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Geospatial Assessment of Forest Fires in Jharkhand (India)

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Abstract

Background: The forests in India and worldwide are threatened by many factors, one among them being the increasing frequency of forest fires. It damages the forest ecosystem and the environment thus altering the global climate. A proper monitoring and understanding of forest fires both spatially and temporally would assist in management of forest and help in protecting the biodiversity and wildlife habitat. Satellite remote sensing and GIS help in visualizing the extent and damage of forest fire at various scales and time periods. **Objectives**: To analyze the incidences of forest fires in Jharkhand state of India. Forest fire hotspot district were identified and analyzed. **Methods/Statistical Analysis**: The forest fire point data from the year 2005 to 2016 was analyzed in GIS domain for Jharkhand. The Landsat-8 data was utilized to obtain the forest cover of 2015 for Paschim Singhbhum district. The 2km*2km grid was generated to evaluate each grid with reference to forest fire incidence. **Findings:** Analysis of the datasets revealed that highest forest fire district of Jharkhand state is Paschim Singhbhum, it retain 30% of total forest fire whereas it contain approximately 17 % of the state forest cover. The study reveals very high frequency of forest fire grids in Paschim Singhbhum district falls in north-west of Pansuan dam of Porhat forest division. It provides a spatial view of forest fire occurrence, spread over duration of time which can be incorporated in management objectives to deal with the adverse effect of forest fire. **Application/Improvements:** Appropriate measures can focus on the particular very high to medium forest fire grid to minimize the effect of forest fire impact.

Keywords: Conservation and Management, Forest Fire, GIS, GRID Analysis, Jharkhand, Paschim Singhbhum

1. Introduction

Apart from the several tangible benefits forests provide, they are the most valuable resources because it regulates the natural balance, affecting the climate and water body of the region, preventing air pollution and soil erosion. As per various studies forest fires have influenced the flora and fauna of the forests and millions of hectares of forests across the world are affected by it every year. Thus the consequences are adverse leading to deterioration of forest health and wealth[1,2]. Many researchers[3-14] have provided details on the negative impacts of forest fire are given in Figure 1.

The deciduous forests have been observed to be more vulnerable to forest fires. In India, such fires 40% of all the forest fires reported are found to be in deciduous forest[15,16]. There are many factors responsible for the start and spread of forest fires, one of them being the anthropogenic factor which has a major influence[17,18].

Summer season is favorable for the spread of fire. There are many reasons attributed to the forest fire occurrences. Sometimes it is accidental or due to negligence. More than 90% forest fires are caused by anthropogenic activity by human beings due to, deliberately (for personal gains or rivalry) or merely due to negligence or just by accident. Forest fires sometimes starts due to accidental or unintentional reasons. Some of the instances are as follows: To facilitate collection of non-timber forest produce (NTFP) the collectors usually ignite the fire, which accidentally may spread in the forest due to extreme hot weather,

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resulting into a major fire. The main non-wood forest product that contributes to forest fire in Jharkhand is the Mahua flowers (*Madhuca indica)* collected by the local people. They are boiled with Sal seeds (*Shorea robusta*) to produce a popular local beverage. Mahua pickers burn the dry leaves under the trees to get a neat and clean floor to facilitate flower collection. While the objective is only to clear a small circular floor beneath a single tree, these fires often spread out of control due to hot weather. Since the collection of Mahua flowers is done during the summer months mostly March and April month, the hot dry weather due to high temperature, high wind velocity and low relative humidity aggravates the situation. In some cases the cause of ignition of fire is to increase the production of Tendu leaves, to meet the demands of fodder for grazing animals, sometimes as a result of rivalry with the forest staff and to keep wild animals away. Smugglers and illegal loggers of the area many times start forest fires to hide the stumps of illicit felling in order to conceal it. Natural causes, that originates the forest fire in Jharkhand is only due to the bamboo mixed forest areas where forest fires may occur due to high wind velocity during summer by the collusion together of clumps of dry bamboos.

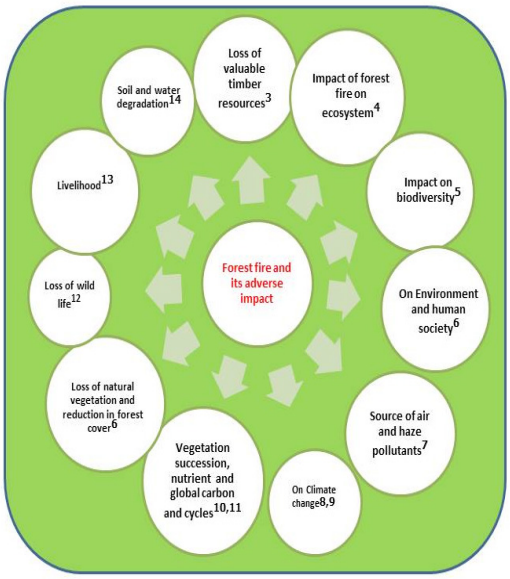

Figure 1. Forest fire and its adverse impact.

The major fire spread patterns are related to the special/particular weather conditions, the topography of the area or potential fuels[19]. The nature of fire starting from ignition to spread can be grouped into three types: 1) the ones where it is influenced by topography 2) wind 3) fuel accumulation[20,21]. Other important parameters related to weather are temperature and moisture. Temperature affects the sparking of forest fires, because heat is one of the three pillars of the fire triangle. The fallen pole, trees and underbrush on the ground receive radiant heat from the sun, which heats and dries up the potential fuels. Warmer temperatures allow for fuels to inflame and burn faster, adding to the rate at which a forest fire spreads. For this reason, forest fires tend to rage in the afternoon, when temperatures are the highest.

Wind probably has the biggest impact on a forest fire's behavior. It is also the most unpredictable factor. Winds supply the fire with more additional oxygen, further dry potential fuel and push the fire across the forestland more rapidly. The stronger the wind blows, the faster the fire spread risk. The speed of the fire and direction do not change during this stage. Due to the wind the fire is brought closer to fresh fuel accelerating the spread of fire in the direction of the wind[22,23]. While wind can help the fire to expand, moisture works against the fire.

Moisture, in the form of humidity and precipitation, can slow the fire spread and reduce its intensity. The potential fuels can be hard to catch fire if they retain high levels of moisture, because the moisture absorbs the fire's heat. When the humidity is low in the air, meaning that there is a little amount of water vapor, forest fires are more likely to start[24]. The higher the humidity in air, the fuel is moistened and less risk of ignition. When the air becomes saturated with moisture, it releases the moisture in the form of rain drops. Rain and other precipitations increase the amount of moisture in fuels, which forcibly putting an end of any potential forest fires from breaking out.

The majority of forest fires occur in between January and June in India. In various biogeographic zones of India, more frequent forest fires occur in between February and May[18] indicating that it is a major concern during the dry season[25]. Approximately 3.73 Mha of forest is burnt annually in India as a result of forest fire[26]. A complete understanding of forest fire regimes is necessary, but hardly any data is available which would assist it. Therefore a thorough investigation is needed in studying the different forest fire regimes in various states of the country. To achieve this target satellite data at various spatial and spectral resolutions offers the potential to study at regional and local scales. Besides this GIS platform helps to manage large datasets and analyses them efficiently and in a cost effective manner.

The forests of India have been broadly classified into sixteen types[27]. Recurrent forest fires in tropical deciduous forests have raised an alarm about its existence[28]. Statistical analysis and modeling when coupled with remote sensing and GIS provides a platform to predict when and where the likelihood of forest fire occurrence is more[29]. Many sensors nowadays provide a wide range of coverage of forests and the damage caused to it. Some of them are LISS III, MODIS, ETM+, AVHRR and A WiFS[30,31]. AATSR satellite data and fire occurrence data provide information that maximum number of fires occur during March and April mostly in the tropical parts of India[32].

The present study has made an attempt to study the forest fire trends in the state of Jharkhand using remote sensing data and GIS. Landsat data (2015) was utilized for the study area to derive the forest cover. Grid analysis was done. Forest fire data (point data) was downloaded and was utilized to get forest fire risk map. High forest fire districts were identified on the basis of district forest area and fire percent data. In one of the identified high forest fire district (Paschim Singhbhum), the GRID ANALYSIS was done using existing forest fire data of the district.

2. Materials and Methods

2.1 The Study Area

The study area, the state of Jharkhand in India Figure 2 having total geographical area 79,714 km² accounted lies between 21 ° 58' 02" N to 25 ° 08' 32"N latitude and 83° 19' 05"E to 87° 55' 03 '' E, longitude, surrounded by West Bengal on the east, Chhattisgarh on the west, Bihar on the north and Orissa on the south. The major rivers of the state are Sone, Koel, Damodar and Subarnarekha. The elevation varies from 6 m to 1366 m from the mean sea level. Jharkhand has a tropical climate with average moderate rainfall (950 to 1300 mm) and temperature varies in winter to summer from 6°C to 47°C respectively.

2.2 Data Preprocessing and Analysis

2.2.1 Forest Fire Analysis

The Jharkhand state and district boundaries used for the analysis were downloaded from DIVA GIS website (http://www.diva-gis.org/Data). Districts wise forest cover percent of Jharkhand was published by Forest Survey India (2015) was utilized for visualization in the graph. The forest fire data from 2005 to 2016 for the state of Jharkhand was downloaded from Forest Survey of India (http://fsi.nic.in/forest-fire.php) from 2005 to 2016. The forest fire point file data which retains the latitude and longitude was brought in GIS domain by exporting into point vector file using ARC/ GIS Software. Now each of the districts was evaluated for forest fire occurrence and frequency based on forest fires point data. The district wise forest fire percent was analyzed and high forest fire district was identified.

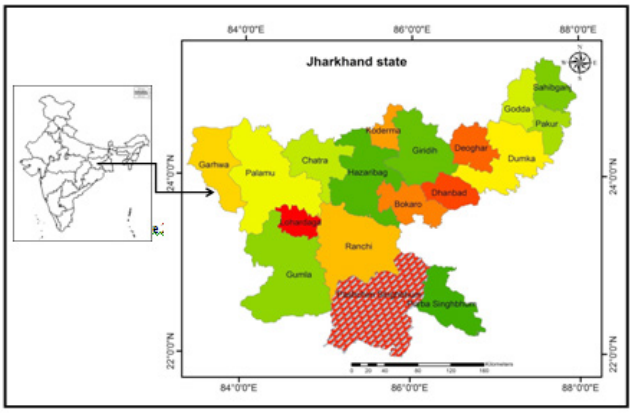

Figure 2. The location of the study area

2.2.2 Forest Fire Grid Analysis

To obtain the Paschim Singhbhum district forest map we used the Landsat 8 images in Table 1 of December 2015 which was downloaded from USGS website. The study area is covered in two scenes. The images were mosaicked and FCC was generated. To separate the vegetation from non-vegetation class we utilized the Normalized Difference Vegetation Index (NDVI). Based on evaluation of NDVI value a forest and non-forest mask was created. The forest area for the district was extracted using the district shape file. A 3X3 filter was executed to smoothen the image and to remove noise.

Table 1. Satellite data details

Satellite	Sensor	Path/ Row	Dates
Landsat 8	OLI_TIRS	140/44 140/45	19-12-2015 19-12-2015

A grid of 2km X 2km was created over the Paschim Singhbhum district from the shape file. For this study we have evaluated complete grid having 4 square kilometer

area. The partial grid along with the district boundary edge was not been considered for the analysis. In the first step all the non-forest grids were masked out from classified forest cover map of 2015. The number of forest fire frequency from 2005 to 2016 has been used for spatial grid wise analysis. The criteria of evaluation of forest grid risk was based on the forest fire occurrence viz. very high risk, high risk, medium risk, low risk and least concern where forest fire frequency are >7, 6-5, 4-3, 2-1 and 0 respectively.

3. Result and Discussion

3.1 District Wise Forest Fire Frequency Analysis

The district wise analysis of entire forest fire frequency data (2005 to 2016) revealed that Paschim Singhbhum, Palamu and Garhwa districts are subjected to 30.48%, 18.39% and 8.98% of forest fire respectively, when considering the whole Jharkhand forest fire as 100 % (Figure 3).

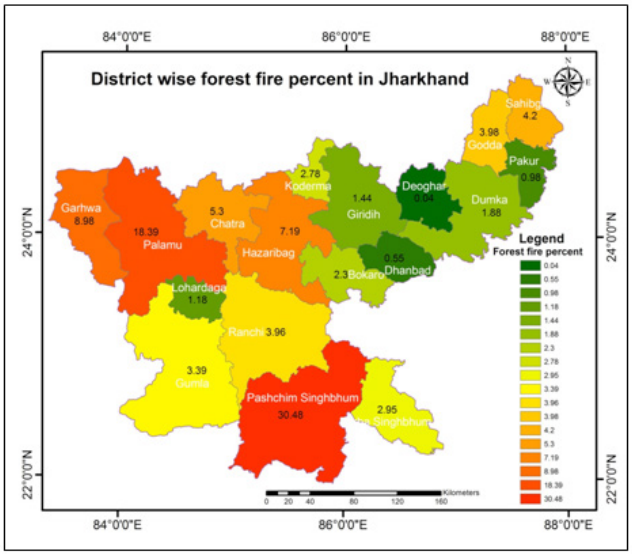

Figure 3. District wise forest fire % in Jharkhand.

Paschim Singhbhum and Palamu district together represent 49% of state forest fire frequency. We have integrated forest fire percent and also forest cover area percent district wise based on FSI 2015 report mentioned in Jharkhand Economic Survey 2015-16[33]. Paschim Singhbhum represents roughly 17% of Jharkhand forest cover (considering total forest cover of Jharkhand 100%) whereas it represents 30% of Jharkhand forest fire frequency in Figure 4 Gumla district in Jharkhand is 3rd highest district represent 11.3 % forest cover but represent only 3.4% of fire frequency. So Gumla is least effected district from forest fire even though it is 3rd highest district in Jharkhand as far as forest cover is concern.

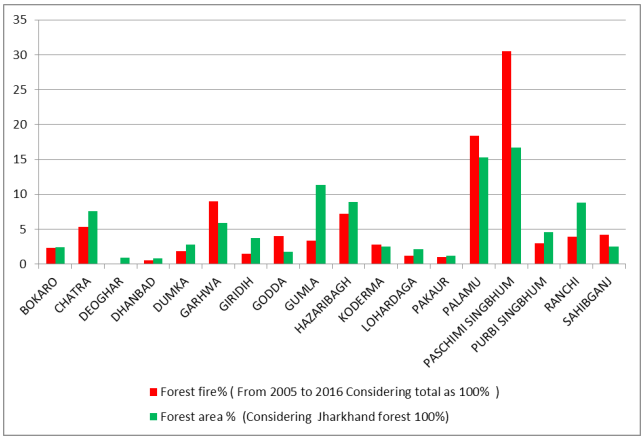

Figure 4. District wise forest fire % with respect to forest cover % of Jharkhand.

3.2 Grid Wise Analysis

The identified high forest fire district in Jharkhand was Paschim Singhbhum, is famous because it retains Saranda forest known for their biodiversity and a high quality sal forest. This forest provides livelihood and home for several tribes and suitable habitat for several wild animals including elephant. The grid based analysis here focuses on continuous threats from forest fire in the district of Paschim Singhbhum , Jharkhand. The study reveals 52 % of grid cell of Paschim Singhbhum forest was affected with fire. The result of analysis of various forest risk grids are given in Table 2 and Figure 5. The very high, high forest risk grids were 16 and 55 respectively mostly falls in Porahat and Kolhan forest division need immediate attention for forest conservation and management. The grid showing very high frequency of forest fire falls in north-west of Pansuan dam of Porhat forest division. The composition of forests in this region is mainly dry deciduous forest dominated with sal mixed with bamboo. It is important to understand such process and to identify threatened ecosystem grid for forest conservation and management perspective[34].

Frequent fire frequency and severity of forest ecosystem sdegrade the forest and is considered to be influence post fire landscape composition, configuration, and

regeneration[35,36] thus grid wise conservation approach as an unit was suggested[37] and utilized for prioritization and identification of forest ecosystem suffering from the threat of fire[34], which not only mitigate future fire occurrence based on their landscape pattern[38], but also facilitate native species regeneration process in depleting and degrading forest grid.

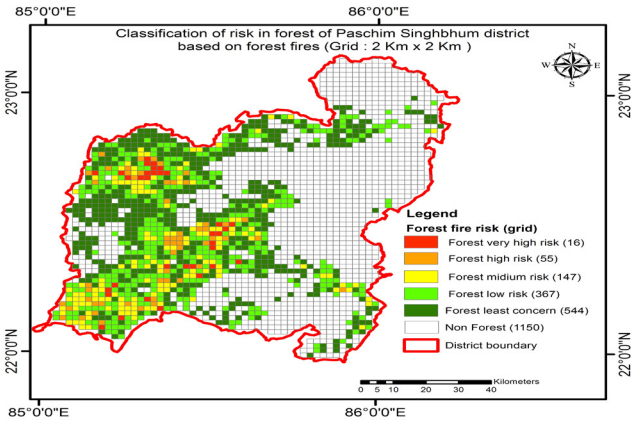

Figure 5. Grid based forest fire risk map of Paschim Singhbhum of Jharkhand.

Table 2. Analysis of risk of forest grid based on forest fire

Forest grid risk	Forest Fire	
	No. of grid	% of grid
Very high risk	16	0.7
High risk	55	2.4
Medium risk	147	6.5
Low risk	367	16.1
Least concern	544	23.9
Non-forest	1150	50.4

4. Conclusion

The present study has utilized the historical forest fire data of Jharkhand and analyzed it for all districts in GIS domain. The study reveals that the districts Paschim Singhbhum and Palamu of the state Jharkhand roughly retain 50% of total forest fire counted in the state. The grid analysis was performed in one of the highest forest fire district (Paschim Singhbhum). The study reveals that 218 forest grids are in a vulnerable stage to forest fire and the degree varies from very high to medium risk. These areas should be considered by management for future planning to mitigate forest fire occurrence and its impact.

The Jharkhand state has witnessed several forest fires in the past leading to the deteriorating condition of the forest. Loss of biodiversity is a major concern especially in the Paschim Singhbhum district which represents a unique ecosystem of sal forest of Saranda which is famous in Asia. Large numbers of flora and fauna are lost annually due to forest fire in Jharkhand.

The forest of Jharkhand are a home for several tribes and also the habitat for several wildlife. The preferable place for wild elephant corridor is deteriorating.

Appropriate measure should be adopted to safeguard the forest ecosystem which includes the use of advance technology such as remote sensing &GIS. Grid based analysis with synoptic coverage of forest has been one of the limitations in the conventional assessment techniques which can be potentially overcome by using geospatial approach. Weather forecasting system during summer and it is more important to involve local and tribal people in forest protection and restoration.

The periodic monitoring and mapping of forest and incidence of forest fire should be facilitated by the government especially in very high forest districts so that it will encourage effective pre-fire operations planning and will improve fire control efficacy in the forests of Jharkhand state.

5. Acknowledgement

The authors are grateful to the USGS for free download of Landsat data. The required GIS vector layers including forest fire point were downloaded from DIVA GIS and Forest Survey of India (FSI) website.

6. Authors' Contributions

FA proposed the idea, analyzed the satellite and ancillary data in GIS domain and drafted the manuscript, LG supervised the analysis and improved the manuscript. Both authors read and approved the final manuscript.

7. Competing Interests

The authors declare that they have no competing interests.

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