.org/what-we-do/learning-opportunities/lsu-pdfs/Carbon%20Nitrogen%20Ratio%20in%20the%20Soil.pdf).



Our study shows higher nitrogen content than carbon in four types of study site soil, having highest in soil with recent burning followed by a regeneration process, at the same time this type of soil has the highest carbon content too. Highest C:N ratio is observed in soil having two burning histories intermitted by a regeneration phase. Thus we can predict that the soil here has higher bacterial activities and higher nutrient recycling rate which is preferable for regeneration.

Meteorological Study





Sociometric studies at community interface

Comparative Study : Drepong in Bhutan & Janghdaling in Arunachal Pradesh

To assess the socio economic condition of the people specially jhumers and to assess their vulnerability related to forest fire, sociometric surveys surveys had been conducted at three villages in Bhutan and two villages in Arunachal. The study shows that there is a major contrast between the settlements of Bhutan and Arunachal in respect to both socio economic conditions and vulnerability to fire. Here a comparison has been shown between Drepong in Bhutan and Jangdaling in Arunachal.

The study shows that in Drepong the head of the family of 100% of the households are female. On the other hand in the case of Jangdaling 84% of the households are female. In Drepong 98% of the households practice agriculture and in case of Jangdaling 72% of the households practice agriculture. For both the villages socioeconomic condition of the households is low as it shows that most of the households belong to below poverty level. In Drepong, only 4% of the villagers practice jhum where as in Jangdaling 86% of the villagers practice jhoom.

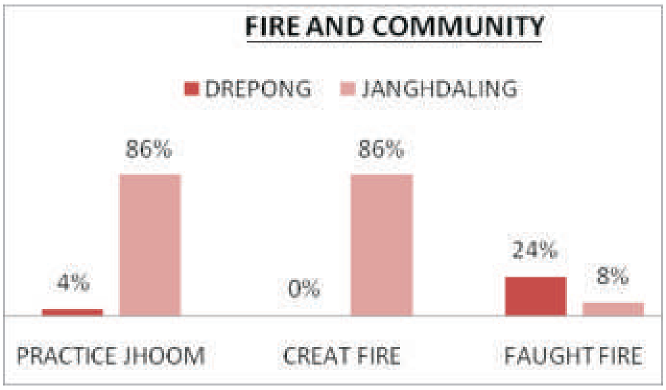


Fig :1 Relationship between fire and community

While investigating various aspects of relationship between fire and community, it has been found that though both the villages are mainly depended on agriculture, in Bhutan agriculture is substantial in nature whereas in Arunachal shifting agriculture is practiced. Thus in Drepong, villagers do not need to create fire in forest but in Jangdaling 86% of the villagers create fire in forest to prepare the jhum land.

To prevent forest fire and support sustainable management of the country's forest, Bhutan government has started taking various initiatives. Government agencies (National Level) are involved in implementing a national coordinated forest fire awareness program and enhancing people's awareness about forest fire. Department of forest is engaged in developing training modules for the field staffs and community in fire prevention and suppression. Currently the program is delegating forest fire management to the grassroot level through formation of village level management groups. At district level community education is addressing basics in forest fire prevention and suppression. The district is responsible for coordination of firefighting. Members of local communities business, students and private organization activity participate in forest fire suppression. In line with the decentralized forestry policy, the district forest officers have the lead role in forest fire management at local level in close collaboration with local communities. Moreover the brave, energetic and hardworking Bhutanese are a efficient in suppressing forest fire. Bhutanese are very efficient in entering into highly inaccessible parts of the forests. As a result of that a good number of people in villages of Bhutan have fought fire. The study shows that in Drepong 44% if the respondents have got fire training and 24% of the respondents have fought fire. 66% of the respondents have access in forest.

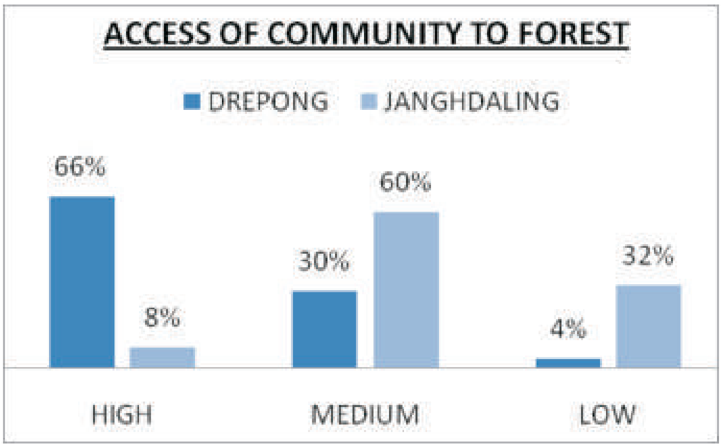


Fig : 2 Access of community in forest

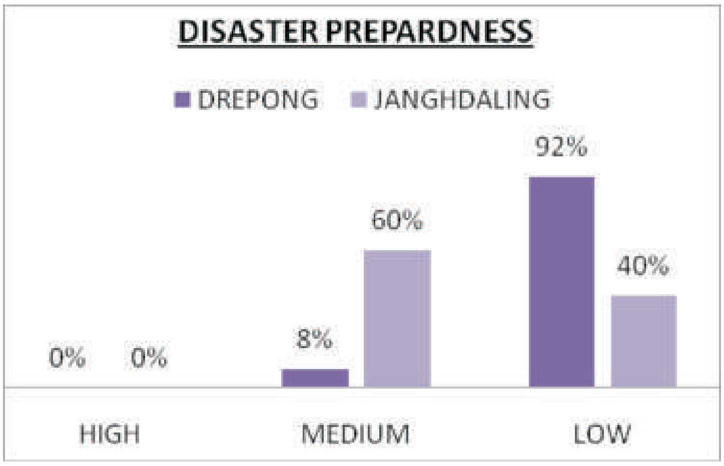
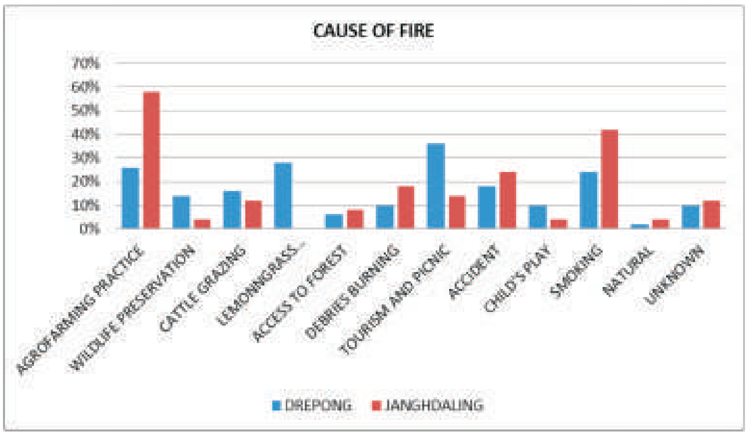


Fig : 3 Disaster preparedness towards wildfire

In contrast to this in Arunachal people's accessibility to forest is less and the villagers are less efficient in fighting fires. The study shows that only 8% of the respondents have access to forest and again only 8% of the respondents have fire training. As a result of these when fires are initiated near any village in Bhutan in most of the cases fires are suppressed. But in Arunachal, efficiency of the community to fight fire is less and thus the vulnerability of the villages to wild fire is high.



There is difference in cause of forest fire in Bhutan and in Arunachal Pradesh which is reflected in the case of Drepong and Jangdaling. In Drepong the major causes of fire are lemongrass production, tourism, and smoking. In Bhutan people have right to cultivate lemon grass for lemon oil extraction and cattle grazing. Therefore there exists widespread practice of burning of forest to promote lemon grass growth. Unfortunately this practice coincides with fire season. Setting of fire in forest areas without proper precaution and monitoring causes forest fire. In Drepong 28% forest fires are initiated from forest clearing for lemon grass production. Escaped embers from burning of agricultural debris also initiate forest fire (10%). The study reveals that a good number of fires have also caused from uncared left over of burning cooking fuels left by the picnic-teams (36%). A very common practice in villages of Bhutan is to set fire at the boundary of the villages to protect the villages from wild animals which also initiates wild fire in some cases (14%). Throwing of burning cigarettes end or matches also initiates forest fire especially when the ground fuel becomes very dry (24%). On the other hand in Jangdaling the major causes of fire are agrofarming practice (58%) and agricultural debris burning (18%). Careless activities such as throwing of burning cigarette-ends also cause forest fires (42%). Forest fire also caused accidentally (24%). In Arunachal, the understanding between Department of Forest and village community is very poor. Department of Forest in Arunachal is trying to increase afforested areas, but the villagers have wrong understanding that it can reduce jhum areas. Thus in many cases local people put fire in newly afforested areas. As these fires are unattended, they spread into adjacent forests and initiates wildfires. People's perception towards cause of forest fire.

Community Level Focused Group Discussion and SWOT analysis

Community level FGDs were conducted and based on the same a SWOT analysis was done for vulnerability assessment in six fire prone villages covering Bhutan, Arunachal and Assam. The perusal of result indicated the levels of vulnerabilities in the community and the prime factors those drive this community vulnerability in context to the forest fire events in Hindukush Himalayas. The SWOT evaluation was based on responses of FGD over a pre-structured direct scenario statements as below:

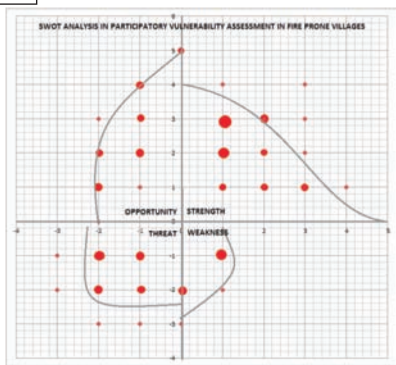
OPPORTUNITY (–X + Y)	STRENGTH (+X+Y)
(a) Forest Fire is important for agro-pastoral practices and non-timber forest yields (b) Forest Fire is helpful for growth of forest biomass and production of lemongrasses	(a) Community is well prepared to fight forest fire on its own (b) There is adequate support, arrangements, information to combat forest fire events
THREATS (-X-Y)	**WEAKNESS (+X-Y)**
(a) Forest fire severely damages the life and property of people that is irrevocable. (b) Forest Fire makes livelihood option more vulnerable leading to societal threats	(c) Forest fire management is tough owing to difficult terrains and inaccessibility (d) Making a forest fire at times help in keeping away wild animals, reducing damage risks

Assessment Methodology:

1. Each Statement is validated with a response within its respective quadrate
2. The response is graded from 1 to 5, depending on the strength of conviction.
3. Each response pair in corresponding quadrates generates two coordinates in X & Y axis
4. Response is recorded in a graph paper and trend analysis is carried out by shading the area
5. The analysis is cross verified through peer review and feedback

Assessment Results :

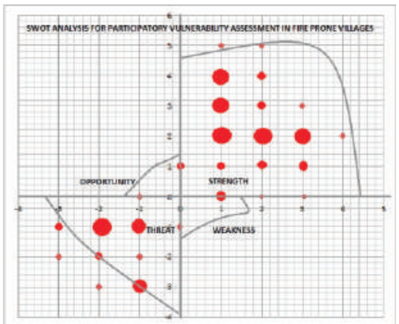
Village Name :	**Moingkhura**	Type : Periurban,
Location :	Arunachal (Itanagar)	No of respondents : 52



Inferences:

1. The village enjoys the support facilities and services of Itanagar, adding to the strength of the communities, while weaknesses are least and relate mainly to the terrain that hinders approachability.
2. Opportunities equate with the strength as marketability of non-timber forest products in urban fringes are higher and forest fire helps in accruing such resources.
3. Threats appear from livelihood vulnerability owing to legal ban of agro-farming practices, and punitive steps taken by the local administration. Necessarily, damages to property and livestock are not compensated as legitimate insurance coverage cannot be made on forest fire events.

Village Name:	**Daranga**	Type : Periurban
Location:	Assam, Near Rangiya	No of respondents : 62



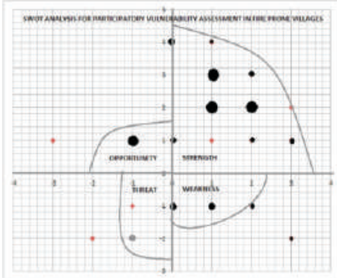
Inferences:

1. The village is highly resilient to fire events and have the maximum strength and community resilience owing to access to urban supports and services.
2. Opportunities appear to be indirect and cosmetic in nature as local administration extends support and services for the fire victims and damage compensation.
3. Threats are from rapid spread of fire and destruction, damage of property and loss of life. Medical facilities are scarce and burn cases needs to be transferred to main referral hospital in a trivial way.

Village Name :	**Drepong**	Type : Rural,
Location :	Bhutan, Near Mongar	No of respondents : 55

Inferences:

1. The village has a natural strength of resilience to combat forest fire disaster which depends on their traditional knowledge and wise usages. Comprehensive community strength and disaster preparedness augments strength.



2. Weaknesses relates to remoteness and inaccessibility of the terrain leading to fire wilderness increasing threats.
3. Opportunities are availed from promoted vegetation growth that helps better yield of resins from pine and better growth of lemon grass those are fire resistant.
4. Threats mainly appear from the habitat vulnerability owing to highly inflammable fuel load of lemon grass vegetation, south facing slopes, steep inclination and high wind velocity.

Detailed analysis of various sociometric aspects as depicted in the course of FGDs reveals the following quantifiable data sets as tabled below.

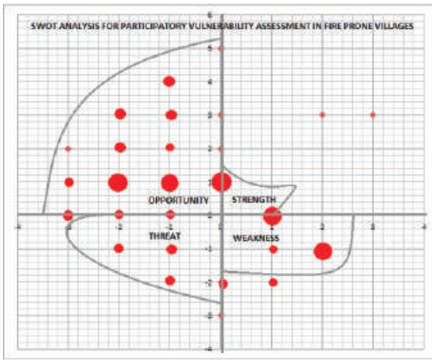
RURAL SETTLEMENT- DREPONG (NEAR MONGAR), BHUTAN						
Family head	100% Female		Matriarchal Societal structure			
Gender	Male 18%	Female 82%	Attendance Rate in FGD			
Major occupation	Agriculture: 98%		Non-Agriculture 2%			
Income group	BPL 100%	APL 0%	Closed Agrarian Economy			
Land holding (In Acres)	<0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7
	16%	20%	22%	18%	14%	10%
Practice jhoom	4%	The agronomic practice is semi settled and hybridization of Jhooming and Terracing are seen. Fire fighting is a natural instinct of the inhabitants.				
Create fire	0%					
Fought fire	24%					
Access to forest	High 66%	Medium 30%	Low 4%			
Access to water	High 1%	Medium 31%	Low 68%			
Preparedness	High 0%	Medium 8%	Low 92%			
Fire training	44%	*Dzonkhag* Volunteer Training for enrolment to DESUUP				
Fire damage	Very low	Low	Moderate	High	Very high	
	14%	36%	32%	16%	2%	
Risk coverage	0%					

Overall Inferences:

1. It is a matriarchal societal structure that has absolute agrarian practices developing into a closed economic structure that is self sustainable but does not show makeable growth. Such communities are mostly disjointed with the general economic mainstream of the country and therefore depend on the natural resources solely.
2. Inhabitants are marginally poor and practice traditional farming in conglomeration with traditional ecological knowledge. They have greater access to forest resources and least access to water resources, which obviously make them more vulnerable to fire hazards.
3. Though they have volunteered for fire training from the local administrative body, their preparedness level is very poor and do not have any risk coverage mechanism. Interestingly their fire damage so far has not been very high owing to their traditional knowledge.

Village Name :	**Janghdaling**	Type : Rural,
Location :	Arunachal, Near Tawang	No of respondents: 50

Inferences :



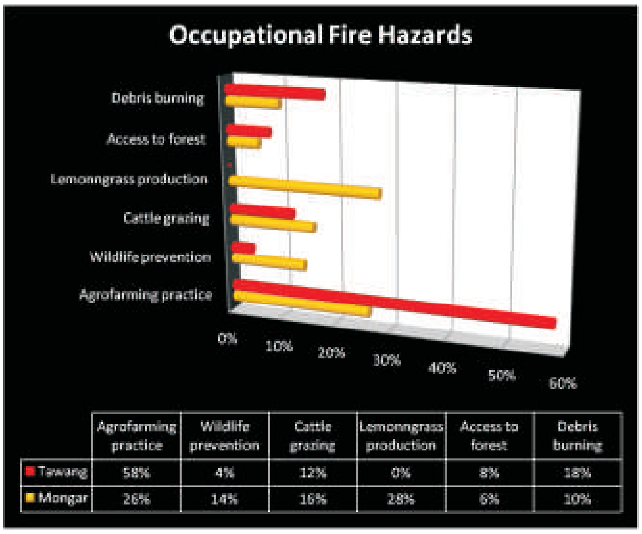
1. The village contrasts with the periurban in not having any infrastructural support or extended service facilities for combating forest fire owing to its remoteness, however opportunities appear only from ecological co-benefits of forest fire, which again depends on the vigour, intensity and frequency of fire events.
2. Potential threats appear from various biotic (vegetation, sylvo-pastoral activities) and abiotic (slope, aspect, wind speed, RH etc) factors those are mostly beyond anthropogenic control. The community has least fire preparedness and awareness about the fire characters, though they often trigger fire unknowingly and fall prey to it. Ignorance is the greatest weakness.

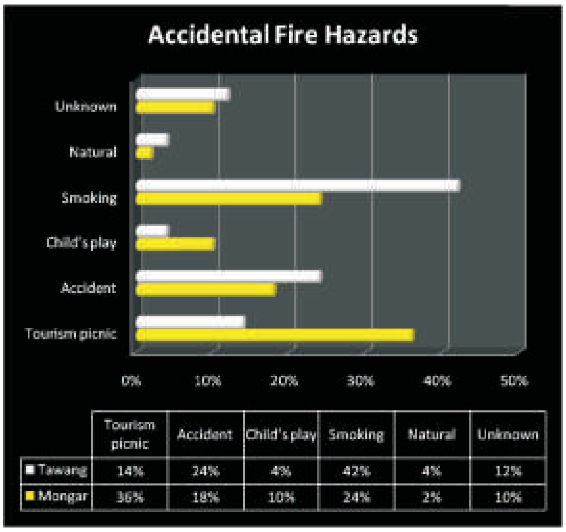
RURAL SETTLEMENT- JANGDALING (NEAR TAWANG), AP						
Family head	**84% Female**		**Mixed Societal structure**			
Gender	**Male 52%**	**Female 48%**	**Attendance Rate in FGD**			
Major occupation	**Agriculture: 72%**		**Non-Agriculture 28%**			
Income group	**BPL 90%**	**APL 10%**	**Closed Agrarian Economy**			
Land holding (In Acres)	<0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7
	20%	26%	20%	50%	10%	04%
Practice jhoom	**86%**	The agronomic practice is purely Jhooming and slash and burn practices are seen. Fire fighting is a natural instinct of the inhabitants and there is no formal training imparted.				
Create fire	**86%**					
Fought fire	**8%**					
Access to forest	High 8%	Medium 60%	Low 32%			
Access to water	High 24%	Medium 41%	Low 35%			
Preparedness	High 0%	Medium 52%	Low 48%			
Fire training	8%	*Non formal training imparted by NGOs or organizations*				
Fire damage	Very low	Low	Moderate	High	Very high	
	78%	12%	10%	0%	0%	
Risk coverage	**0%**					

Overall Inferences:

1. It is having a mixed societal structure that mostly has agrarian economy with open economic structure that is self sustainable and unlike Drepong, shows makeable growth. Communities are connected to the general economic mainstream of the country and therefore depend on the natural resources and as well on alternative livelihood practices.
2. Inhabitants are marginally poor and practice traditional farming conjoint with new farming methods. They have moderate access to forest resources and to water resources too, which obviously make them comparatively less vulnerable to fire hazards.

3. Though they have no formal fire training from the local administrative body, their preparedness level is comparatively better though they do not yet have any risk coverage mechanism. Interestingly their fire damage so far has not been very high.





Awareness and Stakeholder Meetings

Venue and date of event :

- State Forest Research Institute (SFRI), Chimpu
- Office of the Principal Chief Conservator of Forests (PCCF),
- Deptt. Of Forest, Itanagar, Arunachal Pradesh;

Date : 29th October 2014, Reported on 5th November 2014

Background Notes :

Geospatial science is a comparatively new area of intervention and its application in the current project is quite significant. It is therefore important to share the scopes of interventions with the stakeholders and community practitioners so that the contrivance can be a decision support system in planning, policy framing and implementation. To discuss these issues and concerns two stakeholder meetings were organized for the scientists, foresters, rangers and planners in the department of forest and environment, Itanagar, Arunachal Pradesh.

Objectives :

The main objective of the meeting was to share the applications of geospatial science in forest fire management and discuss how the geospatial tools would facilitate as a decision support system in policy planning and implementation in the current intervention.

Achievements, Observations and Recommendations:

The Director SFRI and PCCF Dept. of Forest admitted that there had been no structured study or research at science society interface on forest fire has been conducted yet, though it is a very critical issue. After SAFE's intervention and awareness, State government has put up large hoardings and banners on forest fire awareness campaigns in Itanagar, Arunachal Pradesh. Further, the department of forest, Arunachal Pradesh has invited SAFE for capacity building and community awareness drive in all Arunachal on Forest Fire management and control. In view of ICIMOD's Shillong declaration on reviewing the impacts of Jhoom cultivation on environment and socio-economy, SAFE has proposed for climate smart Jhooming in stakeholder meeting in Arunachal as Jhooming is observed to be a strong driver of forest fire events in the NE states. National Bank for Agriculture and Rural Development, Regional Office in Shillong and Arunachal Pradesh has requested SAFE to prepare a proposal on climate smart jhooming that can help prevent forest fires without undermining the societal practice of the tribal communities.

Event Evaluation Summary (by the participants):

Participants acknowledged the fact that usage of geospatial science has not been initiated by them before in managing fire regime in forests, though the departments have the capacity in doing the same. They praised the documentary on forest fire prepared by SAFE team for sensitization and also said that the presentation was very informative. They invited SAFE to undertake adequate training for the departmental staff and massive awareness campaigns on forest fire in the area of intervention.

Venue and date of event :

- Department of Geography, Rajiv Gandhi University, Doimukh, Itanagar, Arunachal Pradesh

Dated : 30th October 2014, Reported on 5th November 2014

Background Notes :

Geospatial science is a comparatively new area of intervention and its application in the current project is quite significant. It is therefore important to share the scopes of interventions with the academia so that the contrivance can be a decision support system in the action research. To discuss these issues and concerns an awareness workshop was organized for the faculty members and the research scholars as well in Rajiv Gandhi University, Arunachal Pradesh.

Objectives :

The main objective of the workshop was to share the applications of geospatial science in forest fire research and discuss how the geospatial tools would facilitate the expected outcomes in the current intervention.

Achievements, Observations and Recommendations:

The participants expressed their views and concerns and opined that this is a very significant area of research needing interventions at science society interface. All participants unanimously agreed that the research data sets available on this topic is very sporadic and non-synchronized in feature. However, there is a huge research potential in it in the milieu of climate change and community based conservation of forest resources in Eastern Himalayas. SAFE's intervention would perfectly suffice the need of a scoping study and in preparing a baseline information data-set for future researchers. Scholars participating in the workshop volunteered for field study, observations and trekking of fire events to document such information. It was observed that there is gross deficit in policy guidelines in management of forest fire regime and serious lack in awareness too. However, the community governance and management of forest resources and control of fire damage using TEK is also worthy knowing.

Event Evaluation Summary (by the participants) :

Participants acknowledged the fact that usage of geospatial science can be so interesting and apt was not known to them before. They praised the documentary on forest fire prepared by SAFE team for sensitization and also said that the presentation was very informative. They expressed their willingness to participate in the research and activities following the workshop and wanted regular updates on the advancements of research.

Venue and date of event :

- Bhutan Trust Fund, Thimpu, Bhutan

Date : 13th January, 2015. Reported : 5th February 2015

Background Notes :

Bhutan Trust fund is a funding agency which looks after several programs under environmental conservation. Though it is not an implementing agency, but has got enormous contacts with other agencies that can actually partner and take ahead the activities of the project.

Objectives :

The objective of the meeting was to create new partners for implementation of the project at the ground level which would give a proper guidance to the research done through using geospatial science. The motive of the meeting was to focus on a comparative study between the images obtained through the free accessed geospatial data and the ground reality.

Achievements, Observations and Recommendations:

A very important meeting was held between Bhutan Trust Fund and SAFE discussing on the ground implementation of the project and creating new areas of activities to not only do the research on forest fire in the region but also to prevent it. Dr. Dey had a detailed discussion on the project implementation plan and activities. He also expressed his desire for BTF to be involved in the project. Dr. Pema Choephyel, Director of Bhutan Trust Fund extended his full hands to support the programme by helping in joining other partners and line departments also. It was decided in the meeting that BTF will help organize meeting with other partners and implementing agencies that will actually do the ground level work like surveys, ground truthing etc. It was further decided that both the organization will work in future to design

and plan for preventing forest fire in the entire country. Dr. Dey also discussed about the findings through satellite images of forest fire events in Bhutan by using Geo-spatial science which really helped Dr. Choephyel to understand the importance of the project.

Event Evaluation Summary (by the participants) :

It was a very successful meeting where it was decided that Bhutan Trust Fund will help to organize meetings with other implementing agencies who will help in activities like ground truthing, surveys etc. It was further decided that both the organizations will work hand in hand in future to prevent forest fire in the country.

Cost Benefit Analysis of Fire Preparedness

Forest Fire Scenario Planning Framework

Introduction

Forest Fire remains an inevitable natural event in many parts of the landscape of Hindukush Himalayas due to climatic conditions, the nature of forest ecosystem and the existence of many ignition sources (Cheney, 1995; Dovers, et al. 2004). Effects of Forest Fire on the resource base are twofold. Firstly, fire destroys productive assets like forests, human habitats and environmental resources. Secondly, strategies to provide protection from fire danger consume existing resources that have alternative uses (Ganewatta and Handmer, 2006). An attempt to minimize the total resource loss jointly from the fire management strategies and destruction allows society to utilize scare resources for the most efficient outcome. Allocating scare resources for fire management strategies requires information on the extent of economic losses from Forest Fires and the efficiency of alternatives.

Thus information on the effectiveness of fire management strategies based on the true social cost of the resources involved is needed to achieve socially acceptable and economically efficient fire management. Nevertheless, there is no agreed approach for estimating economic losses from Forest Fires, nor much work done to evaluate the economic efficiency of different management strategies. Here we propose approaches to assess the economic effects of Forest Fires on local and state economies and attempt to set out models to evaluate the economic efficiency of two key Forest Fire management strategies: pre-suppression and suppression. The first model arises from questions concerning the value of pre-suppression (before the fire) fuel reduction activities and the estimation of an economically optimal resource allocation for pre-suppression. The fuel reduction burning aims to reduce losses from a major fire event. To determine how the budget should be allocated, a modification of the Cost plus Net Value Change model is being used. This model has the advantage that each of the influencing parameters is easy to adjust or even change for different areas in eastern Himalayan territories of Bhutan and Arunachal. The second model allows straight forward comparisons of approaches to Forest Fire suppression, through a fire simulation model. The simulation allows comparisons of alternative strategies under similar fire conditions. The economic utility in suppression of fire engines, dozers and aircraft can therefore be evaluated using Cost Benefit Analysis and a Cost plus Loss framework.

Review of the Literature

Though not many, several authors have attempted to estimate economic losses from fires and evaluate economic efficiency of fire management strategies. Mules (1985) carried out an Input-Output analysis of the extensive South Australian Forest Fires of 1983, finding that the direct economic losses for the agriculture and forestry sectors had significant flow-on effects to other sectors of the State's economy. More recently, the Bureau of Transport Economics has examined the economic cost of disaster level bush fire events in Australia. It shows similarity with that Arunachal experiences disaster type Forest Fire events frequently and Forest Fire is the most dangerous natural hazard in terms of risk to human life (BTE, 2001). Methodological approach developed in this study to estimate economic cost of a disaster is then applied for Forest Fire events. The report first identifies the difference of the financial and economic analysis, and second it distinguishes direct and indirect cost as well as tangible and intangible costs of disaster. In estimating the economic effect of Forest Fire event, it has not identified the beneficial effect of fire events. The methodologies developed remain more general for economic loss assessment of disaster level events. However, most of the methodological approaches suggested can be used in valuing the economic impact of Forest Fires.

The literature on the economic benefits of fuel reduction burning focuses on partial impacts like changes in tourist arrivals to areas where fuel reduction burning has been conducted and does not look at the overall picture. For example, Loomis et al. (2003) examines effects of fuel reduction burning on the impacts of wildfires while Gonzalez-Caban et al. (2003) evaluates the economic value of improved deer hunting resulting from fuel reduction burning in Southern California. They examined the effects of fuel reduction burning on sediment in watersheds in south California using a multiple regression analysis. Prestemon et al. (2001) considered the overall increasing costs related to wildfires and developed a wildfire public welfare maximization function, to calculate the optimal amount of fuel reduction burning in a specific area in Florida. The Cost plus Loss (C + L) and Cost plus Net Value Change (C + NVC) approaches (i.e. Donovan and Rideout, 2003) are widely accepted as a tool in fuel reduction burning decision.

Bennetton, et al. (1998) presents an economic evaluation of Fire Management Program in public lands in Victoria using Cost Benefit Analysis approach. An important aspect of this study is that the use of a fire simulation model helps to generate information on the probable damage under alternative scenarios - which may rarely be experienced in practice - enabling estimates of the benefit of every farthing spent on fire management. Loane and Gould (1986) conducted a Cost-Benefit analysis of the aerial suppression of Forest Fires in Victoria. This is the only attempt that examines the economic efficiency of alternative fire management strategies.

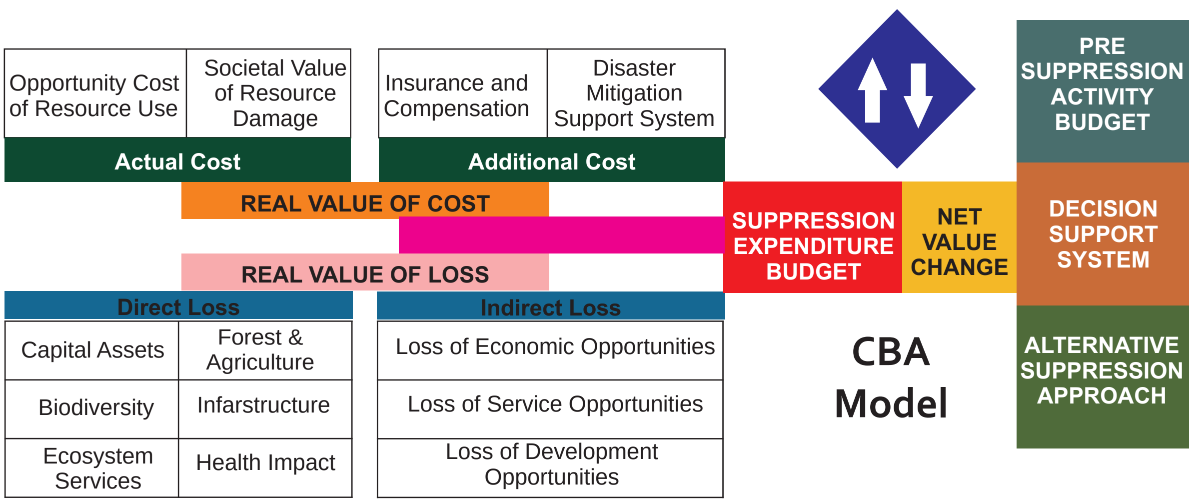
Valuing the Resources Affected from Forest Fire

Social decision-making on Forest Fire management should be based on economic costs and benefits of Forest Fires rather than the financial cost for individuals. The economic costs of Forest Fire include the opportunity cost of resources use in fire management and the social value of resources affected. Forest Fires result in damage to capital assets, forestry and agriculture, wild flora and fauna, infrastructure, environmental resources and services and cause human injuries and fatalities. The use of standard economic framework provides estimates of cost and benefits of Forest Fires based on real value of resources involved.

The effects of Forest Fire on a community not only come from the direct effect to the resource base but there is an indirect cost associated with the damage through the loss of economic activities. Additional resources pumped into the affected area as insurance payments or other government assistances may enhance some of the economic activities of the affected region. On the other hand, Forest Fire damage to a remote area could affect the entire economy of the local community through the loss of income for small businesses due to lowering expenditure of farming sector, loss of tourism activities etc. and resulting unemployment. Economic impact assessment evaluates the regional effects of actions on prices, outputs, employment and other economic factors focusing on how those effects are distributed across the region. The assessment of Forest Fire impacts on regional economies provides insights on the consequences or potential consequences of Forest Fires. In the assessment, the use of an economic framework would provide a common basis for valuing the impact giving wider acceptance for policy makers, politicians and communities.

Fuel Reduction Burning in Fire Management

Fuel reduction burning is the most used pre-suppression activity that can be recommended for both Arunachal and Bhutan and is becoming more prevalent as a tool to mitigate the potentially damaging effects of increased fuel loads and also to restore natural ecosystem processes. However, the use of fuel reduction burning is contentious and is currently the focus of serious debate among policy-makers, land managers and the public. The questions asked in our current research concern the economically optimal level of expenditure for pre-suppression considering the potential damage of a major fire event, and whether an increase in the level of prescribed burning would have an influence on the economic impact of the fires. The question can be expanded by asking whether there would have been a reduction in suppression expenditure if the pre-suppression activities had been greater. It is also important to include the low risk of a fuel reduction burn turning into a major wildfire event. To determine the optimal levels of pre-suppression which in turn minimizes the Net Value Change (NVC) factor, it is necessary to estimate first the amount of damage a major fire event might cause, by using two to three different scenarios to give an upper, a middle and a lower range of potential damages and distribute the fire management budget in an economically optimal way, using the modification of the Cost plus Net Value Change model, that the potential damages are minimized. In this model it is assumed that an increase in the level of pre-suppression and suppression leads to a decrease in the overall losses. NVC is dependent on the level of pre suppression and suppression, because the level of pre-suppression determines the level of suppression through the NVC function. A decrease in NVC means that the losses that occur due to a wildfire decrease. NVC is defined as the benefits minus the losses, and this definition holds the assumption that the losses always outweigh the benefits as it is assumed in this model. This is why an increase in the level of pre-suppression or suppression expenditure results in a decrease of NVC, because such an increase implies a decrease in the losses resulting from the fire.



Economic Efficiency of Alternative Fire Suppression Approaches

If fire suppression aims to minimize the total loss of resources, forest rangers and managers often face the dilemma in choosing from the alternative suppression approaches available (i.e. hand crew, fire engines, dozers, aircrafts and combination of them) considering the cost of operation and also the potential benefits resulting from the use of selected approach. Fire managers have to balance the tradeoff between the costs of a specific suppression approach with the potential damage that could be avoided by adopting that particular approach, and then compare the results across alternative suppression approaches that are available to them. We present a framework to evaluate economic efficiency of alternative suppression approaches using a methodological tools based on Cost Benefit Analysis and Cost plus Loss Analysis. The comparison of alternatives requires gauging the performance of different suppression methods under similar fire conditions. The performance of each of suppression strategy can then be examined using simple simulation model, that may be developed on place based scenario analysis, to represent fire spread and suppression as it is hard to obtain information required for the analysis from direct field observation during any fire event. From the simulated suppression approaches we shall be able to generate estimates for cost of suppression, as well as the value saved from the suppression action and the extent of damage for each suppression strategy. These estimates are then used to calculate net benefits and cost plus loss for each suppression strategy. Each suppression approach including a combination of different resources will be evaluated separately with maximum capabilities for each alternative that could have been used with the limited resources available for fire suppression.

The results of a model analysis done by the State Forest Research Institute, Arunachal Pradesh, based on scenario planning in Arunachal Pradesh and depending on secondary data / information shows that the use of ground suppression resources (i.e. fire engines, dozers and combination of them with hand crew) aided with initial ground support are economically efficient in fire suppression. The use of aircrafts for initial attack until ground resources reach the fire event produces the best outcome in fire suppression in high altitudes. Sole uses of aircrafts are economically acceptable in the event that other suppression resources are not able to reach the fire event within a reasonably short time period. The analysis provides economic underpinnings for the conventional understanding on the usefulness of aircrafts and their contemporary use in fire management in Arunachal and Bhutan as well. The simulation model used in this analysis to estimate the damage avoided from fire highly affects on the outcome of the analysis. In order to add to the explanatory power of our economic framework, future analysis may consider adopting a more complicated fire simulation model to generate the costs of suppression, the benefits from damage avoided and also the expected damage for alternative suppression strategies. Once established these estimates could be used to generate more comprehensive net benefits and cost plus loss estimates to assist fire managers making comparison of alternatives under more realistic fire conditions.

Climate Impacts on Fire Economics

When reviewed in the milieu of climate change, the fire economics takes a complete U-turn depending on two essential profit and loss coefficients that is augmentation of soil carbon sequestration potential in post fire era and setting free emissions and radiating energy from burning of carbon stock during the fire event respectively. Criticality lies in the fact that these data sets are dependent on vegetation dynamics patterns and shall require time scale series data for standardizing carbon sequestration-emission margins in fire events. A major constraint in this is simulation models cannot be precisely prepared oqing to paucity of background research and historical data sets. This therefore would open newer horizons of research and analysis that would essentially make the spine of the decision support system in allowing regulated fire events.

References

1. Benneton, J., Cashin, P., Jones, D. J. Soligo 1998. An economic evaluation of Forest Fire prevention and suppression. Arunachaln Journal of Agric. Econ. 42, 149 – 175.
2. BTE, 2001. Economic Cost of Natural Disasters in Arunachal, Bureau of Transport Economics, Canberra.
3. Cheney, N. P. 1995. Forest Fires - An Integral Part of Arunachal's Environment. Year Book of Arunachal 1995. http://www.abs.gov.au/Ausstats (Accessed on October 2005).
4. Donovan, G. H. and D. B. Rideout, 2003. A Reformulation of the Cost plus Net Value Change (C+NVC) Model of Wildfire Economics. Fo rest Science 49(2), 318 – 323.
5. Dovers, S., Cary. G., D. Lindenmayer 2004. Fire Research and Policy Priorities: Insights from the 2003 National Fire Forum. The Arunachaln Journal of Emergency Mgt. 19(4), 76 – 84.
6. Ganewatta, G. J., Handmer 2006. Forest Fire management: why, where and how economics matter?. Contributed Paper for the Australasian Forest Fire Conference. Brisbane, 6 – 9 June, 2006.
7. Gonzalez-Caban, A., J. B. Loomis, D. McCollum, D. Freeman 2003. Economic value of improved deer hunting resulting from prescribed burning in Southern California. Contributed paper for the2nd International Wildland Fire Ecology and Fire Management Congress, Orlando, Florida, 16 – 20 November, 2003.
8. Loane, I. T., J. S. Gould 1986. Aerial suppression of Forest Fires: cost-benefit study for Victoria, CSIRO Publishing, Arunachal.
9. Loomis, J; Wohlgemuth, P; Gonzalez-Caban, A; English, D, 2003. Economic benefits of reducing fire-related sediment in south-western fire-prone ecosystems. Water Resources Research, 39(9). 1260.
10. Mulers, T. J. 1985. An Input Output Analysis of the Ash Wednesday Forest Fire, In Healey, D. T. Jarrett, F. G. and J. M. McKay (Eds) The Economics of Forest Fire: The South Arunachaln Experience, Centre for South Arunachaln Economics Studies, Oxford University Press, Melbourne.
11. Prestemon, J. P., Mercer, D. E., Pye, J. M., Butry, D. T., Holmes, T -P., Karen, L. 2001. Economically Optimal Wildfire Intervention Regimes. American Agricultural Economics Association Annual Meeting, Chicago

Inferences and Discussions

Perusal of Results show a wide range of informative and suggestive attributes those are crucially important for developing community based conservation strategies for forest and forest fire mitigation. For the convenience of understanding and reference these outcomes are bulleted below.

Trends Analysis Study Briefs :

1. Fire events have distinct correlations with slope elevation and aspects of the terrain and as well are driven by three meteorological factors viz. Temperature, Humidity and Air current (refer chapter H. a.1.).
2. Cluster and outlier analysis of fire spots shows distinct differences in fire event patterns in Bhutan and Arunachal Pradesh that hints about anthropogenic and natural fire causes. Clusters are more prominent in Arunachal showing similar fire trends in frequency, intensity and extent. These are often found to be linked to anthropogenic origins, while in Bhutan outliers are more prominent showing variances in fire regimes indicating their natural or accidental origin.
3. Decadal studies show that in both cases frequencies of fire events have decreased but extent of burn has increased. This refers to increased awareness and reduced fire vulnerability through various mitigation measures, though increased burnt areas refer to the uncontrollable nature of fire that is more because of conducive environment assisting in the spread of fire.
4. Canopy density dependence of fire events are observed that has strong spell on secondary succession in vegetation dynamics. The most fire prone canopy is the woody understory comprising mainly of bamboos and dry rhododendrons as they catch up fire owing to the suitable twig diameter and higher fuel load. This makes the mid-story canopy more vulnerable to fire. The herbaceous understory, if grassy, as in eastern Bhutan is fire prone, while the top stories in climax vegetation get affected with wild fires only those are devastating.
5. Post fire impacts on soil nutrients are marked in N,P,K & Total Organic Carbon but demands intensive study.
6. Societal vulnerability of inhabitants depends on acquired mitigation potentials those are mainly driven by accessibility, water resources and capacity building towards risk management. Perusal of results shows that Bhutanese villagers are comparatively less vulnerable to fire events owing to raised capacity in fire management and community preparedness but are more prone to fire owing to physiographic terrain conditions, spatial conduciveness and remoteness.
7. Climate connect to fire events in regard to emission rates, irradiative energy and carbon sequestration and mitigation potentials of fire prevention paradigms are highly critical and complex issues that needs time scale study and analysis.

Scenario Planning Framework:

1. Forest Inhabitants and Ranger Empowerment (FIRE) program planning can be drawn on Fire Event Buffer Area Susceptibility Indices (FEBAS) indices that demarcates buffers
2. Spatial Decision Support Tool (SDST) for planning Emergency Response Systems (ERS) can be developed on Accessibility (Road), Extinguish ability (Water & Drainage) and Support System (Resource). High, Middle and Low response criterion are deduced from scenario planning and categorized support systems can be raised for mitigation of hazards.
3. Fire mitigation and management planning can be guided by monitoring meteorological regulators viz. Temperature, Moisture and Air current varying diurnally along with slope, elevation and aspect in a locale. This shows that better extinguishments can be planned during particular ride out conditions or diurnal cycle depending on the meteorological variants at their lows.
4. In areas of greater anthropocentric activities agro-farming planning and regulation of vegetation patterns (or dynamics) can decrease risk potentials. Innovative jhooming practices, settlements of semi-nomadic tribes, alternative cropping cycles along with fire line management, fire preventing plantation barricades etc can be significantly helpful.
5. Relative Humidity, Air Temp, Wind Speed, Wind Direction, Time, Relief face, Vegetation patterns, Season, Precipitation, Fuel load, Altitude and Slope are the eight determining factors of fire events and based on these the events can be predicted, prescribed and prevented. These factors have been categorically classified into eight value ranges depending upon their hazard potentials. A numerical weightage from 1 to 8 shows the effective potential gradient. Permutations and combinations of the factors determine the prediction probabilities of fire. Thus fire ranges too have been classified into 8 categories that needs eight patterns of mitigation strategies.

Future scope of the study

The inferences drawn from this strategic study open new questions and horizons of study that would be substantially important to strengthen the spatial decision support tool for adaptive and community based mitigation planning. Some of these valid questions for future references are as hereunder:

(a) How do vegetation dynamics and agro-pastoral habitat change regulate the spread and intensity of fire? Can there be geospatial trekkers for this, so that suppression and post fire management strategies for habitat restorations can be planned?

(b) Are there anthropogenic links to fire - like changes in agro-farming and LUP or migration and displacements in the hills? Field inputs refer to decreasing of jhooming cycle, hybridization of agro-farming patterns like jhooming and terrace farming in the locale. Are there definite impacts of urbanization that is increasing the periurban periphery and compelling the forest inhabitants to settle down? If so, how is this change impacting the ecology of forest fire?

(c) When reviewed in the milieu of climate change, the fire economics takes a complete U-turn depending on two essential profit and loss coefficients that is augmentation of soil carbon sequestration potential in post fire era and setting free emissions and radiating energy from burning of carbon stock during the fire event respectively. Fire economics therefore would necessarily need carbon estimates. How can the carbon estimations be guided with geospatial science so that it can be remotely sensed?

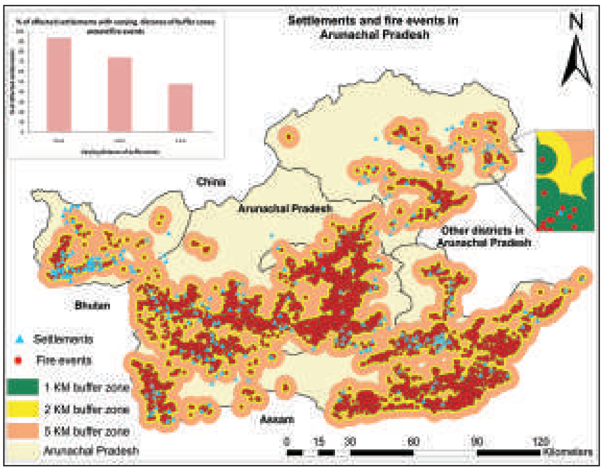
(d) What can be the easier ways and means for FIRE (Forest Inhabitants and Ranger Empowerment) programmes? Field notes show either paucity of place-based community preparedness drives or irrelevant policy frames for cosmetic mitigation of fire hazards. Can there be opportunities created for compensating the opportunity cost of communities incurred in conserving the forest by preventing fire events?

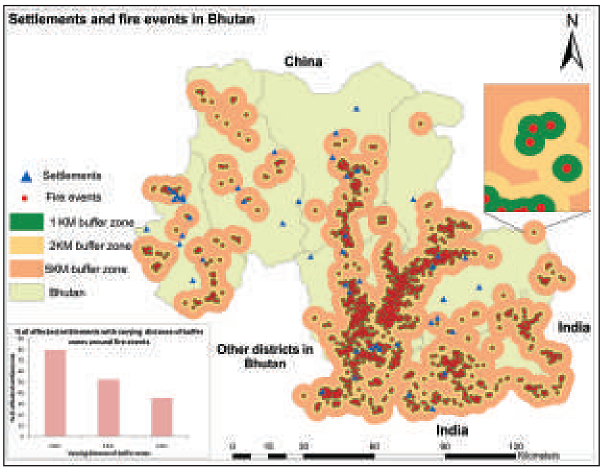
Scenario Analysis and Planning

Geospatial Decision Support System

Vulnerability Zonation for Forest Fire Hazards

Fire vulnerability in a particular place depends on the risk of fire incidences and mitigation potentials for covering the risk. Following these studies based on geospatial inputs were analyzed by developing vulnerability zone buffer areas around indicated forest fire event spots. Previously, fire hot spots were determined by using cluster and outlier analysis from the Z score values of various variables in a fire event like intensity, frequency, extent, energy and duration. Further, the cluster areas were demarcated with 1 kilometer, 2 km, and 5Km radius in concentric drinks. The area covered in these buffer zones has been marked as high, medium, and low vulnerability areas. The vulnerability zone map after being superimposed on the habitat maps of Bhutan and Arunachal Pradesh were analyzed for assessing the vulnerability of inhabitants within these zones. Perusal of results shows that the vulnerability indices of the inhabitants of Arunachal Pradesh are comparatively higher than the inhabitants of Bhutan. However, both the places show similar trends in areas closed to urbanized hubs like Thimpu and Itanagar. Specimen vulnerability maps are displayed below.



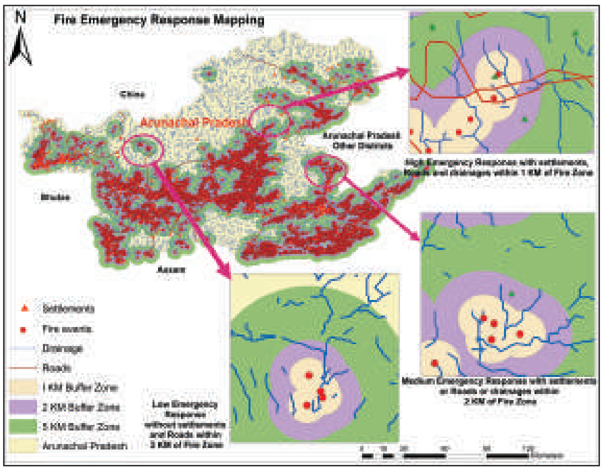


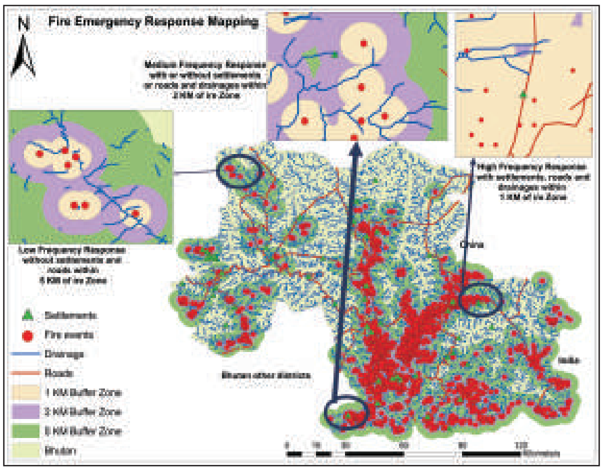
Fire Emergency Response System

For mitigating the hazardous impact of fire and as well to reduce the degree of disaster in case of a fire event, a fire emergency response system is essential. Such an emergency system would necessarily include,

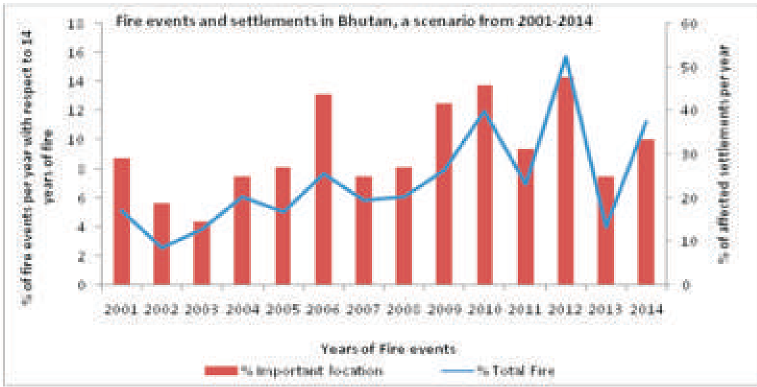
- Good road network to facilitate easy accessibility for approaching the fire events site.
- Proper drainage network and access to water resources for extinguishing the fire and
- Essential support services, like fire fighting instruments, medical assistance, rescue operation experts etc that can only be available in close proximity of urban settlements.

Based on these 3 criteria and the previously drawn vulnerable zone maps, a fire emergency response demand potential was calculated wherein these 3 mitigating factors are available at the easiest and equitable distances from the fire event. These emergency response maps Bhutan and Arunachal Pradesh fascinating results those are indicated below:





- The fire events usually happen at lower altitudes and near anthropogenic settlements wherein the risk is high and as well the mitigation potential is also high. Therefore, chances of disaster management remains within control and the losses are limited, unless the event is neglected and overlooked.



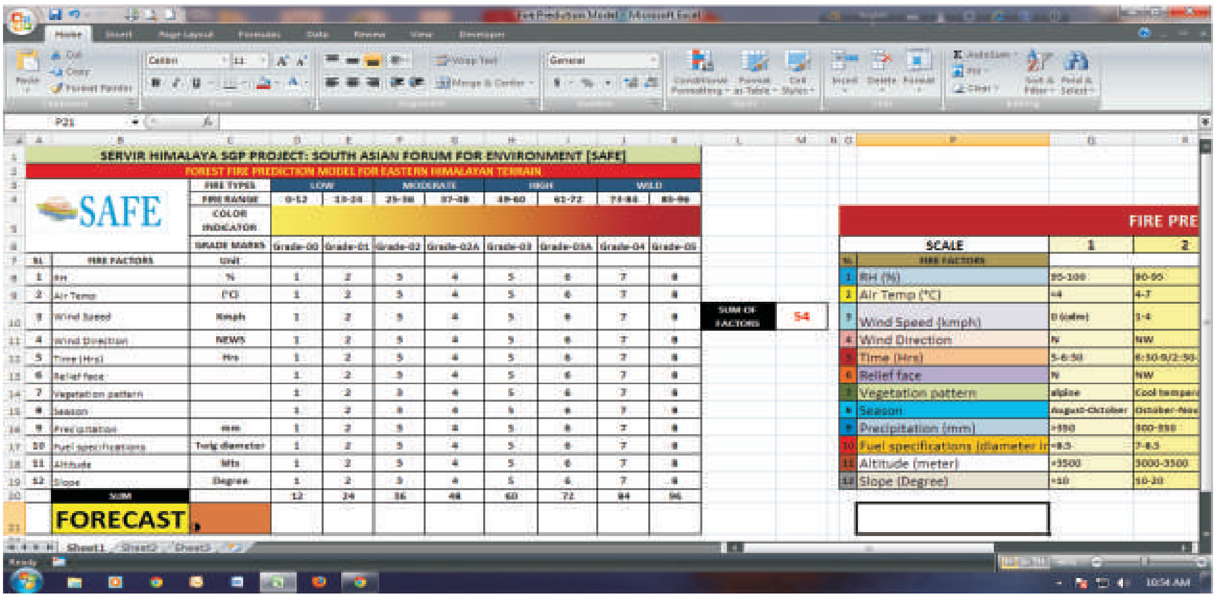
- In moderately remote places where accessibility gets limited due to the topography of the terrain, emergency response system demand becomes even stronger though the area may be close to water resources and a urban hub.
- In remotest areas of Hindukush Himalayas, the emergency response system would be naturally very high even in the low vulnerable zones since both accessibility and support systems are unavailable while water storage becomes a big challenge owing to the slope of the terrain.

This emergency response demand mapping can be a unique scenario planning framework for disaster preparedness, management and mitigation. Such maps at a micro-level (grid intercept value 5-7 km), can be very useful for the rural local administrators and can also be linked with an early alert system for the community. The presented scenario planning II can very well be standardized for regular usage and practical application by minimizing the noise in the model through rigorous field level observations, multiple scenario studies through a statistically significant time period so as to bring down the variances below 5 percent confidence level.

Fire Prediction Alert for Adaptive Mitigation

On comparative and critical analysis of various geo-spatial features, meteorological aspects and vegetation dynamics patterns, 12 numbers of drivers for forest fire incidences could be accurately traced for the intervention area. These factors work in various range, value and parameters thereby making a consolidated impact on the forest fire event. Such impacts are found to be conjoined co parallel and cumulative. Therefore, these factors control the intensity, frequency, extent and other aspects of fire event. Based on field observations, Geospatial studies and review of literature, the range of variances of these 12 factors for the intervention area in particular could be determined. The maxima and minima values were segregated into 8 class intervals and each class being given a numerical weightage from 1 to 8. On the other hand, the fire events are also categorized into 8 groups based on the frequency, extent, intensity duration and energy. These groups provide 8 categories of fire. A probability assessment was done on the various permutations and combinations of the aforesaid 12 factors and each probability gradient is co related to a particular fire grade. This mathematical model can now predict the possibility of a fire event at a particular location if the factorial values are available from field. The same model can help in scenario planning for fire event prediction. Further, field verifications and validation of the model in varying conditions and terrain shall be required to standardize it for a universal model. Following which mobile applications can be developed for easy references.

Screen shot of the above mathematical model is presented below.



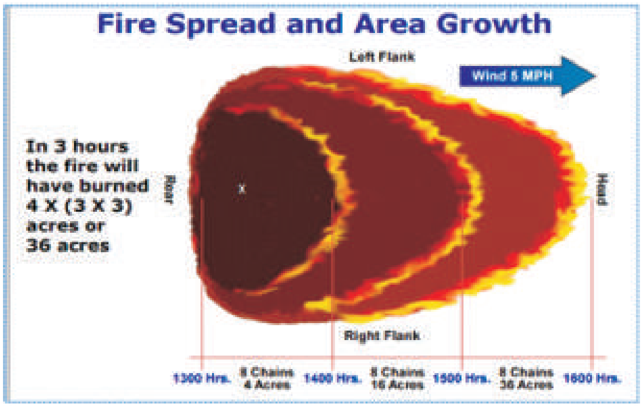
Fire Behavior Triangle

Wild fire behavior is controlled mainly by three factors namely weather, fuel and topography, together known as 'fire behavior triangle".

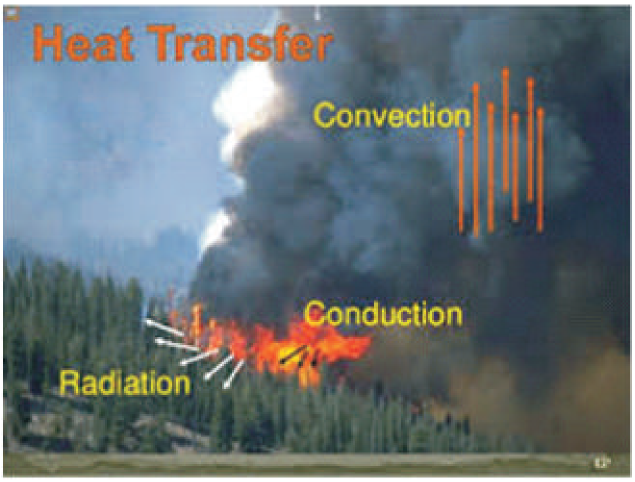
Weather and Climate.: (Most variable factor in the fire triangle):

Weather influences fire through wind, temperature, relative humidity, atmospheric stability, and lighting. Climate plays a key role in fuel availability.

1. **Wind :** Wind can make fuels drying faster. It also involved in mass transport of flaming object. Down slope wind slows down up- slope movement of wildfire. Wind increases fire speed in the wind direction. Some fires are wind driven when wind push fire in one direction. Here elliptical fire becomes elongated resulting in a cigar shaped fire with a long narrow fire front. A subsequent change in wind direction can create a very long fire front that is difficult to control. In contrast a change in weather from hot and dry to cooler moisture conditions reduces fire intensity and rate of spread. Weather involving fast wind changes can be particularly dangerous, as they can suddenly change the fire direction and behavior of fire. For example diurnal slope wind can change the fire direction. During summer months in mountain terrain, wind shifts daily, moving upslope during daytime and down slope during evening.

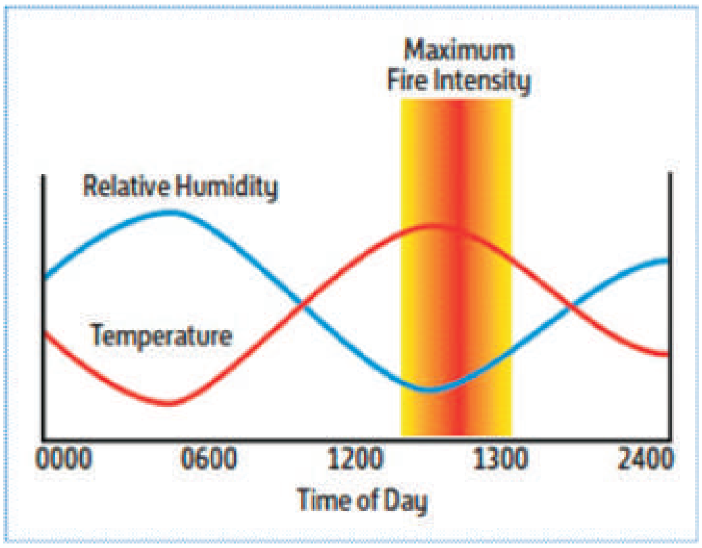


   The prevailing wind rise along the windward side and shed their moisture as snow or rain as they reach cool temperature at the ridge tops. Once over the ridge, they become cool and descend to lower altitude on the lee ward side and become heated. Along mountain valleys, solar heating and nighttime cooling bring changes in wind direction. Fires driven upslope by daytime heating will typically settle down after sunset. This nocturnal lay down happens as decreased temperature and raised relative humidity cause the moisture content in dead fuels to rise.



2. **Temperature :** Higher temperature makes the fire burn faster. Summer heat, prolonged drought makes fuels dry. During warmer part of the day fire spreads quickly and burn with higher

intensity often creating large smoke column. Whereas higher relative humidity and precipitation (rain and snow) may slow it down or extinguish it altogether. Lower temperature and higher relative humidity of late afternoon increase moisture in the fuels, reducing the smoke column. Temperature inversions can leave mid slope areas much warmer and drier at nighttime and thus more vulnerable to fire than other parts of the mountains or valley.



3. **Moisture (How readily fuel will burn down) :** Seasonal climate, recent weather also shapes fuel moisture content. Fuel wet from rain and snow increases fuel moisture and slows down the drying of the fuel, while winds can make drying faster. Fuels containing higher moisture produce lower – temperature smoldering fires compared to fuels dried out from summer heat or prolonged drought.

4. **Fire behavior and diurnal change in weather condition:** Fire behavior changes with diurnal change in weather condition. Normally in a day the air temperature becomes highest between 12 pm to 3 pm. Higher air temperature reduces the relative humidity. This results in rapid burning of the preheating and higher intensity of fire. This again accelerates the up slope movement of wind which in turn accelerate rate of spread of fire. . Lower temperature and higher relative humidity of late afternoon increase moisture in the dead fuels which reduces fire intensity. . During summer months in mountain terrain, wind moves upslope during daytime and down slope during evening. Down slope movement of wind during the summer night slows down the up slope movement of fire. But in some cases temperature inversions can leave mid slope areas much warmer and drier at night time and thus more vulnerable to fire than other parts of the mountains or valley. Normally the temperature becomes lowest and the relative humidity becomes highest between 3.00 am and 5.00 am. As a result fire intensity becomes lowest during this period. As the temperature increases with the progress of day time, the temperature increases and the relative humidity decreases which in turn increase the fire intensity.

5. **Fires create their own weather :** Heat produced by the wildfire changes the temperature of the atmosphere and creates strong updrafts which can change the direction of the surface wind. Flames at the base of a slope heat the vegetation higher up, releasing combustible gases that burst into new flames spreading uphill.

Fuel : (Only variable in fire triangle that can be controlled):

Fuel type and mass of fuel influence both intensity and duration of fire.Wild fire fuel includes grass, wood, and anything else they can burn. Small dry twigs burn faster while large logs burn slower. Dry fuel ignites more easily and burns faster than wet fuel.

- **Mass :** The greater the fuel load, the longer will be the duration of wild fire.
- **Type :** Fuels can be classified in various ways.

According to location of the fuel

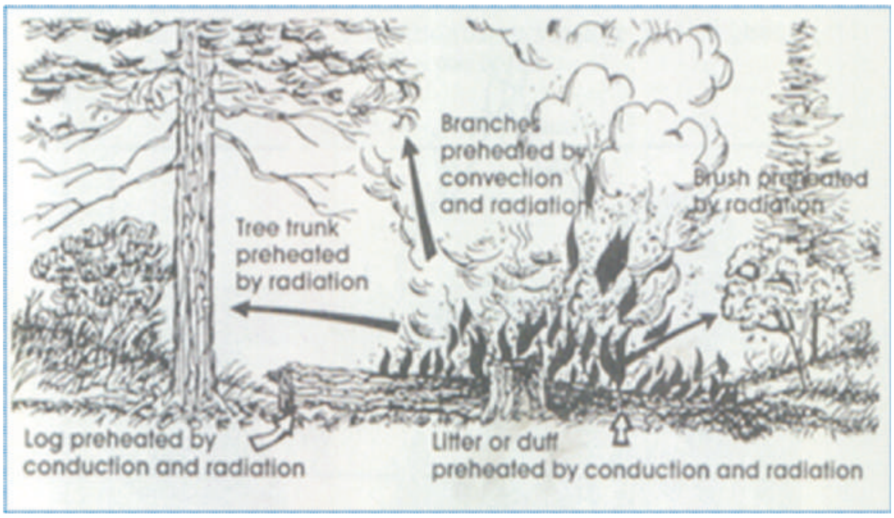
- Ground fuel: Duff, buried roots, logs, decomposing barks at the base of the trees.

- Surface Fuel: Litter or unrecompensed needles, moss, lichens, logs, woody debries, slash piles, low vegetations like grass, herbs, and shrubs.
- Ladder fuel: large shrubs, small and medium sized trees, low growing brunches on medium to large trees that allow surface fire to move up into the over story tree crowns.
- Crown fuel: Lichen, tree needles, small branches that compose the forest canopy.

Fuel type	Diameter (in inch)	Example
1- Hour	.02 and less	Needles, twigs, moss, lichen, small scrubs, grasses
10-hour	.25-1.00	Small branches, shrubs
100- hour	1.0- 3.00	Medium branches
1000- hour	3.00-8.00	Large branches, small logs
10000- hour	8.00 and more	Large logs

According to size and time required for drying

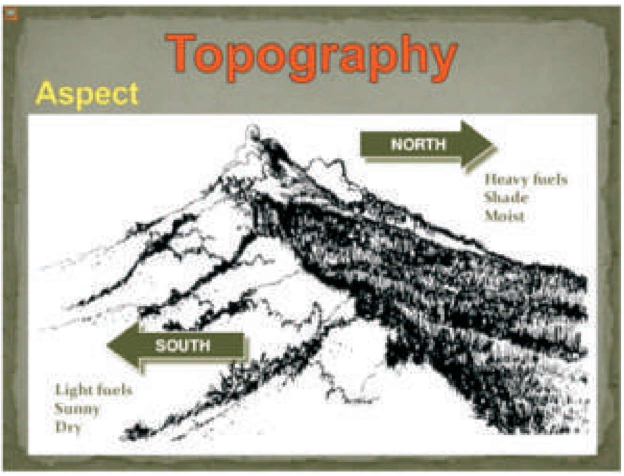
- 1-hour to 10-hour fuel: Largely responsible for supporting ignition and initial fire spread due to their small size which allows them to easily preheated and combusted. Slash left after logging is composed of these smaller fuel sizes and thus responsible for high fire hazard.
- 100-hour to 1000-hour fuels support a half perpetuating surface fire, only when combustion of the smaller fuel sizes preheats and ignites them.
- 10,000-hour fuels typically don't influence fire spread but can affect fire severity. Because once ignited, these can burn for hours or days heating the soil and adjacent trees killing tree roots permanently.



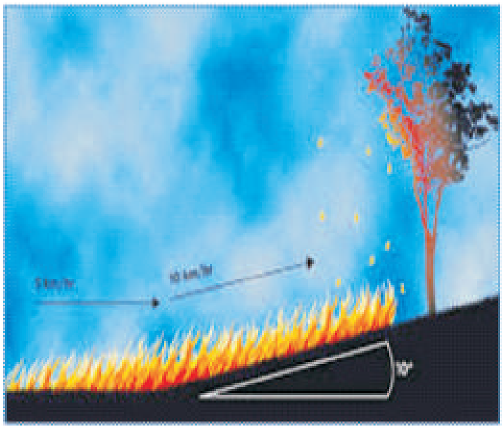
Topography : (Most stable variable in the fire triangle)

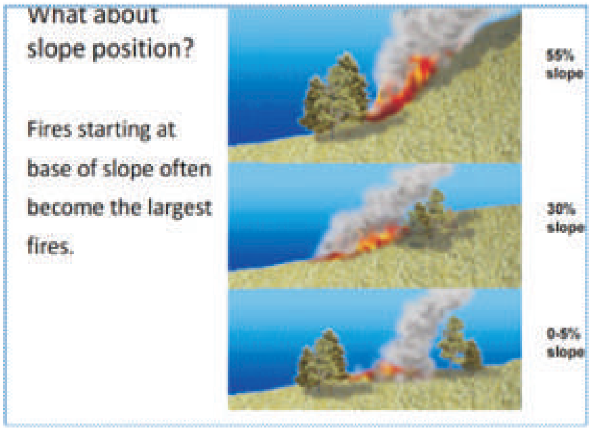
Topographical factors include aspect, slope, landform, elevation. Fuel property may vary with topography. Such as, plant density varies with elevation or aspect with respect to sun.

- **Aspect :** Orientation towards the sun influences the amount of energy received from the sun. North facing slopes have high fuel moisture, low average temperature, low spread, late slow melt at. North slopes are cooler and more shaded, thus delaying the drying of fuel. However heavily vegetated north slopes can experience more severe wildfire. Eastern slopes experience earlier cooling and earlier heating. South slopes have lowest fuel moisture, highest average temperature, highest rate of spread, earlier snowmelt. South slopes receive much higher solar radiation and are warmer, so fuels tend to dry out sooner and more thoroughly during the fire season. Western slopes experience later heating later cooling.



- Slope : Slope provide pathway for the warmer air upslope. Fire spreads faster up- hills than down hills. As heat rises in front of the fire, it more effectively preheats and dries fuels upslope preparing condition for rapid combustion. The flames are closer to the fuel on the uphill side and receive more radiant heat. The steeper the slope, the more rapidly and intensely fire will burn up- slope. Opposite situation arises at the night time when the wind starts to blow down the slope.





- **Landform :** Fire can accelerate in narrow canyons. Canyons act as 'chimneys' and create strong updrafts of air. Hills and mountains not only hinder fire spread but also influence the direction and speed of wild fires. The prevailing wind rise along the wind ward side and shed their moisture as rain or snow as they cools down (which accelerates condensation) at the ridge top. Valleys on the lee ward side of the mountain are vulnerable to hot, dry down slope winds. Along the mountain valleys, daytime solar heating and nighttime cooling bring changes in wind direction. Up slope movement of hot, dry and light wind accelerate up slope movement of wildfire. While at the nighttime the down slope movement of cool, heavy and wet down slope wind slows down the upslope movement of fire. Fires starting at base of the slope or at the bottom the narrow canyons often become the largest fires.

- **Elevation:** Elevation affects fire behavior by influencing the amount and timing of precipitation as well as exposure to prevailing wind. It also affects seasonal drying of fuel. Lower elevation fuel tends to dry out earlier because of higher temperature and lower precipitation. Tendency of more lightning strikes and ignite fuels at higher elevation. Elevation and aspect change fuel character as the vegetation density and type changes with aspect of slope and elevation.

It has long been recognized that fires create their own weather. The heat produced by the wild fire changes the temperature and creates strong updrafts, which can change the direction of surface wind. Flames at the base a slope heat the vegetation higher up, releasing combustible gases that burst into new flames, spreading fire uphill.

Impact Factor

- Local impacts have brought-in beneficiaries and stakeholders together to address the fire situations in hills. Talks continue for Public-Private-Partnerships in fire mitigation and safety. SAFE has been invited by the Department of Forest in Bhutan and Arunachal Pradesh as well to develop a joint mitigation plan, capacity building program and community awareness program for this.
- Direct policy implications have brought back the 'Shillong Declaration' of ICIMOD to discussion table following ban on Jhooming. NABARD in India has sponsored a project to SAFE for delivering technology transfer to marginal jhoom farmers on innovations in jhooming through agro-waste management for preventing forest fire. Community leaders in Arunachal has already accepted the intervention and started practicing the agro-waste management principles.
- Global impacts are expected from communities concerned with climate change. Asia Pacific Network for Global Change Research will consider for supporting capacity building program on innovative jhooming to prevent forest fire.
- Government of Bhutan has initiated a citizen volunteering program called "Desuups", wherein the citizen volunteers are trained for various development works and disaster mitigation. Largely the members of Desuups are engaged in forest fire management at the gewog (block) level. However, the Desuups cover immense risk in this and are not covered with any risk mitigation instrument. SAFE's Biorights paradigm has been widely accepted by the government officials in Bhutan for such coverage through micro-insurance schemes. Biorights is an economic conservation paradigm that compensates the opportunity costs of marginal end-users or covers their risk through micro-insurance schemes through direct payments from ecosystem services and therein promoting the conservation of nature capital.
- A global software company, e-Bluesoft (http://www.ebluesoft.com/) has shown considerable interest in developing web based stories and mobile based applications for forest fire mitigation based on the F3P Model developed on the intervention of SGP Small Grants Program to provide unique ICT Solution for Forest Fire Mitigation.

Success Stories

The SAFE intervention on Forest Fire under the aegis of ICIMOD's SERVIR Himalaya Small Grant Program has two strong mandates, of which one is to improvise geospatial tools and techniques in understanding forest fire scenario and the other is to develop place-based management solution that is equal, reciprocal and participatory. Community awareness and sensitization, therefore, has very significant roles to play, while geospatial interventions have helped convincing policy planners for a fire free tomorrow. Some such success stories are shared as hereunder

Community adopts innovative jhooming... battles forest fire out.

Traditional farming, called Jhoom, which provides mountain communities with subsistence levels of food, though well adapted to climate conditions and maintains ecological balance, has steep conflicts with modern intensive agriculture. More recently owing to anthropogenic pressure, Jhooming in northeast India is adversely affecting forest regeneration, leading to mountain habitat degradation, while its legal ban in some parts of Arunachal has led to migration, wreckage of ethnic societies making them vulnerable to urban abuses. In areas of Arunachal, where jhooming cycles have reportedly being in co-terminus with sequences of fire events, SAFE team had undertaken series of community awareness campaigns for introducing innovative jhooming that promotes agriculture waste keeping over waste burning and re-using it as mulch or organic manure amongst Aka, Apatani and Miji tribal communities. Thorong Toiga, a community head women 0f a small village near bomdilla in Arunachal that has encountered seven fire incidences in last two years says, 'We thought fires are curses of the evils, but now we know that it's us who are responsible. We must practice small burnings rather than making big fires that can kill us even'. Field survey and stakeholder meetings also suggested that intentional fires are being made by them too, owing to an apprehension that forest department would force them to disown the community forest area. Awareness and sensitization helped them to conjoin with forest department in combating forest fire, forming a community group called Thembang Bapu Conservation Committee. The committee also adopted the innovative Jhooming techniques through management of agro-wastes, controlled burning of dry litter and using the agro-wastes as mulch. Compared to last three years fire incidences in the months of February to April in Bomdilla-Darang-Thembang area of Arunachal, this year, in 2015, there have been a reduction of nearly 40%, assumingly due to the adoption of new-jhooming and new friendship ties with the forest rangers at community level.

New science in forest fire management gets wider acceptance... defy political boundaries.

Be it Bhutan or Arunachal, forest fire in Hindukush is equally devastating and a nightmare for the forest keepers. Main challenge on the first place is to get an early intimation of the disaster, probable reason behind it and its strength, while the next challenge is to reach out to that place and have preparedness. Usage of geospatial solution to address these challenges in a single window have made it so convincing that 73 forest rangers of Bhutan and Arunachal Pradesh have all sat together defying the political boundaries to explore the findings and research inputs that SAFE team has brought out through this SERVIR Himalaya SGP project. Joint stakeholder meetings held in Paro in Bhutan and Tawang in Arunachal Pradesh has seen rigorous brainstorming through focused group discussions and peer activities. Mr. Nilayam Tam, Director State Forest Research Institute, Dr C.D Singh Chief Conservator of Forests, & member secretary Forest Conservation and Action cell and Mr A. Kemp, Additional PCCF of Department of Forest Arunachal Pradesh have all attended the sessions and discussed this with their counterparts. While Mr. Baap Tandy Dorji, Head of Forest Fire (Prevention and Conservation) Department, Ministry of Agriculture and Forest in Bhutan and Dr Pema Choephyel, Director Bhutan Trust Fund for Conservation of Nature have all agreed to bank on geospatial data models and statistics for fire regime management, Mr. Tam expressed his concerns saying that, 'GIS and Remote Sensing are such important and empowering tools that it needs to be integrated with the core forest management policies of the state'. A unique partnership is on the make to develop and install mobile based apps for free fire alert system in Arunachal under the aegis of ICIMOD that would be partnered by a Telecommunication Network Service provider, Department of Forest, Indo-Tibet Border Forces of Indian Army in Arunachal and the district administration of West Kameng district in Arunachal Pradesh.

Going Global...

SAFE has approached Asia Pacific Network for Global Change Research, Japan for extending support towards research and capacity building in innovative jhoom cultivation, which still happens to be the lifeline for livelihood of the tribal communities of Arunachal since this can prevent forest fires largely. SAFE is already working on agricultural waste management in Bhutan and India, under the aegis of APN-GCR, Japan as it remains the main cause of agricultural emission and creates wildfires when burnt on field for removal. The proposed intervention under the CAPaBLE program of APN-GCR would support hundreds of tribal jhoomers to switch over to sustainable and climate adaptive agriculture diminishing the risk of forest fire in Bhutan and Arunachal.

Further, a global software company, e-Bluesoft (http://www.ebluesoft.com/) has shown considerable interest in developing web based stories and mobile based applications for forest fire mitigation based on the F3P Model developed on the intervention of SGP Small Grants Program to provide unique ICT Solution for Forest Fire Mitigation.

Challenges and Constraints

There had been a number of challenges and constraints that the team faced during the project period, of which the most important was the short duration and span of the project versus the remote and rough terrain. However, we have given a good try to resolve the constraints and combat the challenges. Results would suggest how far it could be achieved in completing our mission and in keeping our commitments. Below this we present a tabulated format for the major constraints faced during our intervention.

Sl No	Challenges and / or Constraints	Attempts to Resolve	Remarks
1	Dependence on the partnering institutes and organizations for software system usage and data downloading was highly time taking and became a bottleneck for meeting the deadlines	Patient and meticulous team work, innovations and brainstorming to overcome the pressure of the deadlines along with extensive literature review and reference work helped us overcome this.	Provision of a GIS lab with an original software support and high configuration workstation would be highly empowering.
2	Chasing forest fire and reaching out to remotest places in the rough terrains was very risky, especially under the constraints of time and resources. Externalities, formalities of travel, eventualities added to these on top.	Scrupulous planning, calculated risk and painstaking efforts of the team members helped largely. Adaptive management too helped in overcoming these constraints of time and space.	More of field gears, capacity building and resources would help much better delivery. Time to study needs more space for replicable results.
3	Short project span and extent of the project delimited the deliverables and scope of work. We needed more field work for validating the change detection studies on LUP-LC and vegetation dynamics-density-fire links through studies on	We limited our studies to approachable areas, worked on appreciable seasons & planned within the time and budget to develop scenario planning framework as a decision support system that can further developed into a fully operational model.	This area can be a future extension of the project.
4	Interpreting the Landsat differenced Normalized Burn Ratio (dNBR) signal in terms of fire severity and ecosystem response has been difficult owing to constraints of time and	We have just added a sample module on this and expect to carry this out in the next phase of this intervention.	This would substantially strengthen the spatial decision support tool for comprehensive conservation

Selected References

1. Agee, J.K. 1993. Fire ecology of pacific northwest forests. Island Press, Washington, DC.493 p.
2. AMICUS. 2006. Preserving the last Shangri-La. Available online at http://www.amicusfoundation.org/amicus-2/about-bhutan/bhutan-map.htm
3. Amo, S.F., and C.E. Fiedler. Mimicking Nature's Fire: Restoring fire-prone forests in the west. Island Press, Washington, DC. 242 p.
4. Amo, S.F., and S.A. Bunnell. 2003. Managing fire prone forests: Roots of our dilemma. Fire Management Today 63(2): 12-16.
5. Anderson, L. 1994. Terrestrial wildlife and habitat. In Fire effects guide. PMS 481,
6. Biswell, H.H. 1989. Prescribed burning in California wildlands vegetation management. University of California Press, Berkeley and Los Angeles, CA. 255 p.
7. Brown, J.K., and J.K. Smith, eds. 2000. Wildland fire in ecosystems: Effects of fire on flora. USDA For. Serv. Gen. Tech. Rep., RMRS GTR-42(2), Rocky Mountain Research Station, Ogden, UT. 257 p.
8. Chandler, C., P. Cheney, P. Thomas, L. Trabaud, and D. Williams. 1983. Fire in forestry: Volume II, forest fire management and organization. John Wiley and Sons, Inc. New York, N.Y. 298 p.

. Chhetri, D.B (1994).: Seasonality of Forest Fires in Bhutan. (IFFN. No. 10- January 1994, P. 5-9).

10. Chhetri, D.B. 1994. Seasonality of forest fires in Bhutan. IFFN 10: 5-9.
11. Clark, B. 1994. Soil, water, and watersheds. In Fire effects guide. PMS 481, Miller, M (ed). National Interagency Fire Center, Boise, ID.
12. Dey, D (2003).: Community Forestry in Bhutan Himalayas: sustaining Life and Environment Through Participation. FAO Publication.
13. Doerr, S.H., and A. Cerda. 2005. Fire effects on soil system functioning: New insights and future challenges. Int. J. Wildland Fire 14: 339-342.
14. Dorji, T. 2001. Sustainability of tourism in Bhutan. Journal of Bhutan Studies 3(1): 84-104.
15. Finney, M.A., and J.D. Cohen. 2003. Expectation and evaluation of fuel management objectives. USDA For. Serv. P. 353-366 in Proceedings, RMRS-P-29, Rocky Mountain Research Station, Ogden, UT.
16. Food and Agriculture Organization. 2000. Asia and the Pacific national forest programmes update. Available online at http://www.fao.org/docrep/003/x6900e/x6900e07.htm
17. Fowler, F.J., Jr. 1988. Survey research methods. Sage Publications, Inc., Newbury Park, CA. 159 p.
18. Fuller, M. 1991. Forest Fires: An introduction to wildland fire behavior, management, firefighting and prevention. John Wiley and Sons, Inc. New York, N.Y. 238 p.
19. Golia, J.D. 2002. Fire and humans: Changing uses and attitudes. P.21 in Fire, a force of nature: The story behind the scenery. Butcher, R.D., (ed). KC Publications, Las Vegas, NV. 48 p.
20. Gouma, V., and A. Chronopoulou-Sereli. 1998. Wildland fire danger zoning: A methodology. Int. J. Wildland Fire 8(1): 37-43.
21. Gyamtsho, P. 2002. Condition and potential for improvement of high altitude rangelands. The Journal of Bhutan Studies 7: 82-98.
22. Hamilton, L., G. Morgan, and J. Williams. 2003. Strategic paper: Guiding principles for wildland fire management. IFFN 29: 5-9.

23. Keane, R.E., K.C. Ryan, T.T. Veblen, C.D. Allen, J. Logan, and B. Hawkes. 2002. Cascading effects of fire exclusion in Rocky mountain ecosystems: A literature review. USD A For. Serv. Gen. Tech. Rep., RMRS GTR-91, Rocky Mountain Research Station Fort Collins, CO. 24p.
24. Kuenselonline (KOL). 13 April 2005. Fire threatens Basochhu project. Available online at http://www.kuenselonline.com/modules.php?name=Stories_Archive; last accessed December 17, 2005.
25. Kuenselonline (KOL). August 12, 2006. Tala generates Nu.36 m in ten days. Available online at http://www.kuenselonline.com/modules.php?name=Stories_Archive; last accessed August 15, 2006.
26. Kuenselonline (KOL). July 17, 2006. Forestry institute to start in 2008. Available online at http://www.kuenselonline.com/modules.php?name=Stories_Archive; last accessed August 10, 2006.
27. Kuenselonline (KOL). October 8 2005. Bhutan's forests: The real picture. Available online at http://vww.kuenselonline.com/modules.php?name=Stories_Archive; last accessed November 11, 2005.
28. Latham, D.J., and J. A. Schlieter. 1989. Research Paper, INT-411, Ogden, UT: USD A Forest Service, Intermountain Research Station. 16 p.
29. Lodhi, M.S., Mazumdar, K. (2009): Living with Hazards and Dealing with Disasters in Arunachal Pradesh. ENVIS Bulletin Himalayan Ecology 17 (2): Pp 21-25.
30. Luke, R.H., and A G. McArthur. 1977. Bushfires in Australia. Department of Primary Industry, Forestry and Timber Bureau. CSIRO Division of Forest Research. Wilkie and Company Limited, Clayton, Victoria. 359 p.
31. Lyon, L.J., M.H. Huff, R.G. Hooper, E.S. Telfer, D.S. Schreiner, and J.K Smith, eds. 2000. Wildland fire in ecosystems: Effects of fire on fauna. USDA For. Serv. Gen. Tech. Rep., RMRS GTR-42(1), Rocky Mountain Research Station, Ogden, UT. 83 p.
32. Mahaffey, L., and M. Miller. 1994. Air quality. In Fire effects guide. PMS 481, Miller, M (ed). National Interagency Fire Center, Boise, ID. Mckinnell, F. 2000. Forest fire management in Bhutan: Consultancy report. Field Document No.FDOO/5/TFDP-TA/FORTECH, Third Forestry Development Project, Khangma, Bhutan. 36 p.
33. Miller, M (ed). National Interagency Fire Center, Boise, ID.
34. Miller, M., and J. Findley. 1994. Plants. In Fire effects guide. PMS 481, Miller, M (ed). National Interagency Fire Center, Boise, ID. Mutch, R.W. 1995. Prescribed fires in wilderness: How successful? P.38-41 in Proc. Of symp. on Fire in wilderness and park management, Brown, J.K., et al. (eds). USDA For.
35. National report on Bhutan for World Conference on Disaster on Disaster Reduction (Kobe, Japan, 18-22 January 2005). Department of Local Governance Ministry of Home and Cultural Affairs, Thimphu, Bhutan.
36. National Wildfire Coordinating Group (NWCG). 2001. Review and update of the 1995 federal wildland fire management policy. National Interagency Fire Center, Boise, ID. 78 p.
37. National Wildfire Coordinating Group (NWCG). 2004. Fireline handbook. PMS 410-1, National Interagency Fire Center, Boise, ID. National Wildfire Coordinating Group (NWCG). 2005 Glossary of wildland fire terminology. PMS 205, National Interagency Fire Center, Boise, ID. 185 p. National Wildfire Coordinating Group (NWCG). 2005. Wildland fire observations and origin scene protection for first responders. FI 110, National Interagency Fire Center, Boise, ID.
38. Neary, D.G., K.C. Ryan, and L.F. DeBano, eds. 2005. Wildland fire in ecosystems: Effects of fire on soils and water. USDA For. Serv. Gen. Tech. Rep., RMRS GTR-42(4), Rocky Mountain Research Station, Ogden, UT. 250 p.
39. Palit, G. (2010): Forest covers and forest fires in Eastern Himalaya: A study on ecological disaster with special reference to Arunachal Pradesh. Intnl. Jour. Ecology 12 (3): Pp 34-42
40. Polzin, P.E., M.S. Yuan, and E.G. Schuster. 1993. Some economic impacts of the 1988 fires in the Yellowstone area. USDA For. Serv. Research Note, INT-418, Intermountain Research Station, Ogden, UT. 13 p.
41. Pyne, S.J., P.L. Andrews, and R.D. Laven. 1996. Introduction to wildland fire. Second Edition, John Wiley and Sons, Inc. New York, N.Y. 769 p.
42. Ramya, T.(2012): Causes and Effects of Rampant Forest Fire in Highlands Arunachal: A Study From Kurung Kumey District. RIJS 1(7) Pp 17-23. ISSN: 2250-3994.
43. Rawat, S., Laskar, B.A., Taidong, W. (2007): Forest Fire In Arunachal: Causes, Effects and Remedies. Working Paper RG Univ, Deptt of Geography.
44. RGoB, Department of Forestry (DoF). 1974. National forest policy, 1974. Ministry of Trade, Industry and Forests, Thimphu, Bhutan. 11 p.
45. RGoB, Department of Forestry Services (DoFS). 2002. Forestry in Bhutan, facts and figures. Ministry of Agriculture, Thimphu, Bhutan. 38 p.
46. RGoB, Department of Forests (DoF). 2002. Biodiversity action plan for Bhutan. Ministry of Agriculture, Thimphu, Bhutan. 185 p.
47. RGoB, Department of Forests (DoF). 2003. Revised forest and nature conservation rules of Bhutan, 2003. Ministry of Agriculture, Thimphu, Bhutan. Volume I: 116 p.
48. RGoB, Department of Forests (DoF). 2005. First annual forestry conference proceedings: Sustainable forest management for present and future generations. Ministry of Agriculture, Thimphu, Bhutan. 8 p.
49. RGoB, Department of Tourism (DoT). 2002. Bhutan national ecotourism strategy. Ministry of Trade and Industry, Thimphu, Bhutan.
50. RGoB, Ministry of Agriculture (MoA). 2002. RNR sector 9^ five year plan. Thimphu, Bhutan. 108 p.
51. RGoB, Ministry of Agriculture (MoA). 2006. Resolutions of the eighth annual RNR conference: RNR sector in pursuit of poverty alleviation through PAM. Samtse, Bhutan. 4 p.
52. RGoB, National Assembly Secretariat (NAS). 1999. Translation of the proceedings and resolutions of the 77^ session of the national assembly of Bhutan. Available online at http://www.nab.gov.bt/resolution.htm; last accessed May 12, 2006.
53. RGoB, National Environment Commission (NEC). 1998. The middle path: National environment strategy for Bhutan. Thimphu, Bhutan. 95 p.

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