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RS and GIS Based Spatial Mapping of Forest Fires in Wayanad Wildlife Sanctuary, Wayanad, North Kerala, India

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Abstract: Forest fires are of common occurrence in parts of Wayanad Wildlife Sanctuary in the central western slopes of Western Ghats, especially during the months from February to April. They pose great threat to forest vegetation, animal life and scattered human settlements. The present study aims to demarcate forest fire risk zones in Wayanad Wildlife Sanctuary in Kerala state using Remote Sensing (RS) and Geographic Information System (GIS) techniques. This study considers human related factors as well as environmental factors. The factors selected for the study are land use/land cover, distance from settlement, distance from road, slope, and elevation. The thematic maps are prepared using ArcGIS 9.3 and ERDAS Imagine 9.2 software tools. A Fire Risk Index model is used to prepare the forest fire risk zone map. In the prepared map, the area has been classified into three categories viz., high, moderate, and low risk zones. Analyses of the primary data related to previous incidences of forest fires in this area have validated the reliability of the application of this methodology. The GIS based forest fire risk prone area zonation therefore appears to be valid. Thus the present methodology can be used effectively in mitigation of forest fires, rehabilitation and restoration programs.

Keywords: *Forest fire, Western Ghats, Fire Risk Index, mitigation*

1. Introduction

Forest is a major natural resource and it plays an important role in maintaining environmental balance (Ghobadi et al., 2012). Hence conservation of forest vegetation and its pristine environment is very important. However forests are at the risk of elimination by causes like forest fires, human intervention, environmental change, etc. A forest fire poses threat not only to forest wealth but also disturbs the biodiversity, ecology and environment of the forest. Fires are responsible for the loss of vast areas of forests. Forest fires are sources of emission of a variety of gases, some of which can be toxic. Forest fires can be due to natural as well as man-made causes. The human induced fire can be classified under two categories; those caused by the carelessness of people, and those purposefully caused by local inhabitants.

In India, the estimated fire prone area under heavy, moderate and mild fire are 1.33%, 6.48% and 46.10% respectively, making the total forest fire prone area in the recorded forest area (771,821 sq. km) as 53.91% (FSI, 2013). In the light of this study it is observed that, areas under the Wayanad Wildlife Sanctuary also have been affected by forest fires. Forest fire risk evaluation is a critical part of fire prevention, since pre-fire planning resources require objective tools to monitor when and where a fire is more prone to occur, or when will it have more negative effects (Chuvieco et al., 2010).

Many researchers have prepared forest fire risk zone maps using RS and GIS techniques (Ajin et al., 2014a; Ajin et al., 2014b; Singh, 2014; Veeraanarayanaa and Ravikumar, 2014; Eskandari et al., 2013; Malik et al., 2013; Singh and Ajay, 2013; Sowmya and Somashekar, 2010; Dong et al., 2005; Jaiswal et al., 2002). Malik et al. (2013) delineated forest fire risk zones of Kansrao forest range in Uttarakhand state (India) using RS and GIS techniques. Factors like elevation, slope, aspect, road buffer, settlement buffer, and fuel type were selected, and the Fire Risk Zonation Index was used to prepare the risk zone map. Ghobadi et al. (2012) prepared forest fire risk zone map of Golestan province in Iran using GIS techniques. Parameters that affect the fire such as topography, vegetation, slope, aspect, NDVI, and meteorology factors were integrated within GIS to prepare the forest fire risk zone map. Hernandez-Leal et al. (2006) developed the Fire Risk Dynamic Index (FRDI) to delineate fire risk zones of Tenerife Island in Canary Islands (Spain). Factors like proximity to main roads, type of vegetation cover, insolation and altitude were selected for the study.

In the present study, an attempt has been made to delineate forest fire risk zones of Wayanad Wildlife Sanctuary in Kerala using geospatial techniques. A Fire Risk Index (FRI) model developed as a part of this study is used to prepare the forest fire risk zone map. The factors selected for the study are land use/land cover, distance from settlement, distance from road, slope, and elevation.

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1.1. Study Area:

The Wayanad Wildlife Sanctuary consists of four forest ranges; three of which constitute the larger southern block and the fourth is represented by the northern smaller block. The three forest ranges of the study area, representing the southern block are Kurichiyat, Sulthan Bathery and Muthanga. The present study area is bordered by Wayanad South Forest Division to the west and southwest, the state of Tamilnadu to the east and southeast, and the state of Karnataka to the north and northeast. This area is bounded within 76˚12'0" and 76˚28'0" E longitudes and 11˚34'0" and 11˚50'0" N latitudes. The temperature in this sanctuary varies from 13˚C to 32˚C and the annual average rainfall is 2000 mm. Of the total 369.12 sq. km area of the Wayanad Wildlife Sanctuary, the present study covers an area of 282.98 sq. kms, which represents 76.66% of the total area. The sanctuary is rich in biodiversity and is an integral part of the Nilgiri Biosphere Reserve. The major tree species are *Tectona grandis*, *Terminalia sp.*, *Dalbergia latifolia*, *Anogeissus latifolia*, *Grewia tiliaefolia*, *Adina cordifolia*, *Cinnamomum zeylanicum*, *Pterocarpus marsupium*, *Vateria indica*, *Lagerstroemia lanceolata*, *Artocarpus hirsutus*, *Macaranga peltata*, etc. This area is potentially one of the best habitats for Asiatic Elephants. Tiger, Gaur, Panther, Sambar deer, Spotted deer, Barking deer, Wild boar, Sloth bear, Nilgiri langur, Bonnet macaque, Common langur, Wild dog, Common otter, Malabar giant squirrel, etc are the major mammals.
The Wayanad Wildlife Sanctuary with an amazingly rich biodiversity and ecological significance is under recurring threat of forest fires, especially during the months of February, March and April. The study area map is shown in Figure 1.

2. Materials and Methods:

The Wayanad Wildlife Sanctuary was delineated from the Survey of India (SOI) topographic maps (Map numbers: 58 A/1, 58 A/2, 58 A/5 and 58 A/6) of 1:50,000 scale. The thematic maps required for this study were prepared using ArcGIS 9.3 and ERDAS Imagine 9.2 software tools. The land use/land cover map was prepared from the Landsat ETM+ image of 30 m resolution. The supervised classification was done using ERDAS Imagine software tools. The settlements and road networks were digitized from the SOI topographic maps using ArcGIS tools. 'Google Earth' data was used to update the settlements and road networks. The distance from settlement and distance from road maps were prepared using ArcGIS spatial analyst tools. The contour data was derived from the Cartosat – 1 DEM of 30 m resolution. ArcGIS spatial analyst tool was used to prepare the contour data at 10 m interval. The slope and elevation maps were prepared from the contour data using ArcGIS spatial analyst and 3D analyst tools. These thematic layers were reclassified by Natural breaks (Jenks) method. A FRI model was used to delineate the forest fire risk zones. Weight was assigned to each factor, and rank was given to each class of the factors, according to its influence on fire occurrence. The index was derived from the rank and weight (Table 1). The forest fire risk zone map was prepared by overlaying the index maps using ArcGIS tools. Finally the prepared risk zone map was validated with the fire incidence points.

3. Results and Discussion:

The present study has identified factors like land use/land cover, distance from settlement, distance from road, slope, and elevation, are significant in the forest fire disaster of the Wayanad Wildlife Sanctuary. Their significances are briefly discussed below.

3.1. Land use/land cover:

The land use/land cover classes in the study area are deciduous forest, forest plantation, agricultural land, built up area, and water body. The deciduous forest with dry and thick vegetation constitutes a major portion of the study area. This area is more susceptible to forest fire. Therefore highest rank is assigned to deciduous forest areas. The land use/land cover map is shown in Figure 2.

3.2. Distance from settlement:

The forests in areas close to the human settlements are more prone to forest fire, because of the possibility of accidental fire due to the cultural/livelihood practices of the inhabitants. There is high density of settlements within the sanctuary area with human and cattle population. The distance from settlement classes have been grouped into five *viz.*, 0 – 928.57 m, 928.57 – 2241.39 m, 2241.39 – 3778.35 m, 3778.35 – 5379.35 m, and 5379.35 – 8165.09 m. Highest rank is assigned to areas which are close to settlements (0 – 928.57 m). The distance from settlement map is shown in Figure 3.

3.3. Distance from road:

The chance of forest fire is more near the roads, mainly due to carelessness and irresponsible deeds like throwing lighted cigarette butts, 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 distance from road classes have been grouped into five *viz.*, 0 – 310.94 m, 310.94 – 637.82 m, 637.82 – 948.76 m, 948.76 – 1323.49 m, and 1323.49 – 2033.07 m. Highest rank is given to areas closer to road networks (0 – 310.94 m). The distance from road map is shown in Figure 4.

3.4. Slope:

Fire moves most rapidly up-slope and least rapidly down-slope (Rothermel and Richard, 1972). In steeper slopes, rate of fire spread might rise, since flames are angled closer to the surface of ground and wind

effects can supply the process of heat convection for the fire produced (Zhong et al., 2003). The slope of the area has been grouped into five classes *viz.*, 0 – 2.68˚, 2.68 – 5.03˚, 5.03 – 8.38˚, 8.38 – 13.87˚ and 13.87 – 28.52˚. Highest rank is given to areas with higher slope values (13.87 – 28.52˚). The slope map is shown in Figure 5.

3.5. Elevation:

The high elevation forests are more prone to fire. The typical geomorphology of the area characterised by hills separated by deep valleys are ideal for orographic air movement. This can flare up small fires to dangerous dimensions. High elevation zones are more exposed to the prevalent winds. Also the number of lightning strikes and related ignitions are more in the higher zones. The elevation of the sanctuary area has been grouped into five classes *viz.*, 730 – 828.39 m, 828.39 – 882.93 m, 882.93 – 924.63 m, 924.63 – 984.55 m, and 984.55 – 1144.24 m. Hence highest rank is assigned to areas with higher elevation values (984.55 – 1144.24 m). The elevation map is shown in Figure 6.

3.6. Forest fire risk zones:

The forest fire risk zone map of Wayanad Wildlife Sanctuary is prepared from the index maps of land use/land cover, distance from settlement, distance from road, slope, and elevation, by overlaying them using GIS techniques. The area of the risk zone map is grouped into three classes' *viz.*, low, moderate and high. Finally the risk zone map is validated with the fire incidence points collected from the Forest Survey of India (FSI). Result shows that out of the 45 forest fires during the period from 2003 to 2013, 34 (75.55%) occurred in the high risk zone, 10 (22.22%) occurred in moderate risk zone and only 1 (2.22%) occurred in low risk zone. Majority of the fire incidence points spatially fall over areas closer to roads, used by the local inhabitants. This validates the fact that majority of forest fires are due to deliberate or accidental human intervention. The forest fire risk zone map is shown in Figure 7.

4. Conclusion:

The present study using RS and GIS techniques based on spatial mapping has shown that the Wayanad Wildlife Sanctuary and bordering forests can be classified as high, moderate, and low fire risk zones. The environmental and human related factors are selected for this study. GIS thematic maps show that the majority of the forest fire risk zones are vulnerable more because of proximity and access to human intervention. One major observation revealed by the present study is that the high risk zones cover maximum area and hence can seriously affect the other two zones also. The present study therefore concludes that forest fire protection corridors are to be delineated to mitigate any future instance of fire disaster in this area. Further the result of the study shows that the high risk zone delineated based on the parameters identified in this study has experienced the highest incidence of forest fires (75.55%), and hence the methodology of risk zone delineation is validated. This shows that the RS and GIS based techniques and method can be effectively used in risk assessments.

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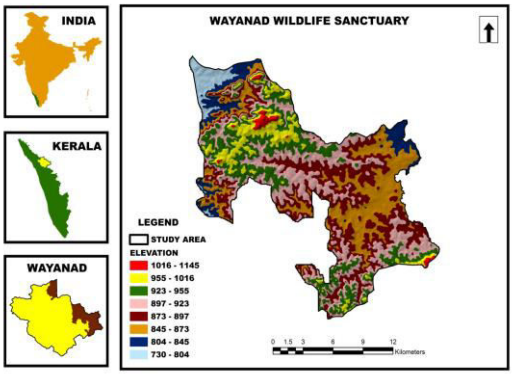

Figure 1: *Location map of the study area*

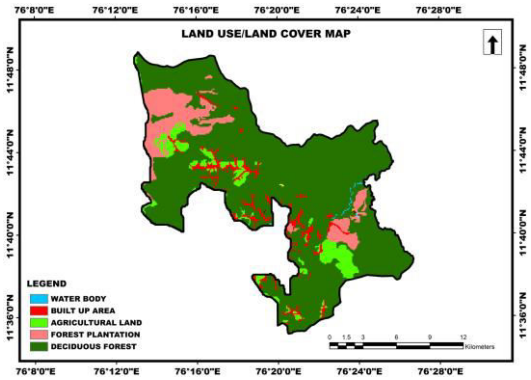

Figure 2: *Land Use/Land Cover map*

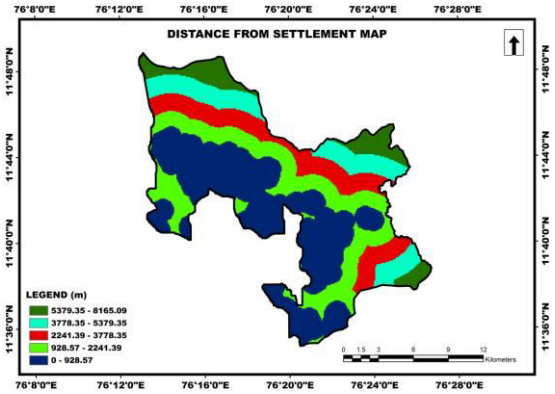

Figure 3: *Distance from settlement map*

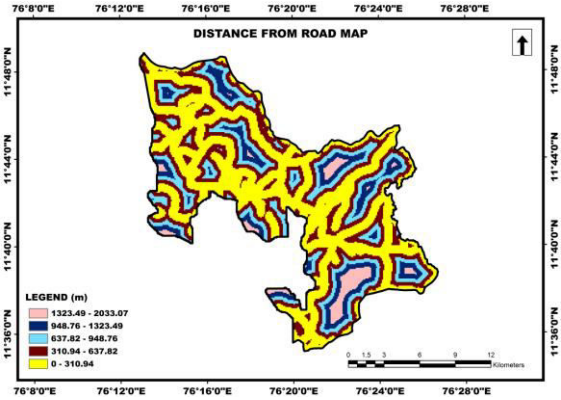

Figure 4: *Distance from road map*

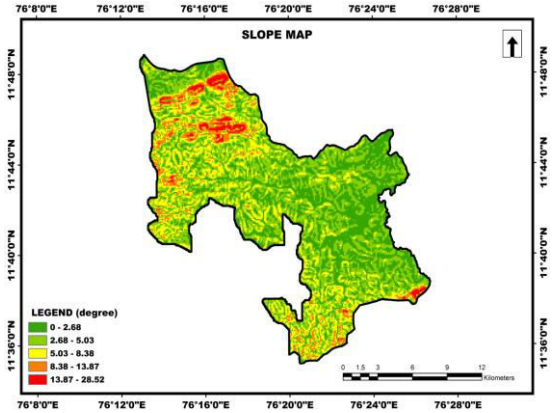

Figure 5: *Slope map*

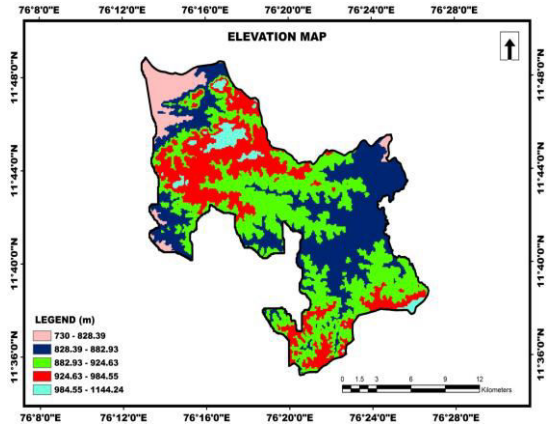

Figure 6: *Elevation map*

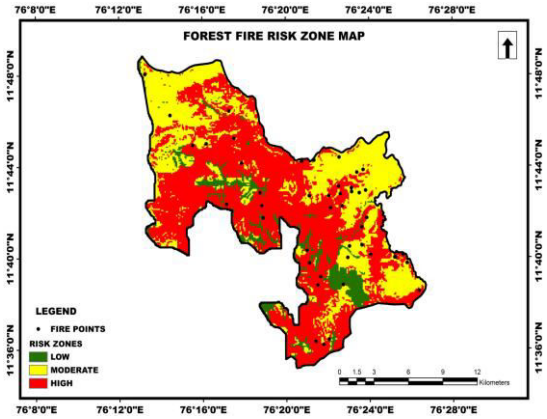

Figure 7: *Forest fire risk zone map*

Table 1: *Rank, Weight and Index assigned for different factors*

Factor	Class	Rank	Weight	Index
Land Use/Land Cover	Deciduous forest	5	10	50
	Forest plantation	4		40
	Agricultural land	3		30
	Built up area	2		20
	Water body	1		10
Distance from settlement (m)	0 – 928.57	5	2	10
	928.57 – 2241.39	4		8
	2241.39 – 3778.35	3		6
	3778.35 – 5379.35	2		4
	5379.35 – 8165.09	1		2
Distance from road (m)	0 – 310.94	5	2	10
	310.94 – 637.82	4		8
	637.82 – 948.76	3		6
	948.76 – 1323.49	2		4
	1323.49 – 2033.07	1		2
Slope (degree)	0 – 2.68	1	3	3
	2.68 – 5.03	2		6
	5.03 – 8.38	3		9
	8.38 – 13.87	4		12
	13.87 – 28.52	5		15
Elevation (m)	730 – 828.39	1	1	1
	828.39 – 882.93	2		2
	882.93 – 924.63	3		3
	924.63 – 984.55	4		4
	984.55 – 1144.24	5		5