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The Indian Forest Fire Response and Assessment System (INFFRAS)

Monitoring and management of forest fires is very important in tropical countries like India where 55 percent of the total forest cover is prone to fires annually causing adverse ecological, economic and social impacts (Gubbi, 2003). Studies on the impacts of tropical wildfires on the environment indicated high carbon emissions (Hao et al., 1996; Fearnside, 2000), emissions of large amounts of trace gases and aerosol particles (Crutzen and Andreae 1990), black carbon (Dwyer et al., 1998) release of almost 100 million tons of smoke aerosols into the atmosphere as a result of biomass burning (Hao and Liu 1994). These sub-micron smoke aerosols play a major role on the radiation balance of the earth-atmospheric system (Kaufman et al. 1998). Also, there is widespread concern about the loss of biodiversity, effects on atmospheric chemistry and increase in surface albedo and water runoff due to biomass burning. In India, about 55% of the forest area, which is predominantly covered by deciduous forests, is prone to fires every year causing loss of about rupees 440 crores (~104 million US dollars). Despite the natural fires, the major sources of forest fires in India are anthropogenic, which include shifting cultivation practices, controlled burning, deforestation, fire wood burning and others. The conventional methods of fire protection cover an elaborate network of fire lines (fire breaks), fire watch towers, block lines and manual fire control systems which at times becomes practically difficult due to lack of man-power, resource constraints and time effective control mechanisms. On the other hand, application of remotely sensed data along with Geographical Information System (GIS) is capable of addressing the problem with good scientific and technical strength in a time effective and cost effective way.

Forest fires are mostly anthropogenic in nature in India and may occur due to the following reasons (Bahuguna et al., 2002):

- Forest floor is often burnt by villagers to get a good growth of grass in the following season or for a good growth of mushrooms.
- Wild grass or undergrowth is burnt to search for animals.
- Firing by miscreants.
- Attempt to destroy stumps of illicit fallings.

The user requirements in forest fire management stands at three different levels viz. pre-fire (preparatory planning for fire control), during fire (fire detection, spread and control planning) and post-fire (damage assessment and mitigation planning). These requirements could only be met from comprehensive spatial and temporal data of different dimensions emanating from satellite and ground based sources. The role of various scientific organizations and forest departments is very critical. The intricate relationships involved in generating required databases and outputs is presented (Figure 1) in conceptual diagram of the “Forest Fire Decision Support System” (FDSS).

The pre-fire scenario needs inputs on effective preparations and planning for managing and combating the fire. This process might stands at understanding of fire proneness / vulnerability and forest fire spread potential. These two parameters together reflect in the Fire Danger Rating (FDR). The spatially explicit fire danger rating of the forests would help to prioritize the areas for detailed fire control planning. Fire proneness / vulnerability could be assessed based on long term history of fire occurrence, location characteristics in relation to vegetation cover and type, climate, topography and biotic pressure. This kind of information needs to be integrated through the databases available with different organizations. Various advanced spatial modelling and analytical tools are being analyzed to characterize spatial and temporal trends to understand local and regional level processes and develop fire proneness / vulnerability zones. In addition, the FDDS is structured to accept database flows at different spatial and time scales and process at backend to generate updated fire vulnerability zones with changing scenarios. The fire-spread simulation is one of the critical process helps to assess the magnitude and direction of the fire spread. It depends on intrinsic substrate flammability properties and extrinsic factors catalyzing the fire spread. The intrinsic substrate properties depend on vegetation type, phenological patterns, and forest desiccation and fuel stick values. Using MODIS derived surface temperature information together with fire frequency information, AWiFS derived burnt area information and vegetation type fire danger index for different forest regions of India were attempted and a case study on Nagarjuna Sagar Srisailam Tiger Reserve (NSTR) was carried out in active collaboration with forest department.

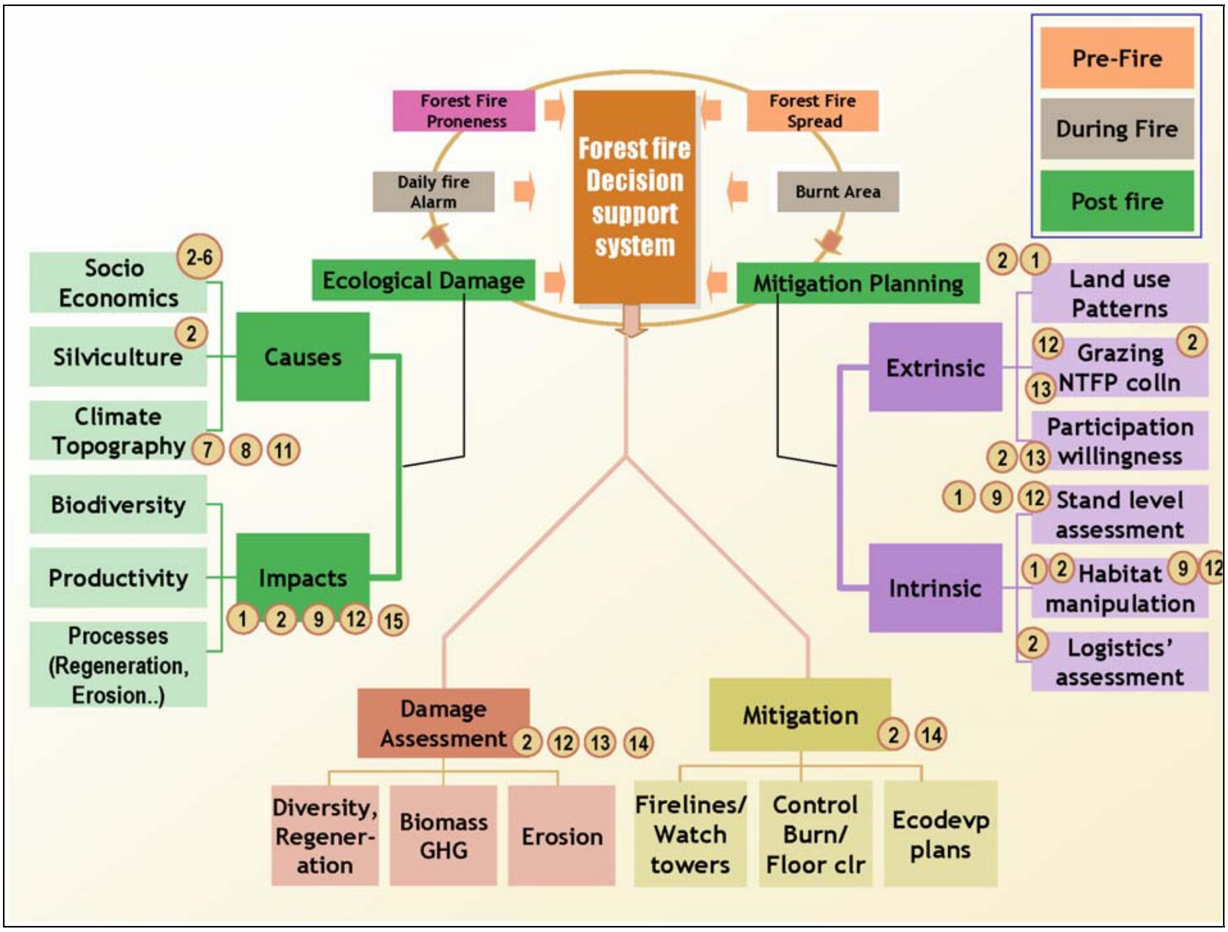

Figure 1. Conceptual diagram of the "Forest Fire Decision Support System" (FDSS). The institutions involved in the FDSS include:

1. Department of Space
2. State Forest Departments
3. Forest Survey of India
4. National Informatics Centre
5. Bureau of Economic and Statistics
6. State Animal Husbandry Departments
7. Indian Meteorological Department
8. Local weather Stations
9. Forest Research Institute
10. NBSSLUP
11. Survey of India
12. University Departments
13. Panchayats / Voluntary bodies / Tribal society
14. Ministry of Environment and Forests
15. Wildlife Institute of India

The information generated from multi sensor remote sensing and ground based data developed at local and regional level involving multi institutional participation will be incorporated in to the data base towards developing contours of forest ignition potential in near future. The lack of locale specific meteorological, topographic and vegetation databases limits developing fire danger rating system in the country. A concerted system involving multi institutional participation to identify existing database and protocols to collect the new databases is under way to develop fire danger ratings for Indian forests. The system upon establishment should provide the user fire prone areas, fire-spread potential in a given season on a continued basis.

Fire detection, spread and control planning are the important issues for the ‘During Fire ‘scenario. Considering the large extent of area of operations and huge number of fire occurrences simultaneously occurring in a day, the identification and combating becomes difficult. Conventional methods of identification of active fire locations need to be augmented with advanced technologies like satellite remote sensing. The remote sensing system should have the capability to provide 3-4 signals on a daily basis backed up with robust process algorithms, data dissemination and reception systems. This would form one of the core segments of FDDS enabling user to interact and receive the data on a daily basis for fire information. However the appropriate development of user segment to receive and utilize the data on real time basis and providing feedback forms the complete chain of events in fire monitoring. Considering the above-mentioned needs, the Indian Forest Fire Response and Assessment System (INFFRAS) is established with a scope to integrate process and disseminate various types of data bases related to pre fire, during fire and post fire scenarios. Currently the INFFRAS addresses a few issues related to fire management and has plans to augment different modules of FDSS. The current structure of INFFRAS as available on the NRSA Home Page (www.nrsa.gov.in) is shown in Figure 2. Users need to query using the appropriate query option. The site is mainly about the information on satellite-based services for forest fire detection, assessment and mitigation. The fire image generated from MODIS and DMSP-OLS sensors over Indian region are provided in the form of JPGs and PDF file on website and typical example is given in Figures 3a and 3b (Kiran Chand et al., 2006).

Figure 2. The structure of the Indian Forest Fire Response and Assessment System (INFFRAS) is available on the NRSA Home Page (www.nrsa.gov.in)

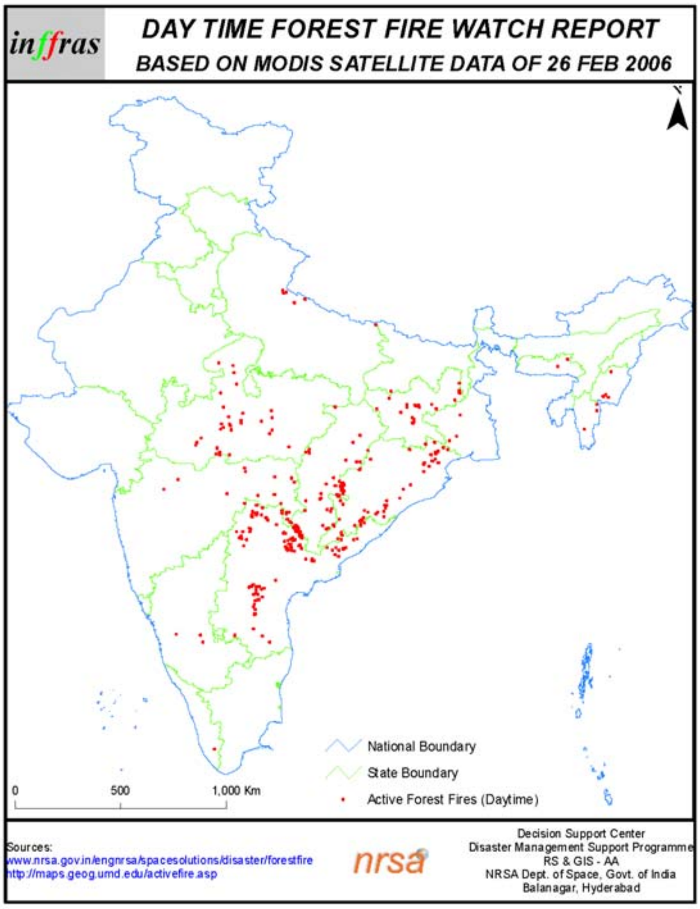

Figure 3a. Map showing active fires during daytime are generated by the MODIS sensor over the Indian region are provided in the form of JPGs and PDF files on the website. The typical example is dated 26 February 2006.

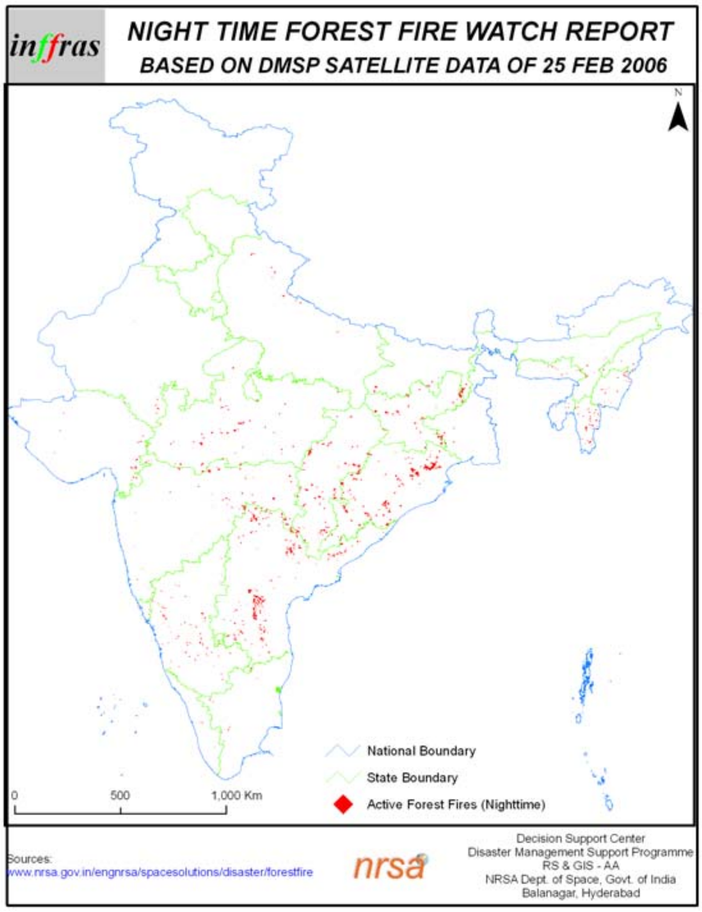

Figure 3b. Map showing active fires during nighttime are generated by the DMSP-OLS sensor over the Indian region are provided in the form of JPGs and PDF files on the website. The example is dated 25 February 2006.

The burnt area information in terms of area and maps will be useful and are the most required database to forest managers and scientific community at different levels. The FDDS provides burnt area assessment on an annual and inter-annual basis to enable primary damage assessment. Studies were carried out using Indian Remote Sensing Satellite (IRS) AWiFS data for assessing burnt area over different forest regions of India. Multi-resolution data sets from Indian Remote Sensing Satellite (IRS) series provide repeated observations over large forest regions and an example of near-real time damage assessment in and around Bhandavgarh National Park, Madhya Pradesh is shown in Figure.4.

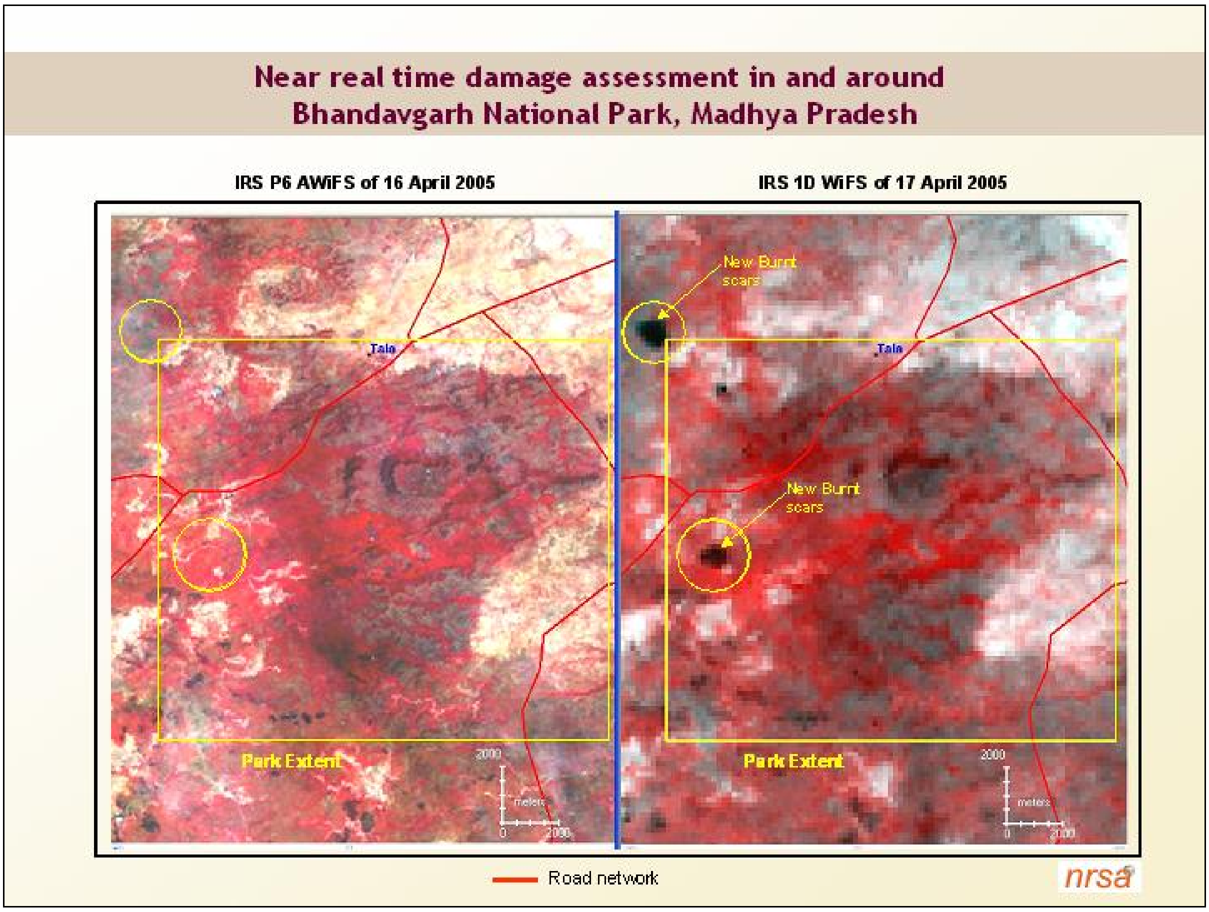

Figure 4. Example of near-real time damage assessment in and around Bhandavgarh National Park, Madhya Pradesh, based on multi-resolution data sets from Indian Remote Sensing Satellite (IRS) series.

The post-fire scenario involves ecological damage assessment and mitigation planning .The ecological damage assessment is complex in terms of Indian context as the fires mostly belong to ground / creeping fire category. In such situations the impacts are mainly in the form of effects on biodiversity, productivity, regeneration and soil erosion etc., which are intangible in nature. These impacts could only be understood based on long term monitoring and measurements over gradients of fire vulnerable areas across the country. So far very little database is available and collected on systematic sampling protocols to enable the measurements to upscale to regional and national context. FDSS is structured to receive such ground databases from different bioclimatic regions and spatially analyze and make explicit assessments. The damage simulation models developed based on site specific experiments become an integral part of FDSS to bring out scenarios of damage assessment and vulnerability. Ecological damage assessment due to forest fires over Orissa state were carried out using fire occurrences derived from MODIS and DMSP-OLS data, burnt area estimates from AWiFS data and phytosociological estimates from ground sampling data sets. Experiments on trace gas emissions from forest fires were carried out Indian region combining satellite derived information on burnt areas and emission factors estimated from ground based measurements (Prasad et al., 2002).

Mitigation planning is dependent on extrinsic and intrinsic factors of forest eco system. Extrinsic factors include around 2 lakh (200,000) villages existing in the forested areas depending for fuel, food and fodder. A study conducted on satellite derived fire locations and spatial vicinity of village suggested that forest areas with in the vicinity of 3km are under more anthropogenic pressure. An assessment has been made on the occurrence of fire locations in dense, open and scrub categories using MODIS fire locations. It was observed that the fire incidences in dense, open and scrub forest constitute, 45, 51 and 4% respectively. It indicates a fact that the fire locations in dense forest on a recurrent basis might affect the regeneration patterns. However, the analysis using fire occurrences data over several years will fine-tune the estimates. The INFFRAS provides services in a continued basis with necessary incorporations from user feedback and technical updates.

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