ECOSYSTEM LEVEL IMPACT OF UTTARAKHAND FOREST FIRE EPISODE 2016 USING GEOSPATIAL TECHNOLOGY

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ABSTRACT: The forest of western Himalaya is prone to forest fire every year during the summer season, mostly due to anthropogenic activities. In the year 2016, a combination of dry spells coupled with less than average rainfall during the preceding year has resulted in extensive forest fires in Uttarakhand state which could not be controlled effectively resulting in huge loss to the forest wealth. A rapid damage assessment of the forested areas in Uttarakhand was carried out to identify the extent of damage to the various ecosystem level components in the state using satellite remote sensing and GIS. Digital classification was carried out to extract the burnt areas in the forested regions of Uttarakhand. The burnt areas, which were confirmed using ground truth were further overlapped with the forest type and biological richness map to assess the extent of damage to the ecology of the area. The results show that 3774.14 km^2, representing 15.28% of the total forest area of the state of Uttarakhand showed indications of damage to the vegetation due to forest fire. Taking advantage of the high receptivity of AWiFS sensor aboard Resourcesat 2A, the progression of forest fire was also mapped from 23rd May 2016 to 2nd June 2016. District level analysis of the forest fire affected areas indicate that pine dominated areas of Tehri Garhwal, Pauri Garhwal and Nainital districts were the worst affected areas. The burnt areas in the state covered around 2.62% of the natural forest areas which had been categorized as very high biologically rich area and around 13.3% as high biologically rich area. Since the area fall under biological hotspots, such extensive damage to ecosystems can have serious impacts on the genepools in the region as well as cause other ecosystem level changes such as incursion of Pine into Oak habitats.

1. INTRODUCTION

Uttarakhand is prone to forest fire annually partially due to its topography and vegetation composition and partly due to the socio-cultural practices. The Uttarakhand state witnessed episodic fire incidents during the last two weeks of April 2016. Recurrence of fire incidences is common in the hilly state in summer season. But during April 2016 the large scale occurrence of forest fire within a short period across the state was unprecedented and episodic in nature. The districts reported as the most affected were Nainital, Pithoragarh, Champawat, Almora, Pauri and Tehri Garhwal. In the post fire scenario, the forest managers in particular and the scientific community at large is keenly interested in knowing the extent of area affected by the forest fire in the Uttarakhand state to plan damage assessment and mitigation actions. In this context, a study on rapid forest burnt area assessment in Uttarakhand was carried out at the Indian Institute Remote Sensing (IIRS), Dehradun in support of the activities of Disaster Management Support Program (DMSP) of ISRO. Pine forests which are dominant in the Uttarakhand, have high content of inflammable resin are also highly susceptible to forest fires. Among the anthropogenic causes and motivations for setting fires reported include those set by honey collectors, Sal seed collectors, to conceal illegal timber extraction, improve grass growth, scare away wild animals, encroach forest lands, accidental and those associated with political agitations and community conflicts (Bhandari, 2012). The majority of forest fires in India are considered to be anthropogenic in nature (Bahuguna and Singh, 2002). Forest dependent communities primarily burn forests for shifting cultivation in the north eastern India, to promote the growth of fresh fodder for grazing in western Himalaya, and to facilitate the collection of non-timber forest products in the central India.

Fire has been one of the prime sources of degradation and ecological disturbance in forests around the world from the time immemorial. Fire, whether natural or anthropogenic, is a widespread and recurring phenomenon in Indian forests (Ankila, 2007). Recurring fires often cause a positive feedback cycle in which the more forests burn the more susceptible to future burning they become. Damage caused due to fire is much more in logged areas (Rowell and Moore, 2000). Repeated burnings in forests also result into destruction of the ground flora, reduce the vegetative growth rate ultimately leading to change in plant community structure (Spanos et al, 2010), site deterioration due changes in soil nutrient status and accelerated erosion. Timber quality is affected by scorching from the base of the tree, which damages the cambium, leading to defective butt logs. Fungal infection may occur through the damaged tissues and cause rot. In Chir Pine forests, resin tapping affects the yield of merchantable timber by damaging the lower part of the tree; the scars enable fires to burn into the heartwood and, in some cases, kill the tree. Emissions from forest fires viz. carbon dioxide associated with other greenhouse gases such as carbon monoxide, methane, hydrocarbons, nitric oxide and nitrous oxide, cause serious health impacts and are also responsible for global warming (Koppmann et al., 2005). As a whole, forest fires have great impact on the physical environment including land cover, biodiversity, forest ecosystem and also the climate in a broader context.

On an average one percent of all forests in India is reported to be significantly affected by forest fire per year. Out of 67.5 million ha of Indian forests, about 55% of the forest cover i.e. 3.73Mha of forests experience fire each year, causing an economic loss of over 440 crores of rupees apart from other ecological effects (Gubbi, 2003). Thus, mapping, monitoring and management of forest fires are very important in the regions where forests are prone to fires annually causing adverse ecological, economic and social impacts (Chand et al. 2006). The accurate mapping assists in harmonizing the required information for mitigation and future preparedness in dealing with forest fires. It provides input crucial to meet the objectives to build back better in recovery, rehabilitation and reconstruction. However, areas affected by the fires are severely underreported, with information missing from many countries (Hansen, 2010). Obtaining accurate identification of fire events has been recognized by international research organizations, such as the International Geosphere and Biosphere program (IGBP), to be crucial in the development of a broader understanding of how fire extent and frequency impact global environmental processes. Understanding forest fires requires careful analysis and assessment of factors responsible for fires, mapping potential fire hazard and risk, detecting forest fire hot spots, monitoring forest fires, and assessing damage.

The paper has attempted to assess the damage caused due to the 2016 forest fire episode in the state of Uttarakhand. Burnt area assessment in the state is done at district level, forest administrative unit level, on the major forests types, biodiversity and protected areas hosted in the state using overlay analysis. This study will help in better understanding this fire episode, strengthening the governance at local level to manage the forest fires, investing in its reduction for resilience and enhancing forest fire preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction.

2. STUDY AREA

Uttarakhand has a total area of 53,483 km². It is situated between 28°43' N to 31°27' N latitude and 77°34' E to 81°02' E longitude in the north India and shares boundaries with Tibet and China in the north, Nepal in the east, Himachal Pradesh in the west and Uttar Pradesh in the south. Lofty Mountains and rugged terrain represent 93% of the area in the state making its topography undulating with ridges and furrows. The altitude ranges from 300m to 6000m above msl and the average rainfall of the state is 1523mm. The wide variation in the topography has resulted in immense diverse ecosystems. The Northern parts of the state are covered by the high Himalayan ranges and glaciers, while the lower regions are covered with dense forests. The recorded forest area in the state is 24,240 km^2, which constitutes 45.32 % of its total geographical area (SFR, 2015) (Figure 1).

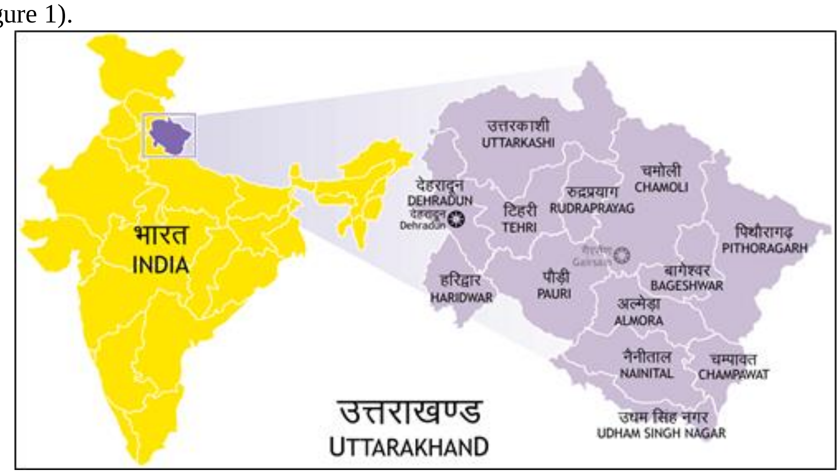

Figure 1: Study area – Uttarakhand

Broadly, Uttarakhand is divided into five major vegetation types. Above 4500m, the Uttarakhand province is covered by ice, glaciers and permanent rock. The western Himalayan alpine shrub and meadows lie between 3000m and 4500m. The temperate western Himalayan subalpine conifer forests range between 2,600 to 3,000m and form a tree line. Below 2600m to 1500m, the temperate western Himalayan broadleaf forests occur. The Himalayan sub-tropical pine forests lie between 900m-1500m. The lower Himalayas or Upper Gangetic plains are covered by dry and moist deciduous forests. Dry savanna and grasslands cover the lowlands along the Uttar Pradesh which are also called Bhabhar. Occurrence of forest fires is frequent in the months of March to June, which resonate with peak of summer with maximum temperature hovering above 40°C. This causes loss to bio-resources, physical assets (in case it spread to the villages) and also affects the health of human, wildlife and the livestock.

3. METHODOLOGY

AWiFS satellite data acquired on the date 23rd, 27th May and 2nd June, 2016 were used for near real time mapping of the fire. To overcome the relief (study area being mountainous) ortho-rectified satellite data were used. The forest area was masked using the forest type map and the burn scars were visually examined based on their unique black color spectral signatures on the false color composite. Ground verification was carried out to corroborate the signature on the ground. The burnt areas were further classified using unsupervised classification of the satellite images of each date. Accuracy assessment was carried out using random points generated over the state based on spectral signature and overall accuracy obtained was 84%. More precise accuracy assessment was done for the district of Nainital based on field data. For assessing the impact of forest fire on forest type and biodiversity, inputs were obtained from bis.gov.in web geoportal of the ISRO, generated as a part of the "Biodiversity characterization at landscape level using satellite remote sensing (RS) and Geographical Information System (GIS) Project undertaken by the Department of Biotechnology (DBT) and the Department of Space (DOS) (Roy et al, 2012). The project mapped the biological richness for the entire country at 1:50k scale using satellite remote sensing, phyto-sociological data and knowledge base in geospatial domain. Biological richness at landscape level was determined as a function of ecosystem uniqueness, species diversity, biodiversity value, terrain complexity and disturbance index (Roy and Tomar, 2000). The burnt area map and statistics of impact of fire on forest types and biodiversity were generated by overlaying corresponding maps using Erdas imagine and ESRI ARC GIS software.

4. RESULTS

The burnt area in the state of Uttarakhand during recent forest fires was found to be 3774.14 km^2, representing 15.28% of the total forest cover in the state. The detailed analysis of the burnt areas in terms of administrative units, vegetation type, biological richness and protected areas as follows:

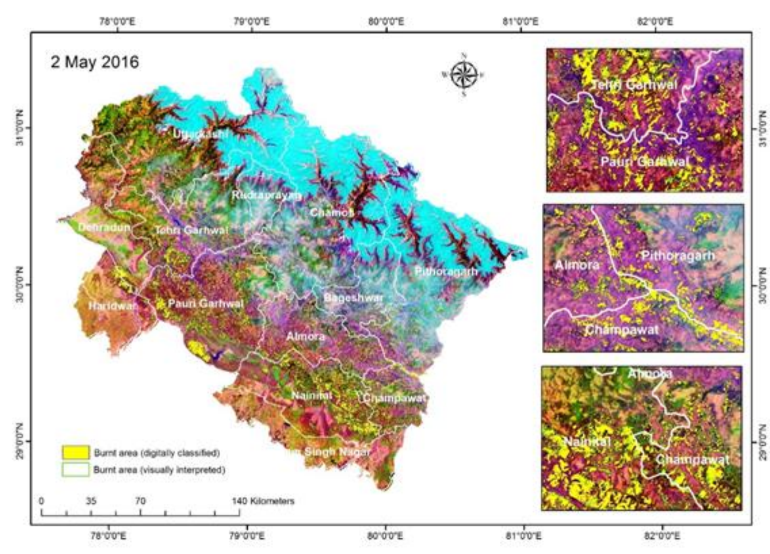

Figure 2: Burnt area due to forest fires in the districts of Uttarakhand based on digital classification

The cumulative burnt area map of the Uttarakhand is shown in map (Figure 2). Using this map, we calculated the district wise burnt forest area (Figure 3). Total forest area burnt is 3774.14 km^2 as on 2nd May, 2016 which is 15.28% of the total forest cover in the state. Tehri Garhwal, Pauri Garhwal and Nainital are the worst affected districts in the state. In terms of percentage, forest areas in districts of Almora, Bageshwar and Chapawat are significantly affected. It is also observed that the area of forest burnt was slow during 23rd or 27th April. However, it almost doubled in all the districts by 2nd May. This was the period which had the highest temperature recorded in the state. The forest in the state of Uttarakhand is managed under 40 forest divisions. Of these, Lansdowne Forest Division, Pithoragarh Forest Division, Narendranagar Forest Division, Almora Forest Division, Champawat Forest Division, Nainital Forest Division, Bageshwar Forest Division and Garhwal Forest Division are the most affected divisions having burnt area ranging from 220 to 350 sq.km. Uttarkashi Forest Division, Civil Soyam Almora, Kedarnath Wildlife Division, Rudraprayag Forest Division, Badrinath Forest Division, Tehri Forest Division and Lansdowne Forest Division are next in the ranking having burnt areas in the range of 90 to 170 sq km in the same order. Remaining all divisions have area less than 90 sq km. and there has been almost no fire in the Nanda Devi Forest Division, Tarai West, East and Central Divisions and Soil Conservation Division in Kalsi. The percentage burnt area was maximum, i.e. 24%, for Nainital Forest Division.

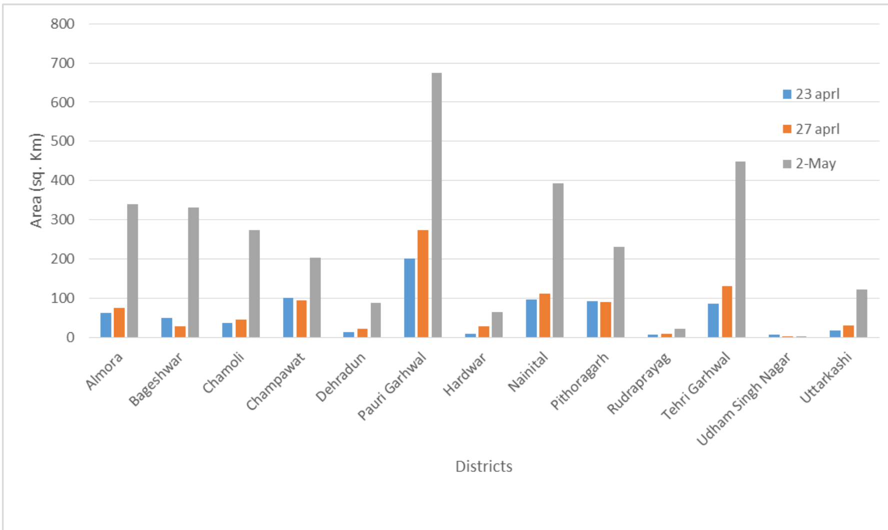

Figure 3: Graphical representation of Date wise burnt area in different districts of Uttarakhand using digital extraction of burnt areas

According to official statistics, more than 60 percent of Uttarakhand is under forest cover. In actuality, the coverage is much less. Forest type wise area affected due to fire is presented in table 2. It shows that Pine forests are the ones which are most affected due to the fire due to obvious reasons of its high calorific value, resinous sap and slow rate of decomposition of the litter. A considerable area under the scrub, Himalayan moist temperate forests and moist deciduous forests has also burnt during the period (Fig 6). An overlay analysis of the burnt area map with respect to the biological richness zones shows that 22.25%, 12.73%, 13.33% and 2.62% of the area is affected in low, medium, high and very high biological richness zones, respectively.

4.1 Hotspots of fire occurrence in Uttarakhand

A forest fire frequency map was prepared for the region. It has been observed that the middle Himalayas mainly dominated by pine and the Himalayan foothills have been most affected by the forest fire. The analysis was done on 2.5 km grid for the entire state of Uttarakhand. The daily forest fire occurrence from MODIS Aqua and Terra was aggregated for last 15 years (2000-2015) and regions prone to forest fire were identified as number of fire occurrence in a grid during the past 15 years (Figure 4).

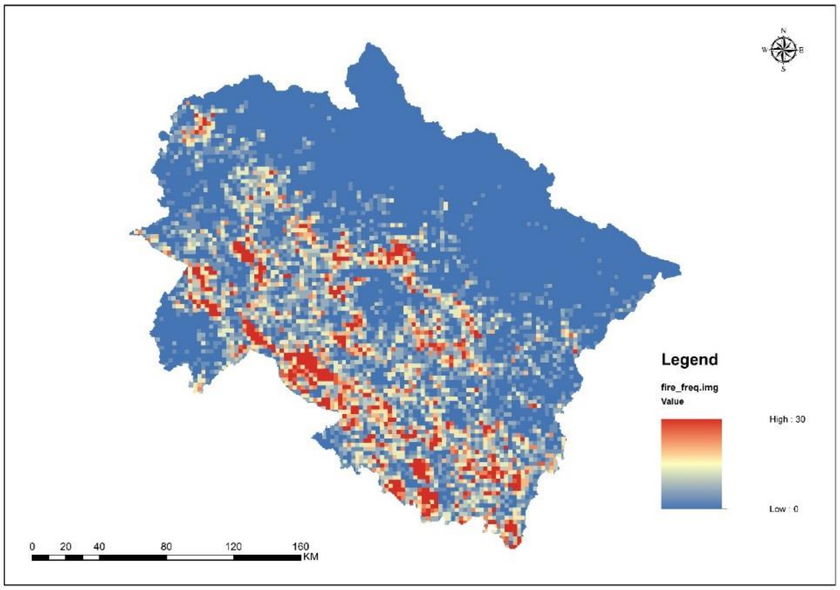

Figure 4. Hotspots of forest fire in Uttarakhand (2000-2015)

Most of the fire hotspots are observed in the districts of Pauri Garhwal, Haridwar, Nainital, Champawat, Almora and Tehri Garhwal. In fact there are the districts which have been mostly affected by the recent forest fire. In view of this there is a need to set up watch towers/ observation posts (Automated) to provide timely inputs for forest fire alerts for timely intervention of fire incidences.

4.2 Impact of forest fires in the protected areas in Uttarakhand

Burnt area and the protected areas present were analyzed by overlaying the burnt are with the vegetation type and biologically rich areas in the protected areas boundaries (Figure 5). The study revealed that Corbett National Park, Rajaji Tiger Reserve/ Wildlife Sanctuary (WLS), Nandhuar WLS and Binsar WLS were the worst affected protected areas. Askot Musk Deer and Sonanadi WLS are also affected upto 26 sq. km area. Though, some animals have a natural threat warning system and usually migrate from the danger areas. It is important to assess the impact to burnt areas in protected areas so that detailed inventories may be done of the possible deaths of terrestrial animals, as they are first to lose their lives due to heat generated. The birds also save themselves by migration, but their eggs are usually destroyed. Therefore, such an assessment is usually helpful in planning post fire census of the animals in affected protected areas.

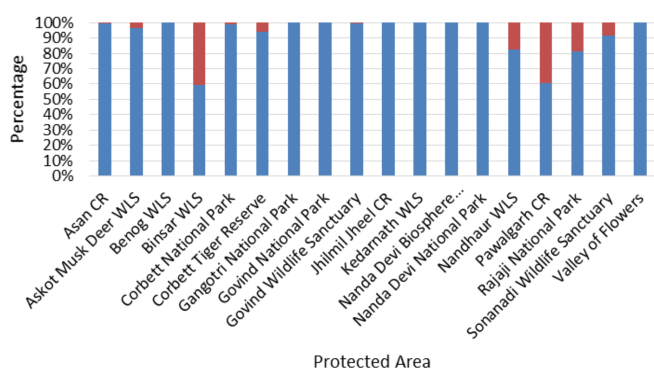

Figure 5: Percentage of protected areas affected by forest fires (part in orange are the % affected by forest fires)

Rajaji Tiger Reserve (RTR) is located the Shivaliks in the foothills of the Himalaya. It is spread over 820 km^2. The total burnt area was estimated to be 32.2% of the total area of reserve. The most affected vegetation types were sal mixed moist Deciduous followed by gregarious Sal and Dry deciduous forests. In total more than 20 burnt scars were mapped inside the RTR including a burnt scar of 162.26 km^2 size was mapped in middle part of RTR.

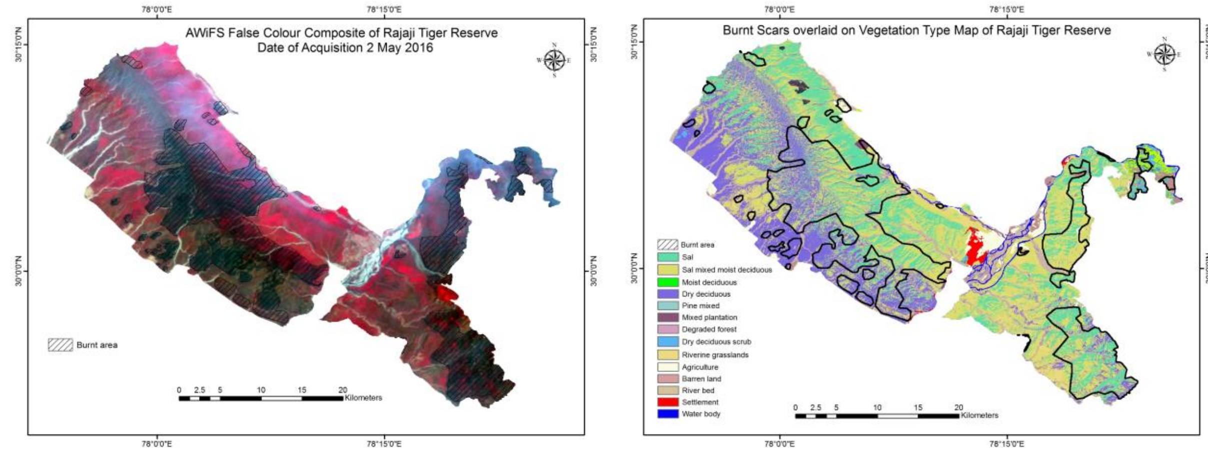

Figure 6: Burnt forest areas in Rajaji Tiger Reserve

A considerable area falling under high and moderate biological richness in the Rajaji National Park has been affected by the forest fire which might have severely damaged the seedling and sapling of the different tree species as well as small animals like the reptiles and soil organisms which might have suffered huge loss of population as well as habitats (Figure 6 and Figure 7).

Corbett Tiger Reserve (CTR) is located in Bhabar region of foothills of Himalaya. The total area of the reserved is 1288 km^2 of which 16.3% has been burnt by forest fire. The most affected vegetation types were Sal followed by Sal Mixed Dry Deciduous forest. The largest size burnt scar was mapped in Sonanadi WLS inside the CTR.

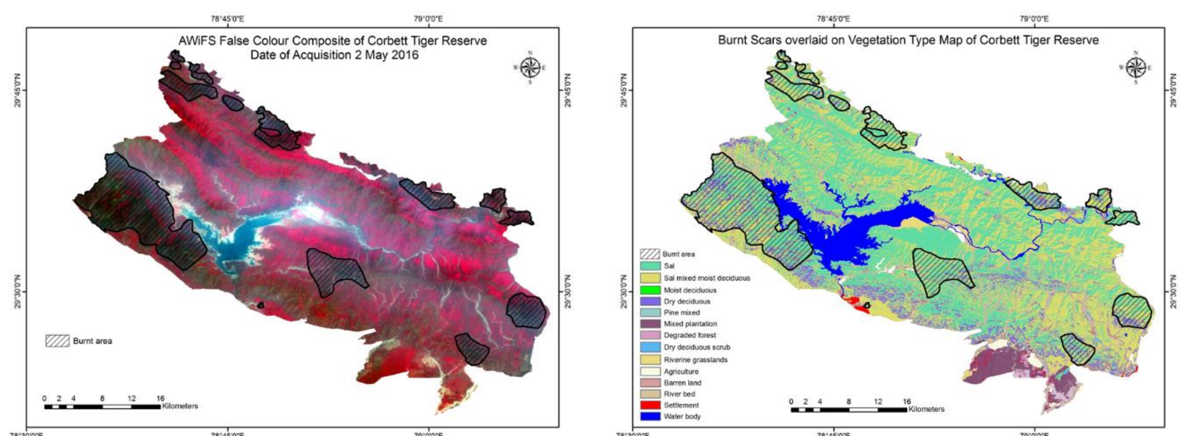

Figure 7: Burnt forest areas in Corbett Tiger Reserve

Almost similar to the Rajaji Tiger Reserve the Corbett Tiger Reserve has also been affected by the forest fire. The regions having high to moderate biological richness has been most affected. In these regions also the organisms like the herbaceous plants, the seedlings and the smaller animals as well as soil organisms are expected to have been affected in the burnt areas.

5. DISCUSSION

Remote sensing has made great strides in terms of providing data to address operational and applied research questions, beyond the scope and feasibility that ground-based studies can provide (Lentile et. al., 2006). An account of increasing role of geo-informatics in reporting real time fire events as happened in Uttarakhand forest fire has been given by Jha et al, 2016 in a quick manner using active fire locations derived from Moderate Resolution Imaging Spectroradiometer (MODIS). They estimated the burnt area in the state in the recent fire to be 2166.07 km^2. However, A comparison of forest fire data of the State Forest Department and those of collected from Forest Survey of India (FSI) by Singh et al (2016) in the Uttarakhand for the fire season from 2009 to 2014 in Bageshwar Forest Division (BFD) (a) and 1993 to 2014 in Chamoli Forest Division (CFD) indicates that MODIS captured only 5.64% and 19.04% fires recorded by the former in BFD and CFD, respectively. The number of fires was 266 and 126 in BFD (2009–2014) and CFD (2006–2014) respectively, according to the State Forest Department records, compared to 15 and 24 respectively, according to MODIS data. They attributed these differences to the coarse resolution of MODIS that failed to detect small fires of short duration particularly from dense forests. Thus, detailed account of post fire damage requires careful understanding of the spectral signatures and sufficient ground truthing for validation though the real time assessments using Modis data gives a preliminary idea. The forest fire in the state of Uttarakhand is classified as high-frequency, low-severity surface fires of small size, largely determined by the moisture conditions of the pre-monsoon season (from March to mid-June), and the traditional practices of biomass collection by local people (Singh et al, 2016). We observed that this is primarily true in case of pine forests that stand tall with separate canopies whereas in case of the broad leaved forests of Oak and Rhododendron, these fires were sufficiently large and also damaged the crowns due to steep slopes. Canopies are rather juxtaposed to form a continuum more so because of the vegetation underneath. The burnt area assessment of the forests in the state as assessed in this study using Awifs data of 58m spatial resolution and ground validation was found to be 3774.14km^2 representing 15.28% of the total forest area of the state, which seems more realistic in a given accuracy of 84%. Accurate assessment of burnt area assists in post-fire rehabilitation treatments that are important in minimizing damage to soil, water and plant resources (Vallejo et al., 2000). Rehabilitation methods such as grass seeding, logging, building of branch barriers and mulching may be used for replenishing the burnt forest areas (Robichaud et al. 2000). The post-fire scenario damage assessment to the biodiversity and protected areas as presented in this study may be useful in mitigation planning to prevent drastic ecological impacts of the fires by monitoring in future to these intangible resources. The ecological impacts on productivity, regeneration and soil erosion etc. may be taken up in the mapped areas 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 IN FOREST FIRE .This limits the upscaling of measurements to regional and national context. There are also gaps in the assessment starting from the detection of fire to organizing preventive measures (Joseph et al, 2009). In order to have timely control of the fires, there is an increased need for Early warning system based on state of art geo-informatics technology. Improved prediction of the forest fires using weather data acquired from Automatic weather stations (AWS) should be targeted in future. Participation of the citizens using crowdsourcing may also be encouraged, as it has the potential to provide contextual information that can provide alerts and ancillary information during the fires and in post-fire events.

6. CONCLUSION

The satellite remote sensing, along with proper ground truth and careful investigation of the spectral signatures make area assessment of the damage highly effective. The inputs generated in this study are shared with the state administrative authorities and the central parliamentary committee for a long term recovery plan.

7. Acknowledgement

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REFERENCES

Ankila, H., 2007. Fires in Indian forests. In Workshop Proceedings, Pillar Human Resource Development Centre, Madurai, India, February 19th to (Vol. 23).

Bahuguna, V.K. and Singh, S., 2002. Fire situation in India. International Forest Fire News, 26, pp.23-27

Bhandari, B.S., Mehta, J.P. and Semwal21, R.L., 2012. Forest Fire in Uttarakhand Himalaya: An Overview. GLIMPSES OF FORESTRY RESEARCH IN THE INDIAN HIMALAYAN REGION, p.167.

Chand, T.K., Badarinath, K.V.S., Prasad, V.K., Murthy, M.S.R., Elvidge, C.D. and Tuttle, B.T., 2006. Monitoring forest fires over the Indian region using Defense Meteorological Satellite Program-Operational Linescan System nighttime satellite data. Remote Sensing of Environment, 103(2), pp.165-178.

Gandhi, S.R. and Singh, T.P., 2014. Automatization of Forest Fire Detection Using Geospatial Technique. Open Journal of Forestry, 2014.

Giglio, L., J. D. Kendall, and C. O. Justice, 1999, Evaluation of global fire detection algorithms using simulated AVHRR infrared data, Int. J. Remote Sens., **20**, 1947–1985.

Gubbi S. 2003. Fire, fire burning bright! Deccan Herald, Bangalore, India. Available online at:http://wildlifefirst.info/images/wordfiles/fire.doc (accessed January 2004)

Hansen, M.C., Stehman, S.V. and Potapov, P.V., 2010. Quantification of global gross forest cover loss. Proceedings of the National Academy of Sciences, 107(19), pp.8650-8655.

Jain, Abhineet, Roy, P.S., Ravan, S.A., Singh, R.K. and Das, K.K. (1996). Fire Risk Modelling using Remote Sensing and Geographic Information System.Current Science,**70**(**10**): 928–933.

Joseph, S., Anitha, K. and Murthy, M.S.R., 2009. Forest fire in India: a review of the knowledge base. Journal of forest research, 14(3), pp.127-134.

Koppmann, R., Czapiewski, K.V. and Reid, J.S., 2005. A review of biomass burning emissions, part I: gaseous emissions of carbon monoxide, methane, volatile organic compounds, and nitrogen containing compounds.Atmospheric Chemistry and Physics Discussions, 5(5), pp.10455-10516.

Landmann, G., Held, A., Schuck, A. and Van Brusselen, J., 2015. European forests at risk. A scoping study in support of the development of a European Forest Risk Facility. European Forest Institute.

Lentile, L.B., Holden, Z.A., Smith, A.M., Falkowski, M.J., Hudak, A.T., Morgan, P., Lewis, S.A., Gessler, P.E. and Benson, N.C., 2006. Remote sensing techniques to assess active fire characteristics and post-fire effects. International Journal of Wildland Fire, 15(3), pp.319-345.

MoefCC 2015. ANNUAL REPORT 2014-15. Government of India Ministry of Environment, Forests and Climate Change page 21

Robichaud, P.R., 2000. Fire effects on infiltration rates after prescribed fire in Northern Rocky Mountain forests, USA. Journal of Hydrology, 231, pp.220-229.

Rothermel, R.C., 1983. How to predict the spread and intensity of forest and range fires. The Bark Beetles, Fuels, and Fire Bibliography, p.70.

Rowell, A. and Moore, P.F., 2000. Global review of forest fires. Forests for Life Programme Unit, WWF International

Roy, P.S. and Tomar, S., 2000. Biodiversity characterization at landscape level using geospatial modelling technique. Biological conservation, 95(1), pp.95-109.

Roy, P.S., 2003. Forest fire and degradation assessment using satellite remote sensing and geographic information system. Satellite Remote sensing and GIS applications in agricultural meteorology, p.361.

Roy, P.S., Kushwaha, S.P.S., Murhty, M.S.R., Roy, A., Kushwaha, D., Reddy, C.S., Behera, M.D., Mathur, V.B., Padalia, H., Saran, S., Singh, S., Jha, C.S. & Porwal, M.C. (2012) Biodiversity Characterization at Landscape Level: National Assessment, Indian Institute of Remote Sensing, Dehradun, India, pp. 140. ISBN 81-901418-8-0.

Singh R.D., Gumber S., Tewari P. and Singh S. P. 2016. Nature of forest fires in Uttarakhand: frequency, size and seasonal patterns in relation to pre-monsoonal environment. CURRENT SCIENCE, VOL. 111, NO. 2, 25 JULY 2016. Pp 398-403

Spanos, I., Ganatsas, P. and Tsakaldimi, M., 2010. Evaluation of postfire restoration in suburban forest of Thessaloniki, Northern Greece. Global Nest J, 12, pp.390-400.

UNISDR/GE/2015 – ICLUX EN5000. United Nations, Office for Disaster Risk Reduction. Sendai framework for disaster risk reduction 2015-2030. 2015; 1st edition.

Vallejo, R. et al. 2000. Reclamation of Mediterranean ecosystems affected by wildfires: forest management recommendations. – In: Balabanis, P. et al. (eds), Mediterranean desertification. Research results and policy implications. European Commission, pp. 407–416.