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2

FOREST FIRE RISK ZONE MAPPING IN CHINNAR WILDLIFE SANCTUARY, KERALA, INDIA: A STUDY USING GEOSPATIAL TOOLS

Ajin R. S*[1], Ana-Maria Loghin[2], Vinod P. G[1] and Mathew K. Jacob[3]

[1]Geomatics Division, GeoVin Solutions Pvt. Ltd., Thiruvananthapuram, Kerala, India

[2]Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, Gheorghe Asachi Technical University of Iasi, Romania

[3]Post Graduate Department of Geology, Sree Narayana College, Sivagiri, Kerala, India
*Email: ajinares@gmail.com

Abstract: *A Forest fire is a major environmental disaster occurring in many countries of the world, causing damage to ecology, economy, and property. This natural phenomenon causes major changes in the forest structure and function, and above all this, it endangers wildlife. Fires are one of the major natural risks in the forests of the Western Ghats, a biodiversity hotspot in India. The present study area is also prone to fire, where a total of 13 forest fires were recorded for the last 11 years. The objective of this study is to demarcate the forest fire risk zones in the Chinnar Wildlife Sanctuary using geospatial tools. In order to prepare the fire risk zone map, the Fire Risk Index method is used. In the mapping process, factors such as land cover type, slope, distance from settlement, distance from road, and elevation are selected. According to their sensitivity to forest fires, five different categories of risk zones are demarcated. Thus the final forest fire risk zone map of the study area comprises very low, low, moderate, high, and very high risk zones. The result of the study is validated with the fire incidence data, and shows that 76.92 percent of fire incidences are in the high and very high risk zones. This study based on geospatial technology will help the authorities to easily identify the risk zones, and can offer an effective control for a better planning and preparation of forest fire control and management.*

Key words*:* Forest Fire, Western Ghats, Geospatial Tools, Risk Zones

1. Introduction

Forests are one of the most important natural resources on earth, and they play a crucial role in maintaining the balance of climate, conserving soil, water, and biodiversity (Kuter et al., 2011). Most of the forests are facing ever increasing risks, especially from fires. Forest fires are influenced directly or indirectly by geomorphology, climate and anthropogenic activities. Fires can be caused by natural as well as human induced factors. Most of the forest fires occurring in India are due to anthropogenic activities. These forests are facing serious pressure from people because of the increasing demand for forest products and forest land. Uncontrolled fire can cause loss of forest resources, loss of biodiversity, land degradation, adverse health problems, and even loss of life. The present study area, Chinnar Wildlife Sanctuary, part of the Western Ghats, a biodiversity hotspot in India and UNESCO world heritage site is also prone to forest fires, with a total of 13 forest fires reported for the last 11 years. In the study area, forest fires occur more frequently during the period between the months of December and May.

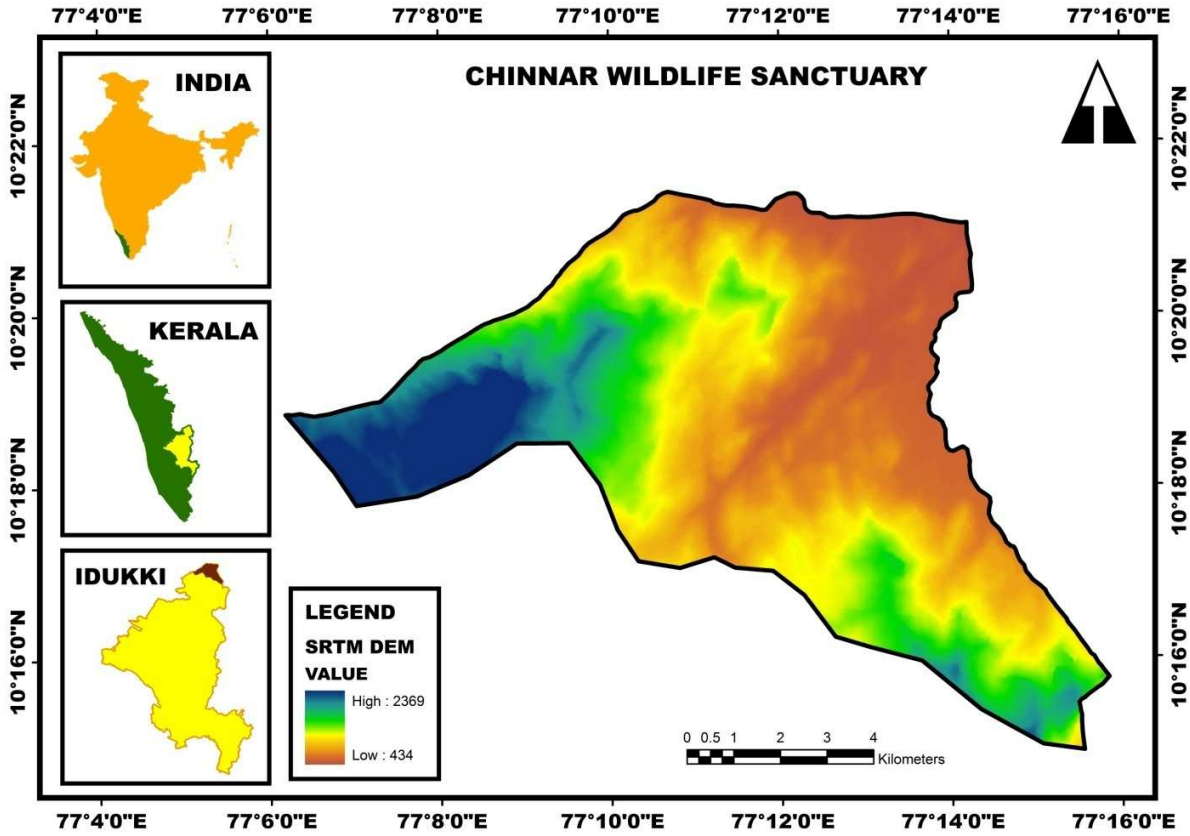
Remote Sensing (RS) and Geographic Information System (GIS) techniques are effective tools and utilized by many researchers (Ajin et al., 2015; Ajin et al., 2014; Gerdzheva, 2014; Soto, 2012; Ponomarev, 2011; Puri et al., 2011; Calle and Casanova, 2008; Riebau and Qu, 2005; Chandra, 2005; Chuvieco et al., 1999) for the delineation of forest fire risk zones. Ajin et al. (2014) demarcated the forest fire risk zones of Idukki Wildlife Sanctuary in Kerala using RS and GIS techniques. The factors selected are land cover type, distance from settlement, distance from road, slope, and elevation. Puri et al. (2011) identified the forest fire risk zones in parts of Northeast India using geospatial tools. Factors such as land use land cover (LULC), vegetation type, Digital Elevation Model (DEM), slope, aspect, proximity to roads, and proximity to settlements are used to demarcate the fire risk zones. Yunhao et al. (2007) demarcated the fire risk areas of the Malaysian peninsula. Variables such as fuel type maps, remote sensing data and meteorological data are used for the study.

The objective of this study is to describe a methodology based on RS and GIS techniques that demarcates the forest fire risk zones, including their classification depending on their sensitivity to forest fires. In order to generate the forest fire risk zone map, five important influencing factors *viz.* land cover type, slope, distance from settlement, distance from road, and elevation are selected. For the delineation of fire risk zones, the Fire Risk Index (FRI) method is used.

1.1. Study Area

The present study area is represented by the Chinnar Wildlife Sanctuary (WLS), a unique protected area located in the Idukki district of Kerala state in south India. The Chinnar WLS, with a total area of 90.44 sq. km, lies between 10˚15’0” and 10˚22’0” N latitudes and 77˚6’0” and 77˚16’0” E longitudes. This WLS is bounded by the state of Tamil Nadu to the north, east, and west, Eravikulam National Park to the southwest, and Munnar forest division to the south. In this area, the temperature varies from 12˚C to 38˚C; and the annual average rainfall is only 500 mm, as it is located in the rain shadow regions of the southern Western Ghats. This area has a large variety of ecosystems. The major thorny scrub species in the WLS are *Acacia arabica*, *Acacia leucophloea*, *Acacia concinna*, *Prosopis juliflora*, and *Opuntia dillenii*; Dry deciduous species include *Santalum album*, *Anogeissus latifolia*, *Terminalia arjuna*, *Tamarindus indica*, *Pongamia glabra*, *Dalbergia latifolia*, *Tectona grandis*, *Lagerstroemia lanceolata*, *Cassia fistula*, *Terminalia bellirica*, *Emblica officinalis*, etc. The common animals found are Elephant, Crocodile, Gaur, Tiger, Sambar deer, Common langur, Bonnet macaque, Hanuman monkey, Nilgiri tahr, Grizzled giant squirrel, etc. The study area map is shown in Figure 1.

Figure 1: Location of the Study Area



2. Materials and Methods

The study area was delineated from the Survey of India (SOI) toposheets (58 F/3, 58 F/7, and 58 F/8) of 1:50,000 scale. In order to generate and prepare the thematic maps, ArcGIS 9.3 and ERDAS Imagine 9.2 software tools were used. The land cover type map was prepared from the IRS-P6 LISS-III image of 23.5 m resolution. ERDAS Imagine software was used for the supervised classification of the pre-processed satellite image. The road networks and human settlements were digitized from the SOI toposheets and Google Earth. The distance from road and distance from settlement maps were prepared from the digitized data using ArcGIS spatial analyst tools. The contour data was derived from the SRTM DEM of 30 m resolution. The slope and elevation maps were prepared from the 10 m interval contour data using ArcGIS spatial analyst and 3D analyst tools. The FRI method (Ajin et al., 2014; Ajin et al., 2015) was used for the demarcation of forest fire risk zones. The thematic map layers were reclassified using the Natural Breaks (Jenks) method. Rank was assigned to each class of the thematic map layers, and weight was given to each thematic map layer, according to their sensitivity to fire or their fire-inducing capability. The index (Table 1) was calculated from the weight and rank (Index = Weight X Rank). The forest fire risk zone map was prepared by overlaying the index map layers using ArcGIS tools. Finally, the risk zone map was validated using the forest fire incidence points collected from the records of the Forest Survey of India (FSI).

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

#	Factor	Class	Rank	Weight	Index
1	Land cover type	Water body	1	10	10
		Plantation	2		20
		Evergreen forest	3		30
		Deciduous forest	4		40
		Grassland	5		50
2	Slope (degree)	0 – 10.03	1	3	3
		10.03 – 19.01	2		6
		19.01 – 27.72	3		9
		27.72 – 39.08	4		12
		39.08 – 67.33	5		15
3	Distance from settlement (m)	0 – 868	5	2	10
		868 – 1619	4		8
		1619 – 2604	3		6
		2604 – 4083	2		4
		4083 - 5983	1		2
4	Distance from road (m)	0 – 407	5	2	10
		407 – 900	4		8
		900 – 1580	3		6
		1580 – 2600	2		4
		2600 – 4334	1		2
5	Elevation (m)	440 – 731	1	1	1
		731 – 1032	2		2
		1032 – 1377	3		3
		1377 – 1806	4		4
		1806 – 2360	5		5

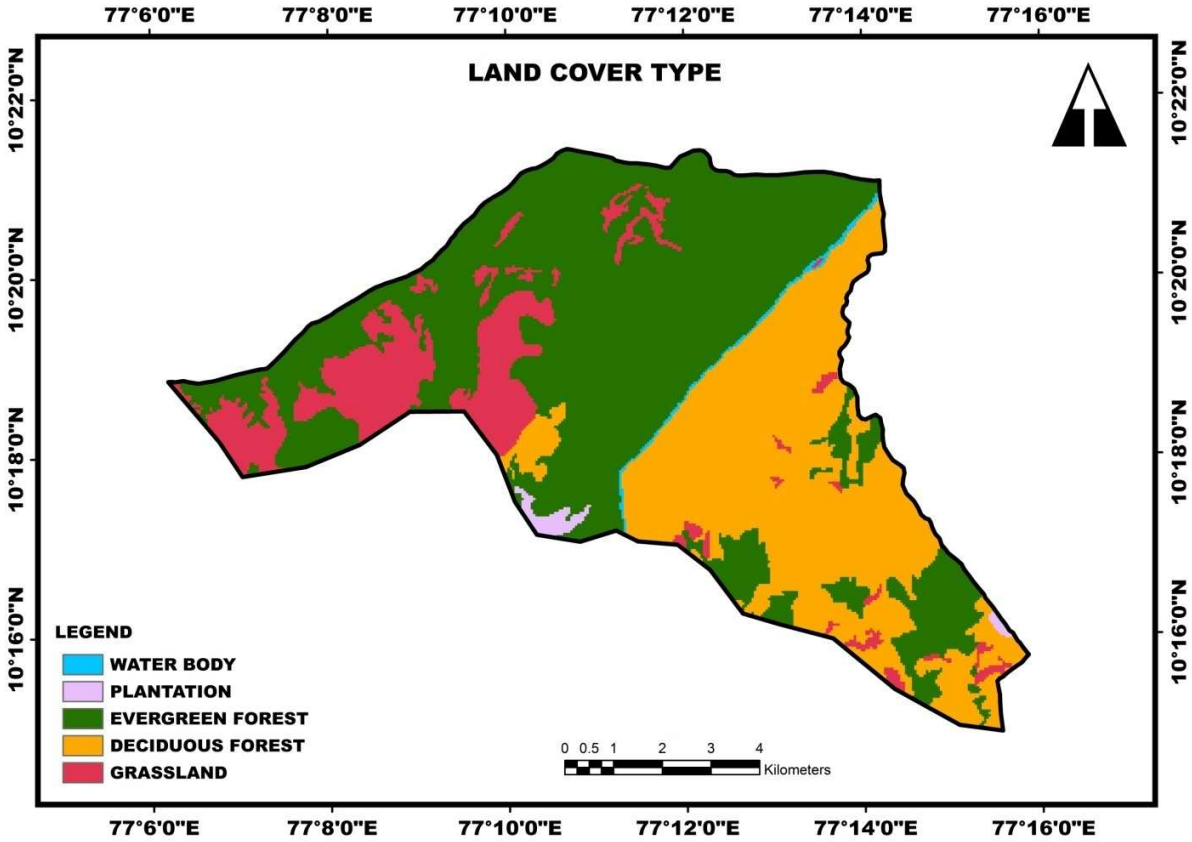
3. Results and Discussion

In order to have a precise evaluation of fire problems in this area and to take good decisions, it is very important to have a fire risk zone map. A forest fire depends on many factors, which have different influences. Each factor plays a significant role in the process of ignition and spreading of fires.

3.1. Land Cover Type

The physical materials like trees, grass, bare ground and also water body located at the surface of the earth form the land cover. The land cover type has an important influence in the forest fire behaviour. In contrast to the areas covered with moist and sparse vegetation, the dry and dense vegetation areas are more susceptible to forest fires. The land cover types found in this study area are grassland, deciduous forest, evergreen forest, plantation, and water body. In this sanctuary, the areas more prone to forest fires are those covered with grassland and deciduous forest. Most of the grasslands are located in the western part of the area, whereas the deciduous forests are mainly found in the central and eastern parts. The land cover type map is shown in Figure 2.

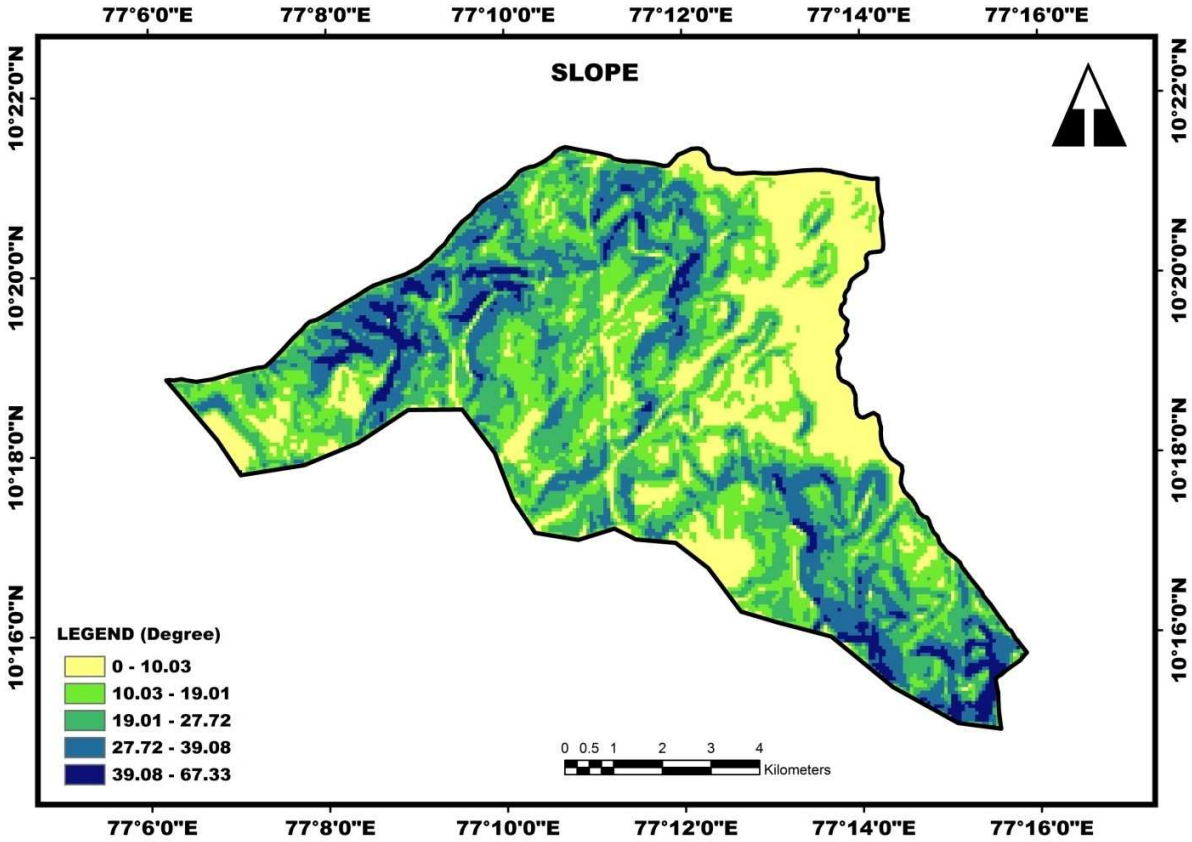
Figure 2: Land Cover Type



3.2. Slope

Slope represents another very important factor that can induce forest fires and influences the fire behaviour. Fire moves most quickly up slope and least quickly down slope (Rothermel and Richard, 1972). In steeper slopes the rate of fire spread might rise, since flames are angled closer to the ground surface and the effects of the wind can supply the process of heat convection (Zhong et al., 2003). Wind currents move uphill and thus the rate of fire spread increases with slope steepness. Thus the fire spreading is more in the areas with steeper slopes. The slope of this study area is grouped into five classes, *viz.* 0 – 10.03˚, 10.03 – 19.01˚, 19.01 – 27.72˚, 27.72 – 39.08˚, and 39.08 – 67.33˚. The slope map is shown in Figure 3.

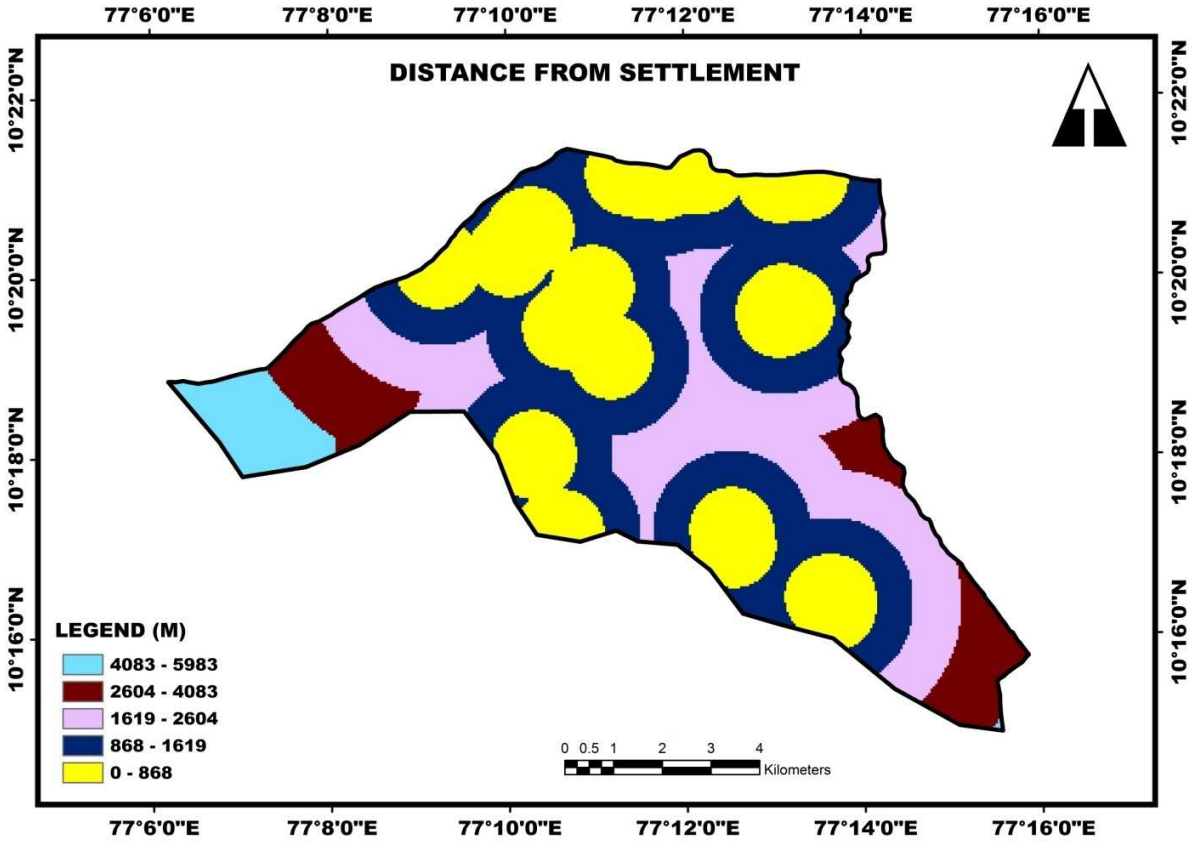
Figure 3: Slope



3.3. Distance from Settlement

The chance of forest fire is higher in the areas closer to the human settlements. The tribals or tourists staying in the forests can cause fires intentionally or unintentionally. Fire set by the poachers to encroach upon forest land, fire set by the tribals to collect Non Timber Forest Products and to clear forest path, and the fire set by timber smugglers to conceal the stumps of illicit felling can cause intentional forest fires. Sometimes the fire set by tribals as a part of their traditions/customs also can result in fires. Accidental forest fires can happen from the fire set to drive away wild animals, from recklessly thrown lighted cigarette butts, and also while burning the agricultural residues. The tourists staying in the temporary shelters can cause accidental fires, mainly from the unextinguished fire woods left after cooking food or after campfires. Depending on the distance from settlements, the study area is grouped into five different classes *viz.*, 0 – 868 m, 868 – 1619 m, 1619 – 2604 m, 2604 – 4083 m, and 4083 – 5983 m. The distance from settlement map is represented by Figure 4.

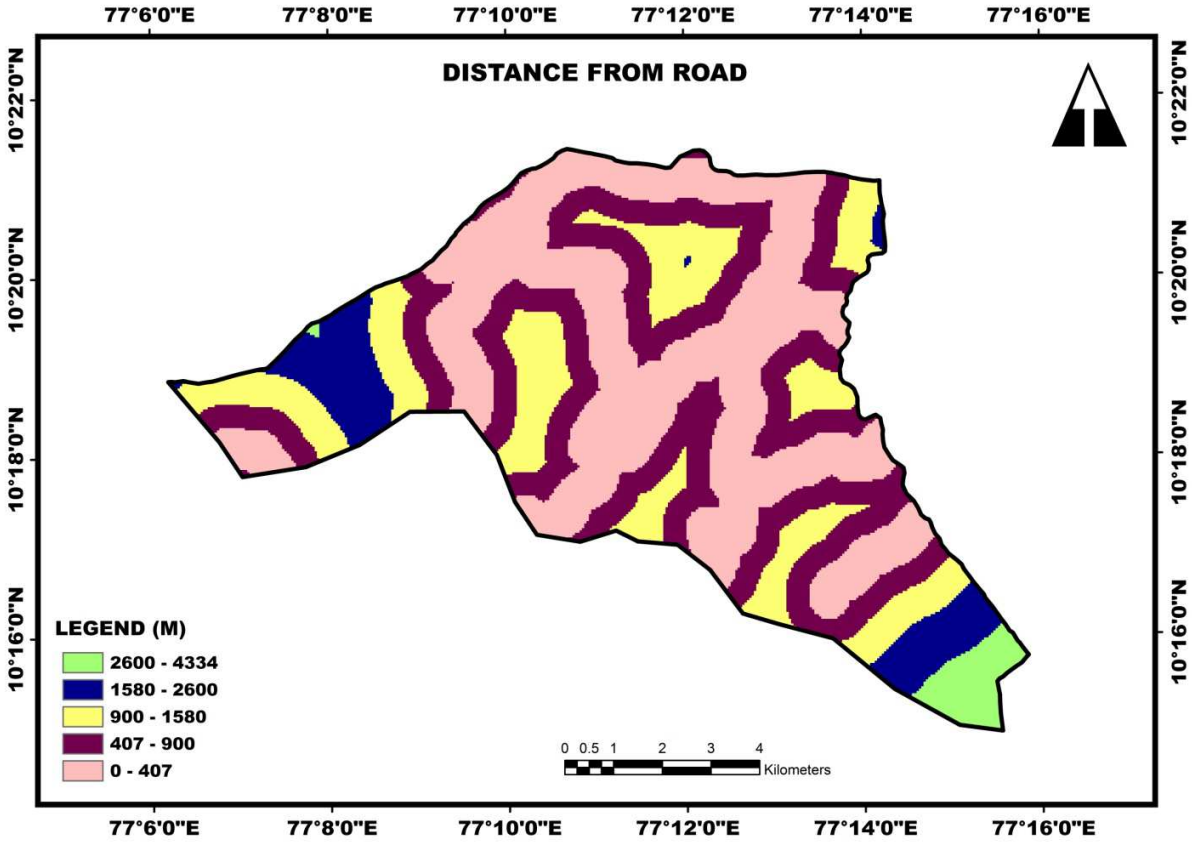
Figure 4: Distance from Settlement



3.4. Distance from Road

Another important factor in causing forest fires is the roads near and within the forests. Forests closer to the roads are more prone to fires, because the villagers and tourists travelling through these roads can cause fires, mainly due to unintentional reasons. The carelessly thrown unextinguished cigarette butts or match sticks, fire released during the heating of coal tar for road construction, etc are the causes of unintentional forest fires. Depending on the distance from roads, the area is grouped into five classes *viz.*, 0 – 407 m, 407 – 900 m, 900 – 1580 m, 1580 – 2600 m, and 2600 – 4334 m. The distance from road map is shown in Figure 5.

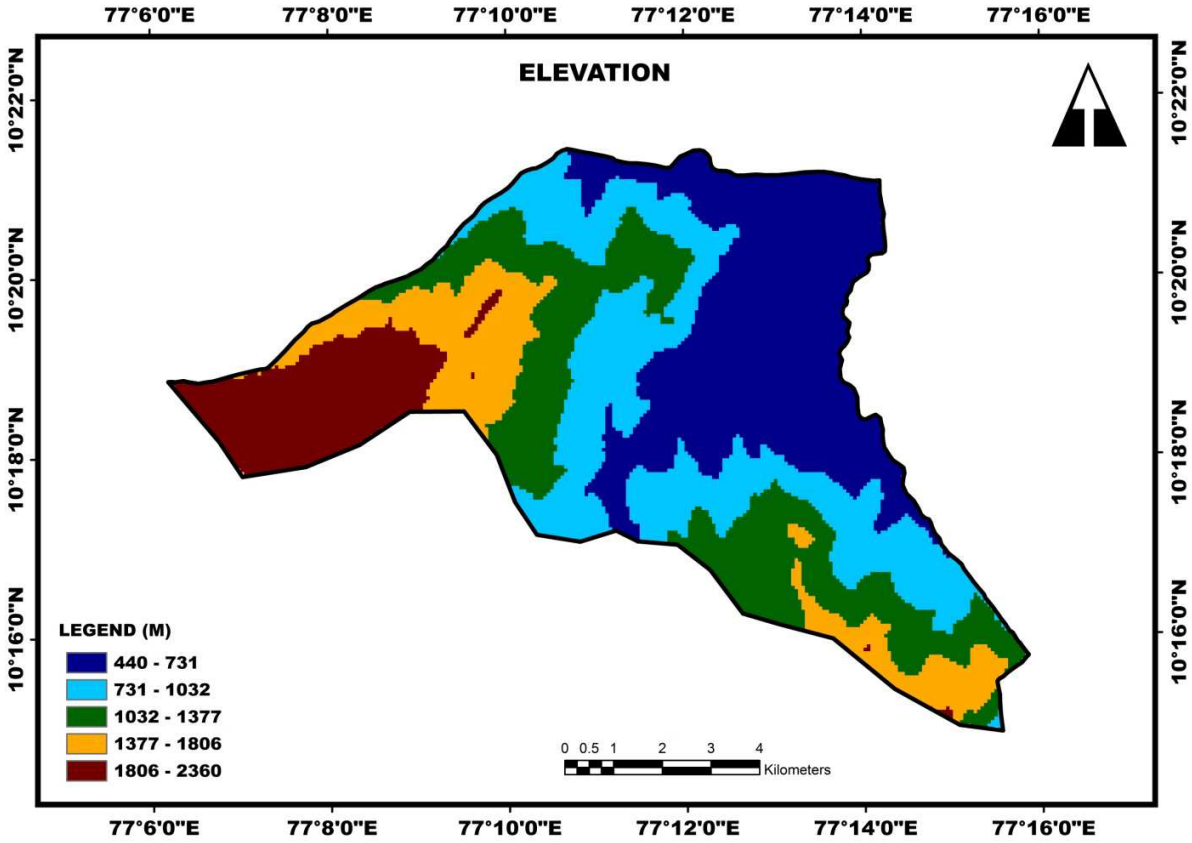
Figure 5: Distance from Road



3.5. Elevation

Elevation is a crucial topographic factor that is associated with wind behaviour, has a large role in fire spreading. The areas with a higher elevation located in the western parts of the sanctuary are more prone to forest fires. These areas are more exposed to the prevailing winds. Due to orographic convective air movement, warm air during day time move in the uphill direction. Also the number of lightning strikes and related ignitions are more in areas of higher elevation. The elevation of the area is grouped into five different classes *viz.* 440 – 731 m, 731 – 1032 m, 1032 – 1377 m, 1377 – 1806 m, and 1806 – 2360 m. The elevation map is shown in Figure 6.

Figure 6: Elevation



3.6. Fire Risk Zones

The forest fire risk zone map of the study area is prepared by combining the index map layers of the selected factors *viz.*, land cover type, slope, distance from settlement, distance from road, and elevation using GIS tools. The study area is divided into five risk zones *viz.* very low, low, moderate, high, and very high. Depending on their fire inducing capability, there were assigned different weights to the influencing factors. Highest weight has been assigned to land cover type, because vegetation has the greatest influence in forest fire support. The second highest weight has been given to slope, because slopes contribute to convectional preheating and, easy ignition and spreading of fire. The risk zone map is validated with the fire incidence points for the last 11 years (2005 – 2015) collected from the FSI. The result shows that out of the 13 forest fires, 10 (76.92 percent) occurred in the high and very high risk zones, 2 (15.38 percent) occurred in the moderate risk zone, and 1 (7.69 percent) occurred in the low and very low risk zones. The forest fire risk zone map is shown in Figure 7. Most of the fire incidence points fall spatially near the roads and settlements, which points out a human induced origin; intentionally or unintentionally. The area of each risk zone is calculated and is shown in Table 2.

Figure 7: Fire Risk Zones

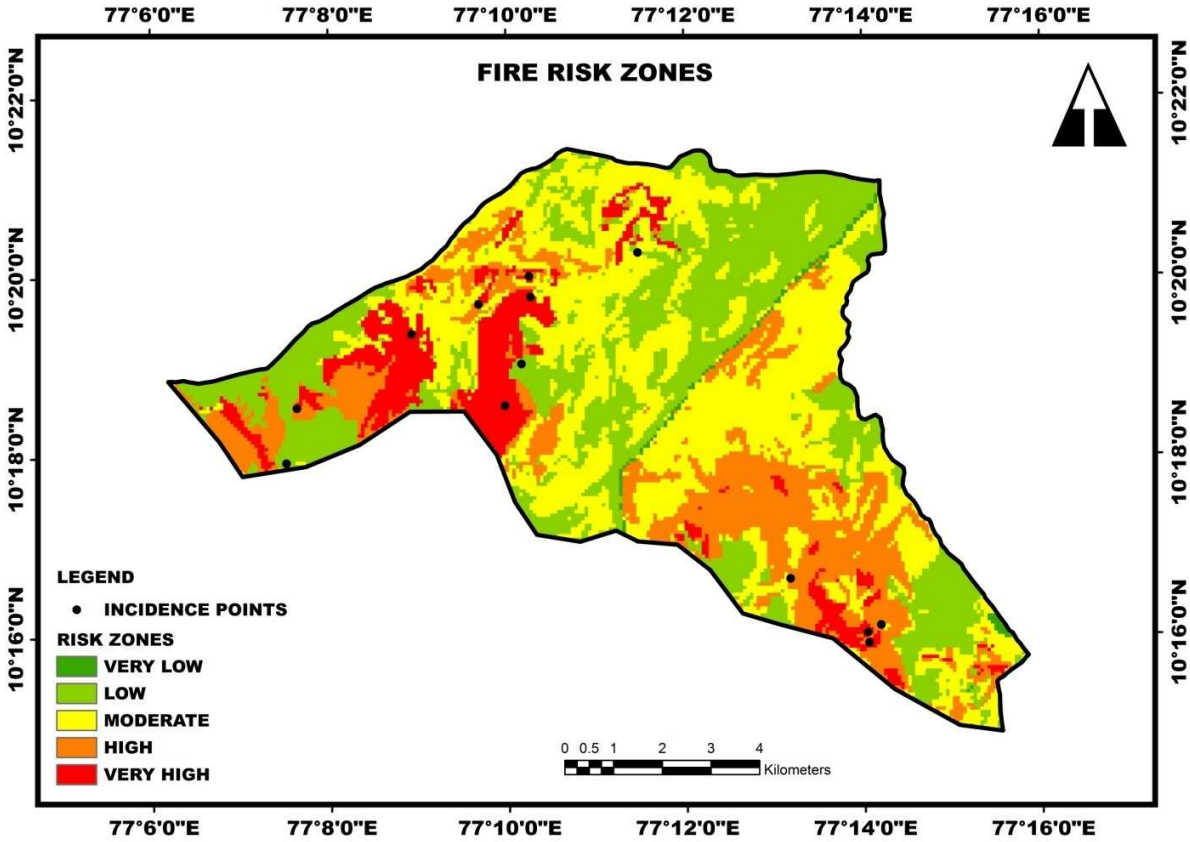


Table 2 Area of Fire Risk Zones

Risk Zones	Area (sq. km.)
Very Low	0.67
Low	28.29
Moderate	34.21
High	18.34
Very High	8.89

4. Conclusion

In the present study, factors such as land cover type, slope, distance from settlement, distance to road, and elevation are used for the risk zone mapping. Based on the risk, the area is grouped into five different zones ranging from ‘very low’ to ‘very high’. Result shows that most of the fires occurred in the areas closer to the settlements and roads; this fact suggests that forest fires are induced by people, in an intentionally or unintentionally way. Therefore the very high, high and moderate fire risk zones are areas which need immediate precautionary measures to prevent fires in future. The result of this study is validated using the fire incidence points, which confirms that 76.92 percent of the forest fires occurred in the high and very high risk zones. Fire risk models are very useful in planning the infrastructure, main roads,

subsidiary roads, inspection paths, etc, leading to a reliable communication and transport system to efficiently fight against small and large forest fires. These maps provide valuable information for taking precautionary measures to reduce forest fire risk and hence for the environmental protection of forests. The final risk zone map will help the forest fire managers to easily identify the risk zones and to plan better forest management.

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