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RISK ASSESSMENT OF FOREST FIRE IN BARIPADA FOREST DIVISION, MAYURBHANJ, ODISHA, INDIA USING GEOSPATIAL TECHNIQUES

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Abstract: Forest fire is a threat to humans, biodiversity, environment, ecology, and economy also. It destroys the environmental balance of a region, sometimes it may be due to human interference or maybe natural hazards. The present study area Baripada forest division is prone to forest fires. In this study area, an attempt has been made to demarcate the forest fire risk zones by applying Remote sensing and Geographical information system (GIS) technologies. Thematic layers like vegetation, agricultural land, settlements, water bodies, and road networks were derived through satellite images and topographic maps. The fire risk index method is used to identify the fire risk zones of the study area, such as low-risk, medium-risk, and high-risk zones. The prepared forest fire risk zone map is validated with fire incident data. The study results that maximum fire happened due to human interference. This study will help the environmentalist, disaster management authorities, and forest departments to take preventive measures for better forest fire management.

Index Terms - GIS, remote sensing, landsat, NTFP

I. INTRODUCTION

Forest is an important natural resource. Forest is vital for ecological balance and play important role in temperature regulation in the atmosphere. Forest fires are considered to be a potential hazard with physical, biological, ecological, and environmental consequences (Somashekar et al., 2009). The impacts of forest fires on the environment are high carbon emissions, loss of biodiversity, soil erosion, forest degradation, and emission of large amounts of toxic gases. Fires can result in deforestation and desertification (Hernandez-Leal et al 2006). During the process of burning, the soil nutrients are reduced and the soil is left bare making it more susceptible to both soil and water erosion. Fire also leads to an increase in greenhouse gas emissions and air pollution due to smoke causing prolonged effects on human health such as respiratory and cardiovascular problems. Forest ecosystems are subjected to a variety of environmental threats of which fire is a potentially serious hazard. Fire depending on where, when, and why it occurs, can be either an essential factor for the ecological cycle of the forest landscape and the survival of associated plants and animals. It is merely a destructive unnatural threat, forest and wildlands 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 human society. The continued high annual rate of loss of forest cover and outbreak of major wildfires over the past decades, in contrast to increased plantation development, successes in sustainable forest management, and increase in protected areas show a complex picture of the past and possible future of the world's forests and mankind's integration with them. Therefore, it is vital to have correct and timely knowledge of the total area burned and the reasons for burning.

Forest fires can occur due to natural forces as well as anthropogenic activities (Adab et al 2013). It is impossible to effectively manage fires without a clear and correct understanding of the distribution and dynamics of forest fires. Remote Sensing (RS) and Geographic Information System (GIS) techniques can be effectively used to locate the forest fire risk zones expressed by many researchers (Manavalan & Jayalakshmi 2013; Ajin et al 2016a; Ajin et al 2016b; Ajin et al 2016c; Ajin et al 2016d; Vinod et al 2016; Ajin et al 2017; Dong et al 2005; Chavan et al 2012; Ghobadi et al 2012; Singh & Ajay 2013;). Geospatial techniques can play an important role in detecting burnt forests and developing a spatial model to predict potential forest fires. This study demonstrates the effective use of geo-information as the main source of information on fire. The study aims for an assessment of forest fire in the Baripada Forest Division. The ultimate goal is to manage and prevent a fire from happening in Baripada Forest Division. In the present study, an attempt has been made to prepare a forest fire risk zone map integrating historical fire records, vegetation status, slope, aspect, elevation, settlement density, and road density data through Geographic Information System (GIS) in the Baripada Forest division Mayurbhanj, Odisha.

II. STUDY AREA

Baripada Forest Division, Baripda falls under the Mayurbhanj district of Odisha state. It consists of seven ranges which are the Bangriposi range, Deuli range, Baripada range, Rasgobindapur range, Betnoti range, Udala range, and Kaptipada range. To pursue an empirical study in geography one has to define one's study area. However, apart from regions, places are not described by their boundaries but by their focus. This gives a kind of point-like character. The Baripada Forest Division is escalating over Mayurbhanj of Odisha around 4314.48 Sq. km. This division is bordered north by West Bengal, south by Balasore and Keonjhar districts, west by Similipal national park, and east by Balasore District. The geographical position of this division is Longitudes 86°21'32.14"E and 87°11'16.48"E and Latitudes 21°17'44.77"N and 22°21'4.93"N elevation is 45 to 720 meters above sea level.

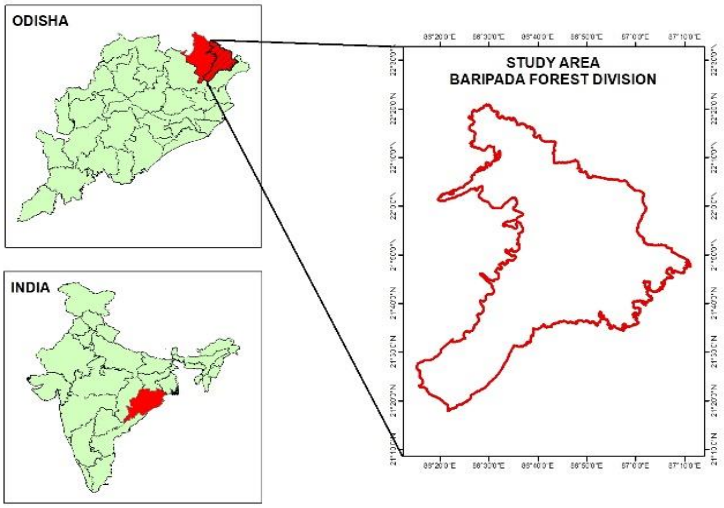

Figure 1: Location of Study Area

III. MATERIALS AND METHODS

The study area was delineated from the Survey of India (SOI) topographic maps numbered 73J-07, 73J-08, 73J-11, 73J-12, 73J-16, 73K-06, 73K-07, 73K-09, 73K-10, 73K-11, 73K-13, 73K-14, 73O-1 and 73O-2. Landsat-8 image is used in this study for the delineation of vegetation-type maps. The Landsat-8 image was acquired from the USGS earth explorer bearing the following link https://earthexplorer.usgs.gov/. The road networks and settlements were digitized from the toposheets and Google Earth maps. Road density and settlement density maps were prepared from the digitized data using ArcGIS spatial analyst tools. The contour data were generated from the SRTM DEM of 30 m resolution. ArcGIS spatial analysis and three-dimensional analyst tools were used to prepare the slope, elevation, and aspect map layers from the contour data.

The FRI method (Ajin et al 2016b; Ajin et al 2017) was used for the demarcation of forest fire risk zones. The thematic map layers were reclassified using the Natural breaks (Jenks) method. Ranks were assigned to each class of the thematic map layers and weights were assigned to each layer according to their sensitivity to fire or their fire-inducing capability. The index was derived from the weight and rank (Index = Weight x Rank). The index, rank, and weight details are shown in Table 1. The forest fire risk zone map was prepared by overlaying the index map layers using ArcGIS tools.

IV. RESULTS AND DISCUSSION

Topography is one of the most and the main factors in a forest fire hazard. Major factors which play a vital role are elevation, slope, aspect, the distance of settlement from the vegetation, and the density of the road (Brown and Davis,1973). The present study on risk assessment on forest fire has taken six major factors; namely land cover type, slope, elevation, aspect, road density, and settlement density. The factors' influence and impacts are described briefly as follows.

Table 1: Rank, Weight and Index Assigned for Different Factor

Sl.No	Factor	Class	Rank	Weight	Index
1	Land cover type	WATERBODY	1	30	30
		BUILTUP AREA	2		60
		SCRUB LAND	3		90
		AGRICULTURE	4		120
		DOUBLE CROP	5		150
		DENSE FOREST	6		180
		FOREST	7		210
2	Slope (Degree)	0 - 7.1	1	22	22
		7.1 - 19.3	2		44
		19.3 - 29.6	3		66
		29.6 - 39.5	4		88
		39.5 - 48.9	5		110
3	Aspect	Flat (−1)	1	18	18
		North (0-22.5)	2		36
		Northeast (22.5-67.5)	3		54
		East (67.5-112.5)	3		54
		Southeast (112.5-157.5)	4		72
		South (157.5-202.5)	5		90
		Southwest (202.5-247.5)	5		90
		West (247.5-292.5)	3		54
		Northwest (292.5-337.5)	3		54
		North (337.5-360)	2		36
4	Distance from settlement (m)	0 - 280	5	12	60
		280 - 710	4		48
		710 - 1240	3		36
		1240 - 1960	2		24
		1960 - 3520	1		12
5	Distance from road (m)	0 - 49	5	12	60
		49 - 98	4		48
		98 - 147	3		36
		147 - 197	2		24
		197 - 246	1		12
6	Elevation (m)	0 - 60	1	6	6
		60 - 127	2		12
		127 - 228	3		18
		228 - 404	4		24
		404 - 720	5		30

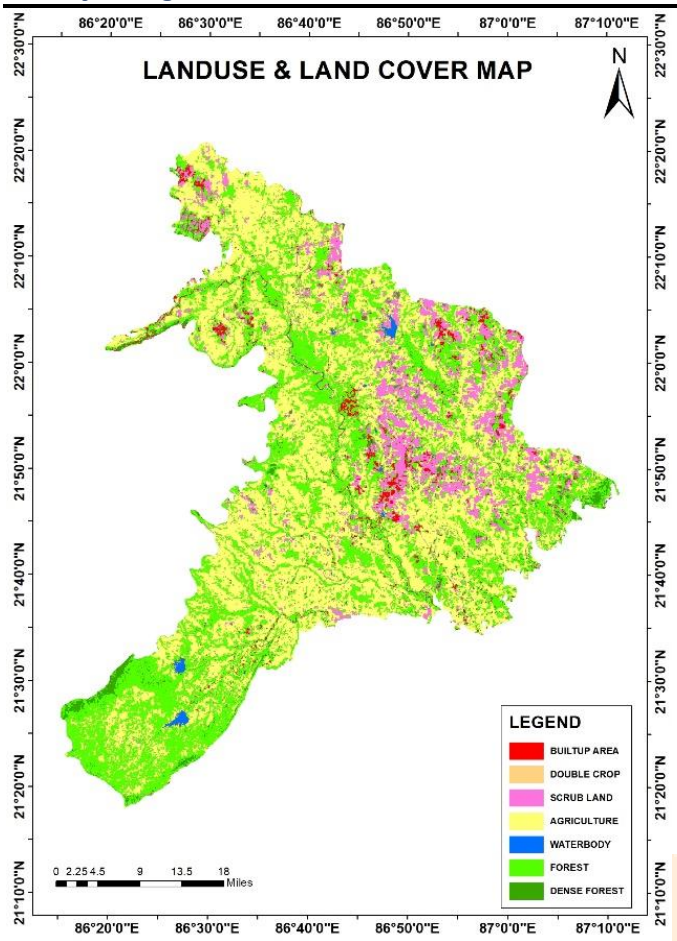

Figure 2: Landuse & Land Cover Map

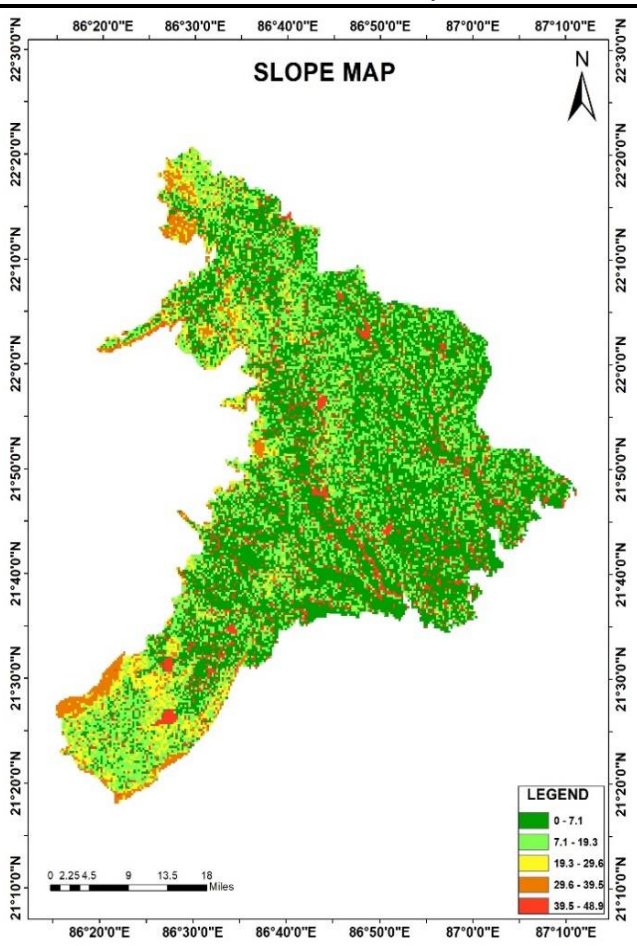

Figure 3: Slope Map

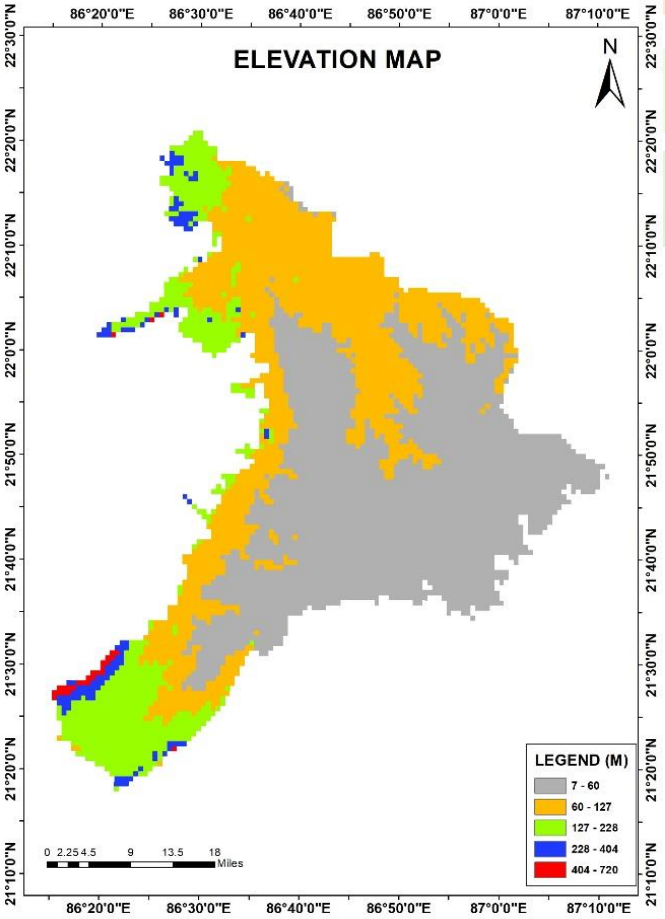

Figure 4: Elevation Map

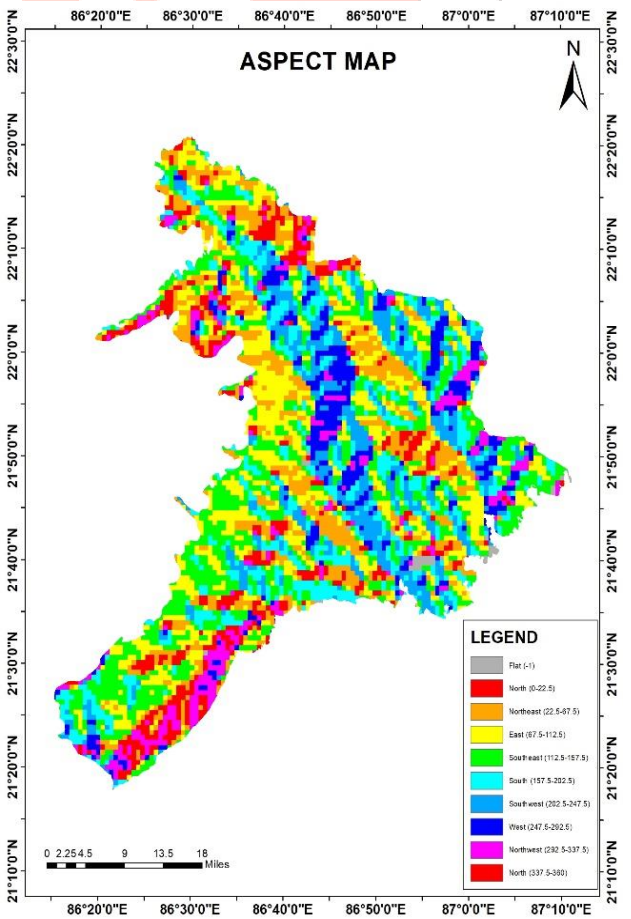

Figure 5: Aspect Map

4.1 Land Cover Type

The land cover represents the physical features on the earth's surface. The vegetation presence on the ground has a prime influence on fire behavior. The nature, amount, and spatial distribution of ignitable fuel largely govern the character of the fire in any forest location (Goldammer 1990). The land cover types found in this area are built-up areas, Agriculture including double crop, scrubland, water body, forest, and dense forest. In this area, the most susceptible to fire are scrubland, forest area, and dense forest areas. The

dense forest is very less in this forest division compared to the total forest area. The maximum area of forest cover is semi-dense and light-dense. The map representing the land use and land cover types of the Baripada Forest division is shown in Figure 2.

4.2 Slope

The geomorphology of an area has the most impact on the forest fire, hence slope is a key factor in the analysis of forest fire risk. The upward drifting of forest fires is faster and more intense than its downslope movement (Rothermel 1972). In steeper slopes, the rate of fire spread may rise, since flames are angled closer to the surface of the ground and wind effects can augment the process of heat convection for the fire produced (Zhong et al 2003). Based on the slope angle of this forest division it is grouped into five classes which are 0°-7.1°, 7.1°-19.3°, 19.3°-29.6°, 29.6°-39.5° and 39.5°-48.9°. The slope map of this area is shown in Figure 3.

4.3 Elevation

The forests present higher elevations are more prone to fire disasters in high elevation areas, and hours of sunshine increase highly during summer with high intensity of heating resulting in frequent fires. Also, in regions with higher elevations, the frequency of lightning strikes is higher, which can trigger forest fires. Figure 4 represents the elevation of this study area categorized into five classes.

4.4 Aspect

The compass direction that the slope faces is an aspect included as a key factor in this study area for analyzing the forest fire. The direction of the slope of a terrain, that is, its exposure to the sun's rays taken as its aspect (Setiawan I et al 2004). It is related to the rate of fuel drying and the movement of the fire (Chuvieco E et al 1989). Eastern aspects receive early heating from the sun, along with early slope winds. Western aspects receive late heating with higher intensity due to post-noon high energy at transfer. The aspect of this area has been grouped into nine classes Flat, North, Northeast, East, Southeast, South, Southwest, West, and Northwest. The aspect map shown in Figure 5 demonstrates the aspect distribution of the Baripada forest division area.

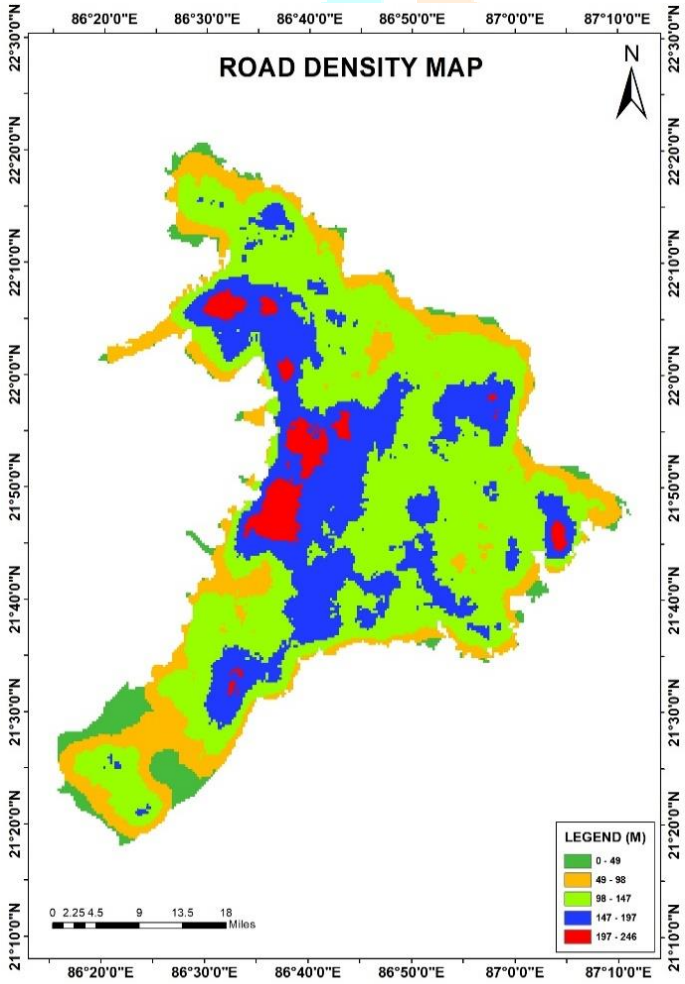

Figure 6: Road Density Map

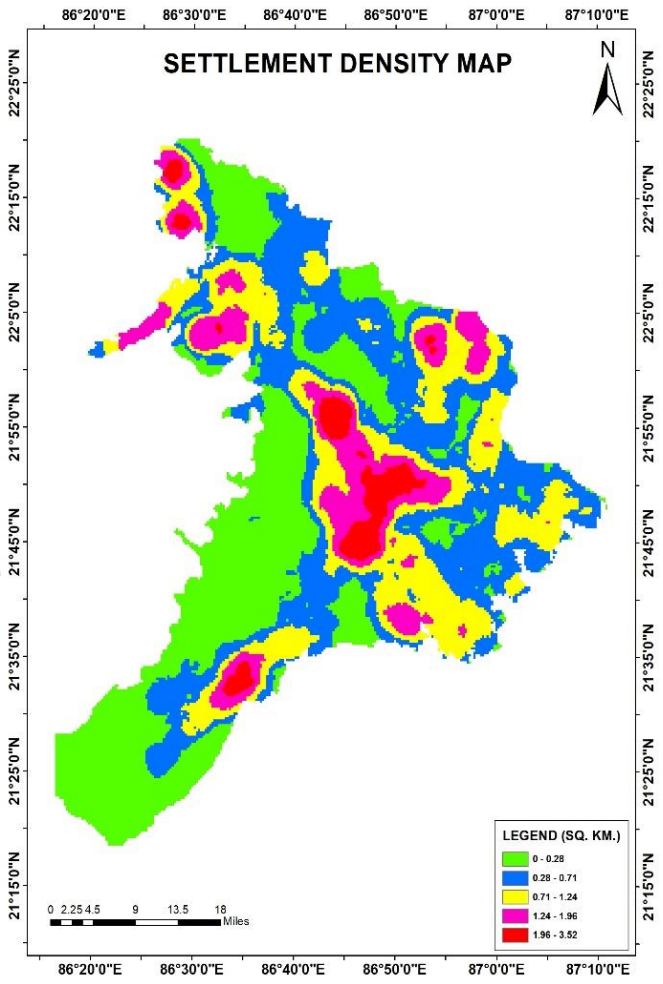

Figure 7: Settlement Density Map

4.5 Road Density

The possibility of forest fire is more near the roads, because of carelessness and irresponsible deeds like throwing lighted cigarette butts, cooking near the forest roads, fires released during the heating of coal tar for road construction, minor fires set by inhabitants for developing land for agriculture and lack of properly maintained forest fire belts on either side of the roads traversing the forest land. The area close to the road is more prone to fire. In this context, a road density map has been prepared which is shown in figure 6. The distance from road classes have been grouped into five viz., 0-49m, 49-98m, 98-147m, 147-197m, and 197-246 meters. The highest rank is given to areas closer to road networks (0-49m).

4.6 Settlement Density

Forest acentric human settlements and tribal settlements within the forest, both are very potential threats to the forest. The tourists traveling through the area or the tribal population living there can be the reason for fire intentionally or unintentionally. In the first case, they often set fire with some intention like clearing forest paths, hiding illicit felling of trees, and encroaching upon forest land. They also set fires as a part of tribal customs/rituals and for the collection of Non-Timber Forest Products (NTFP) like Mahula, honey, etc. settlement density map is shown in Figure 7.

4.7 Fire Risk Zones

The forest fire risk zone map of Baripada Forest Division is prepared from the index maps of land-use land cover, slope, elevation, aspect, road density, and settlement density by integrating all using GIS techniques. The area of the risk zone map is grouped into three classes viz., low risk, medium risk, and high risk. Finally, the risk zone map is validated with the fire incidence points collected from the Forest Survey of India (FSI). The majority of the fire incidence points spatially fall over areas closer to roads, used by the local inhabitants. This validates the fact that the majority of forest fires are due to deliberate or accidental human intervention. The forest fire risk zone map is shown in Figure 8. The demarcated forest fire risk zones of Baripada Forest Division using the Natural Breaks (Jenks) reclassification method. The result of that study reveals that 80% of the past forest fires occurred in high-risk medium-risk zones. Thus it is clear that the Equal Interval method will give more accurate results for the present methodology in this study area.

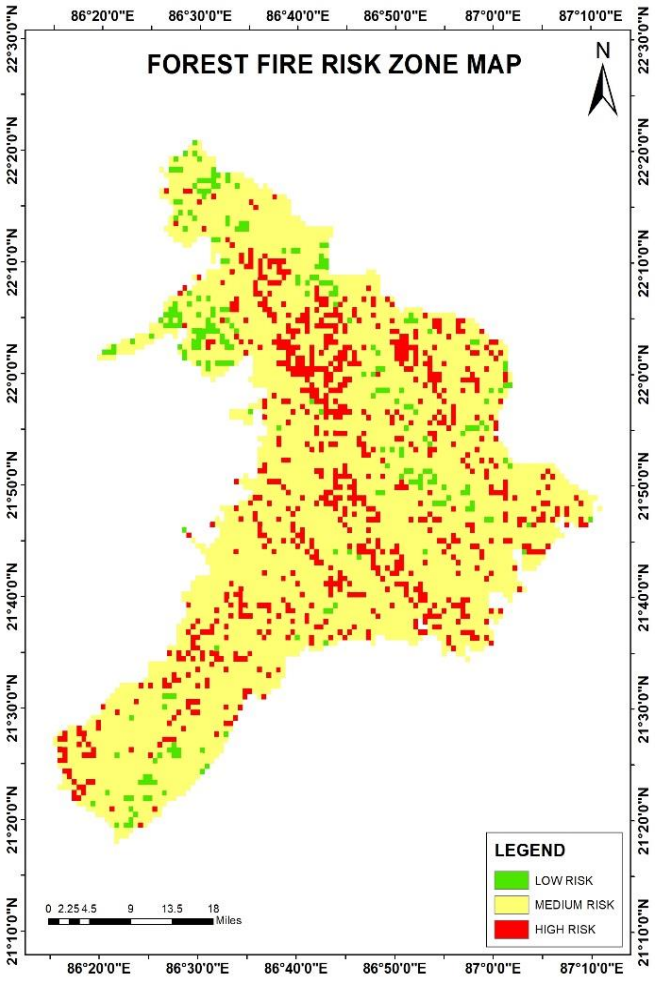

Figure 8: Forest Fire Risk Zone Map

4.8 Preventive Measures

Based on the forest fire risk zone mapping, such precautionary steps propounded for the decrement in a forest fire as follows:

- ✓ Conduct awareness meetings for villagers, tourists, and local tribes conveying to them the losses due to forest fire.
- ✓ Doing random IEC activities like posting hoardings, banners, and distribution of leaflets on the roads connected to the high forest fire risk zones.
- ✓ Creation of a rapid forest fire rescue team with advanced forest fire extinguisher tools.
- ✓ Establishment of watch towers on high and medium-risk zones and appoint an adequate number of trained and well-equipped fire watchers.
- ✓ Build the fire lines (firebreaks) to reduce or prevent the progress of forest fires.

V. CONCLUSION

Geospatial techniques were applied in this study area to demarcate the fire risk zones of Baripada forest divisions. GIS plays a vital role in forest fire analysis because of the integration between fire occurrence and the spatial characteristics of the factors influenced. These factors have different weights applied at the time of fire risk zone analysis. The forest division area is classified into three categories ranging from high risk, medium risk, and low risk. The present study has found that the Baripada forest division has also been affected by forest fires in history. The Outcome shows that the major forest fire that happened in the last several years occurred in high-risk and medium-risk zones. The prime reason for forest fires in this forest division is due to human interference may be it likely knowingly or unknowingly. The Position of settlements near the forest area and the livelihood dependency on the forest increase the chances of forest fire in this division. In this assessment, some suitable solutions were found which suggested preventive measures to undertake from time to time. The techniques used in this study area are a good tool for the analysis and management of forest fire for the departments and organizations to demarcate fire risk zones and to take necessary steps to mitigate the forest fire occurrence of any region.

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