

FOREST AND WILDLAND FIRE RISK ASSESSMENT USING GEOSPATIAL TECHNIQUES: A CASE STUDY OF NEMMARA FOREST DIVISION, KERALA, INDIA

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Abstract: Wildfires bursting into forests are one of the major natural hazards in the Western Ghats region of Kerala. The aim of the present study is to demarcate the forest and wildfire risk zones in Nemmara Forest Division. This area frequently faces wild land and forest fire. In this study a combination of Remote Sensing and GIS technology has been used to develop the Fire Risk Index model. The variables used for the present study were fuel type, slope, elevation, road density and settlement density. The selected variables were weighted based on their impact on the fire occurrence. ERDAS Imagine 9.2 and ArcGIS 9.3 software tools were used to prepare fire risk zone map. The prepared forest fire risk map of Nemmara Forest Division has classified the area into five risk zones: very high, high, moderate, low and very low. To validate the prepared map, the result was compared with forest fire inventory points.

Keywords: GIS, risk zone, Western Ghats, wildfire

Introduction:

A wildfire, also known as a wildland fire, forest fire, vegetation fire, grass fire, peat fire, bush fire, or hill fire, is an uncontrolled fire often occurring in wildland areas, but which can also consume houses or agricultural resources (Modh 2010). The most common causes of wildfire are lightning and human carelessness. Most of the wildfires occurring today are human induced. Forest fires are frequent during summer, when the fuel (fallen branches, leaves etc.) becomes dry and highly flammable.

The propagation of the forest fire has three mechanisms (Modh 2010). They are:

- crawling fire: the fire that spreads through low level vegetation;

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- crown fire: the fire that spreads through the top of the forest at an incredible speed. They can be extremely dangerous particularly on windy days;
- jumping or spotting fire: the burning fuel (branches and leaves) are carried by wind and likely to cause distant fires. Thus the fire can jump over a road, river, or even a firebreak.

Forest fires may result in deforestation and exacerbate the level of carbon dioxide in the atmosphere. It can also affect the forest habitat and species population and distribution. Sometimes wildfires may cause large scale damage to people and property, particularly when these reach the tribal communities. Forest fires affect 37 million ha of forests annually, and about 55% of the country's forest areas are being subjected to forest fires each year (Gubbi 2003). The present study area, Nemmara forest division, is part of Western Ghats, a biodiversity hotspot in India. Many areas in the Western Ghats were frequently affected by forest fire. Whether natural or man-made, forest fires are able to cause widespread destruction within a short time span. Ground fire destroys the organic matter, which is very necessary to maintain an optimum level of humus in soil (Sringswara et al. 2012). Forest fires can hinder the growth of grasses, herbs and shrubs, which may result in soil erosion.

Kimothi and Jadhav (1998) estimated the severity and damage inflicted by the forest fire in Central Himalayan region using Remote Sensing (RS) and Geographical Information System (GIS) techniques. Kanga et al. (2013) prepared fire risk map of Taradevi forest range, Shimla district, Himachal Pradesh using geospatial techniques. Factors considered include fuel type, slope, aspect, elevation, road and settlement. Ajin et al. (2014) prepared forest fire risk zone map of Peppara Wildlife Sanctuary employing RS and GIS techniques. The factors selected were land use/land cover, slope, elevation, distance

from road, and distance from human settlements.

The present study has the objective to identify the areas affected by forest fire using Remote Sensing (RS) and GIS techniques. The factors like fuel type, slope, elevation, road density and settlement density are engaged in this study.

Materials and methods:

Study Area

Nemmara Forest Division (Fig. 1) is situated in the central part of Kerala and has an area of 1437.98 Sq. km. It shares its boundary in the east with Tamil Nadu and in the west with Thrissur Forest Division. To the southwest there is Peechi Wildlife Sanctuary (WLS) and Chimmomy WLS. Chalakudy division shares the boundary in the south along with the Parambikulam WLS. Palakkad division binds it in the north. Nemmara Forest Division consists of 3 forest ranges: Alathur, Nelliampathy and Kollengode ranges. The highest elevation is noticed in the Kollengode Forest Range of this division. The Alathur range of this division is almost plain whereas the Nelliampathy range is steep. The total extent of Nelliampathy range is 207.4 Sq. km, Alathur range is 81.2 Sq. km, and Kollengode range is 68.55 Sq. km. Out of the 3 ranges, only Nelliampathy range contains reserve forests (205.51 Sq. km).

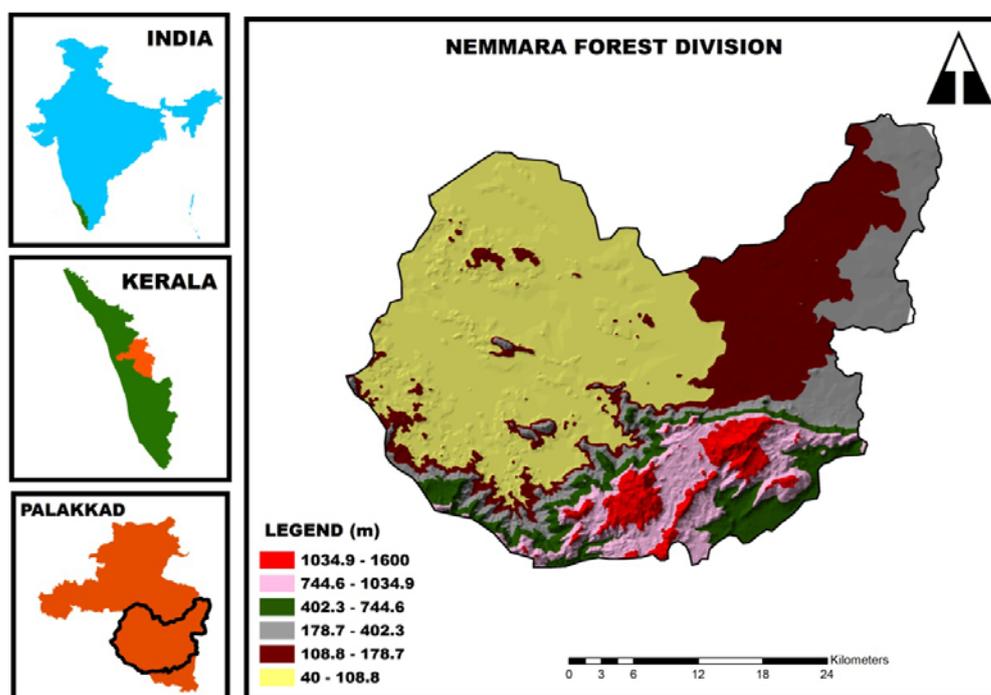
Methods

The present study area, Nemmara Forest Division was delineated from the Survey of India topographic maps (58 B/5, 58 B/6, 58 B/7, 58 B/9, 58 B/10, 58 B/11, 58 B/13, 58 B/14, and 58 B/15). The relevant thematic maps were prepared by using ArcGIS 9.3 and ERDAS Imagine 9.2 software tools. The fuel type map of the study area was prepared from the IRS LISS III image of 23.5 m resolution. The supervised classification method was used. ERDAS Imagine software

was used for the classification of the pre-processed LISS III image. The road networks and settlements of the study area were digitized from the SOI topographic maps of scale 1:50,000 and Google Earth data. The ArcGIS spatial analyst tools were used to prepare the road density map and settlement density map. The Cartosat 1 DEM of 30 m resolution was used to prepare the contour data by using ArcGIS spatial analyst tools. The contour data at an interval of 20 m was used to prepare the slope and elevation map. ArcGIS spatial analyst and 3D analyst tools were used to derive the slope and elevation

maps. A Fire Risk Index (FRI) was developed for the delineation of fire risk zones. The thematic layers were reclassified by the Natural breaks (Jenks) method. Weights were assigned to each thematic layer and ranks were assigned to each class of thematic layers. The Index (Tab. 1, Annexes) was derived from the weight and rank (Index = Weight X Rank). The risk map was prepared by overlaying all the index maps using ArcGIS tools. Finally the risk map was validated with the fire inventory points.

Figure no. 1 Location of the study area



Results and discussion:

Fuel type

The nature, amount and spatial distribution of ignitable fuel largely govern the character of the fire in any forest location (Goldammer 1990). The fuel or land cover types in the

division are deciduous forest, evergreen forest, forest plantation, grassland, wetland, mixed vegetation, crop plantation, built up and water body. The fuel type which is more prone to forest fire is the deciduous forest, hence assigned the highest rank. The fuel type map is shown in Figure 2.

Slope

Slope refers to the nature of landscape. It is a geomorphological parameter controlled by drainage and the stage of evolution of landform. The rate of forest fires advance increases as the slope increases. There is a positive correlation between the slope and fire advancement speed. The slope of the area has been grouped into five classes: 0 – 3.9°, 3.9 – 10.9°, 10.9 – 19.1°, 19.1 – 29.6° and 29.6 – 52.5°. The highest rank is assigned to areas with higher slope values (29.6 – 52.5°). The slope map is shown in [Figure 3](#).

Elevation

The humidity and temperature of an area depend on the attitude or elevation of an area. The areas with higher elevation are more prone to fire. The elevation of the

division area has been grouped into five classes: 40 – 134.9 m, 134.9 – 361.9 m, 361.9 – 682.4 m, 682.4 – 955.8 m, and 955.8 – 1587.2 m. The highest rank is assigned to areas with higher elevation values (955.8 – 1587.2 m). The elevation map is shown in [Figure 4](#).

Road density

One important factor of human proximity to forests is the development of roads into forests. This enhances human activity within forests and one possible result is accidental forest fires. The road density classes have been grouped into five: 0 – 0.33 km/sq. km, 0.33 – 0.78 km/sq. km, 0.78 – 1.19 km/sq. km, 1.19 – 1.70 km/sq. km and 1.70 – 3.34 km/sq. km. The highest rank is assigned to areas with high road density (1.70 – 3.34 km/sq. km). The road density map is shown in [Figure 5](#).

Figure no. 2 Fuel type map

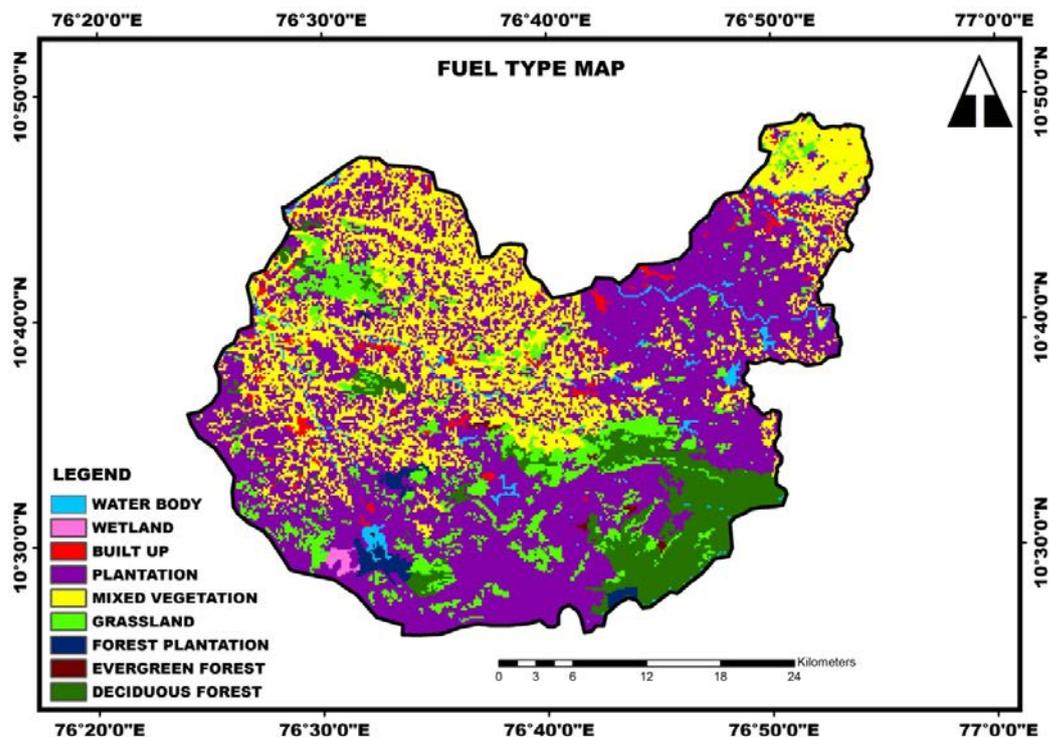


Figure no. 3 Slope map

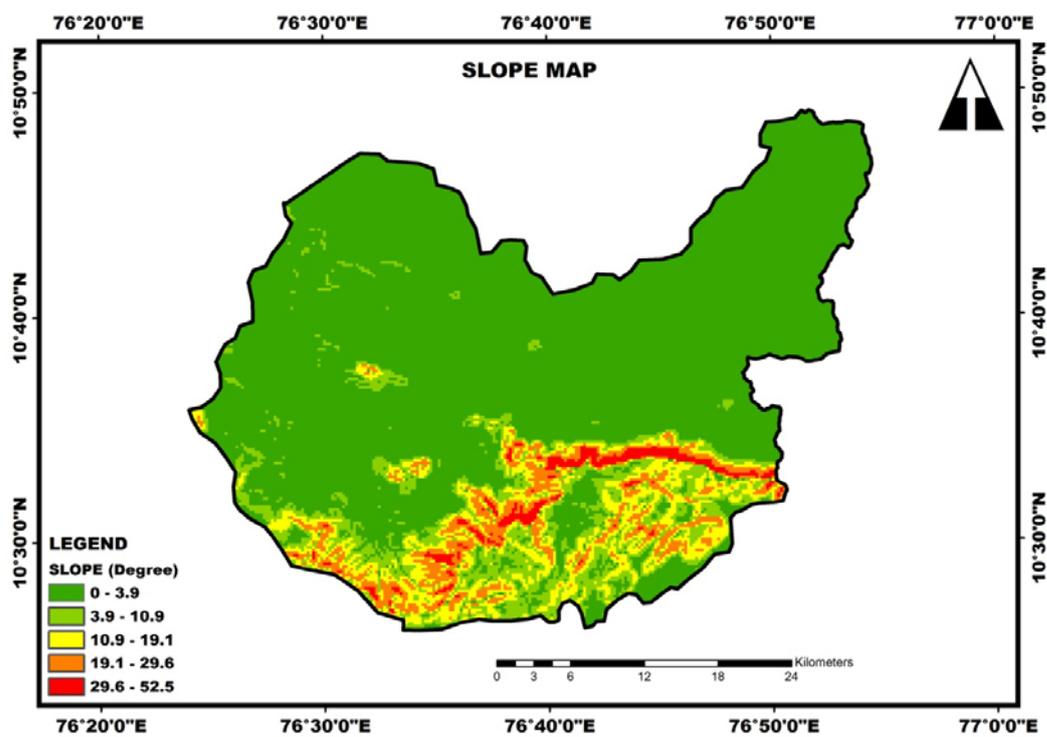


Figure no. 4 Elevation map

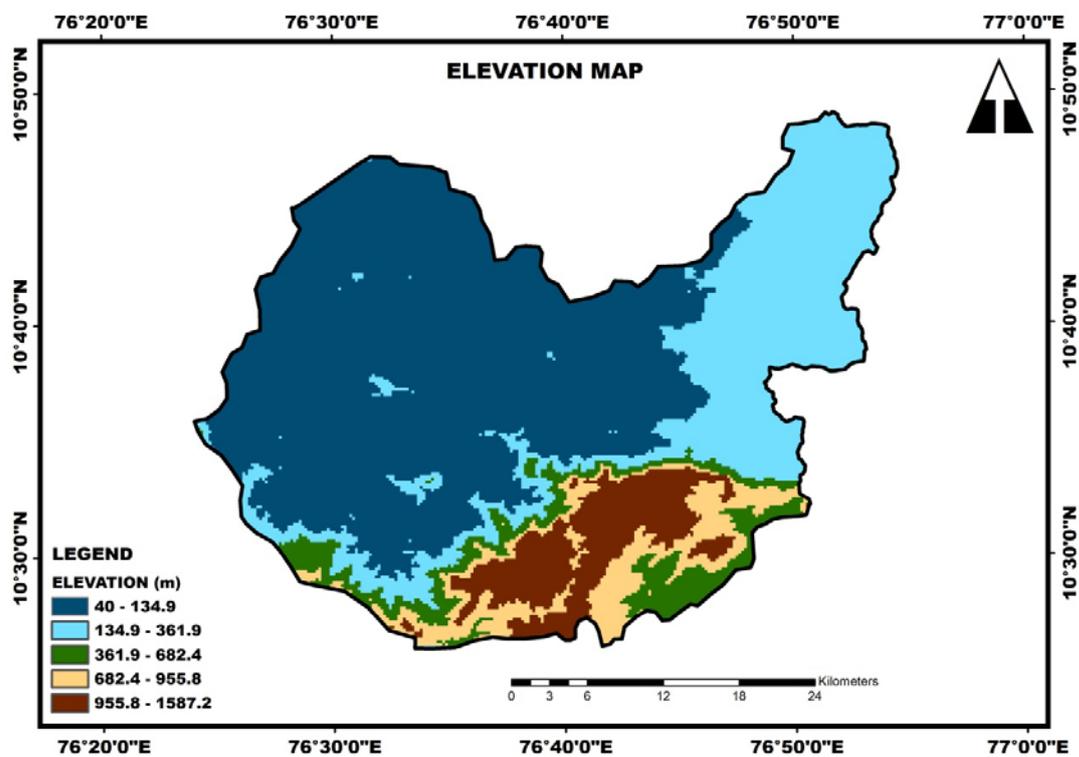
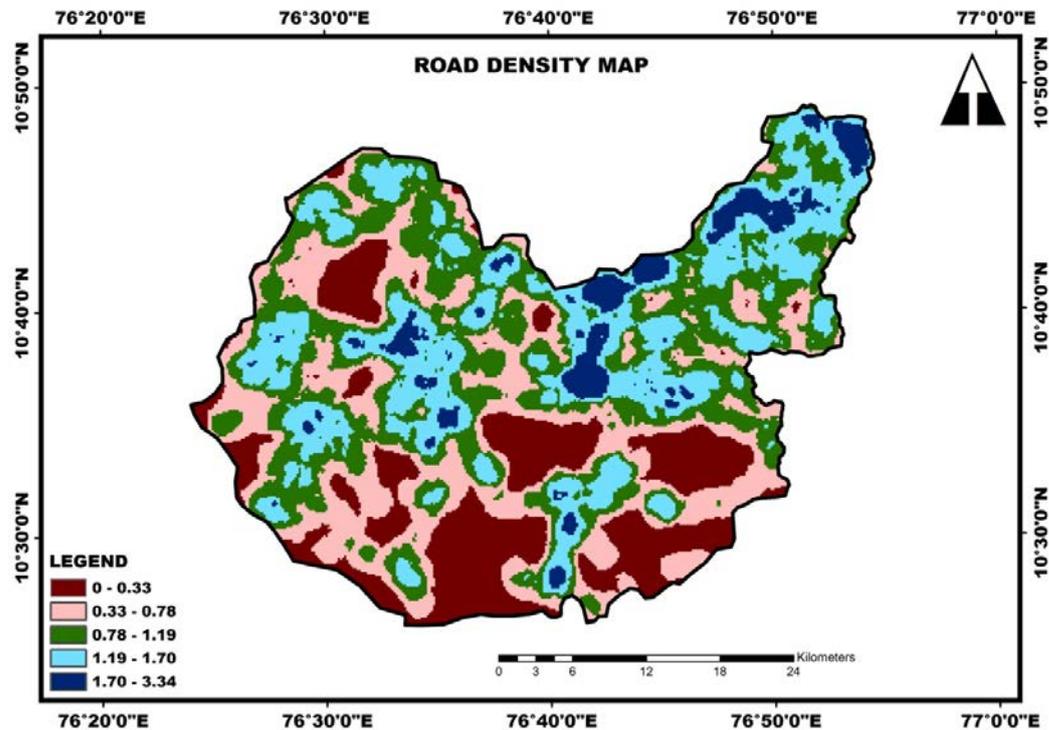


Figure no. 5 Road density map



Settlement density

One important reason for the dwindling of the forested areas is the human encroachment and settlement close to forest fringes. Increasing human access to forests has led to several accidental human induced forest fires. The settlement density classes have been grouped into five: 0 – 3.66 km/sq. km, 3.66 – 9.00 km/sq. km, 9.00 – 14.00 km/sq. km, 14.00 – 19.50 km/sq. km, and 19.50 – 31.34 km/sq. km. The highest rank is assigned to areas with high settlement density (19.50 – 31.34 km/sq. km). The settlement density map is shown in Figure 6.

Fire Risk Zones

The forest fire risk zone map (Fig. 7) of Nemmara Forest Division is prepared by overlaying the index maps of fuel type, settlement density, road density, slope and elevation. The fire risk zones in the study area are grouped into five classes: very low, low, moderate, high and very high. Finally the outlined risk map is validated with the forest fire inventory points (from the year 2000 to 2014) collected from the Forest Survey of India (FSI). The result shows that out of the 27 forest fires, 16 have occurred in high and very high risk zones (59.25%), 9 occurred in moderate risk zones (33.33%) and 2 occurred in low and very low risk zones (7.40%).

Figure no. 6 Settlement density map

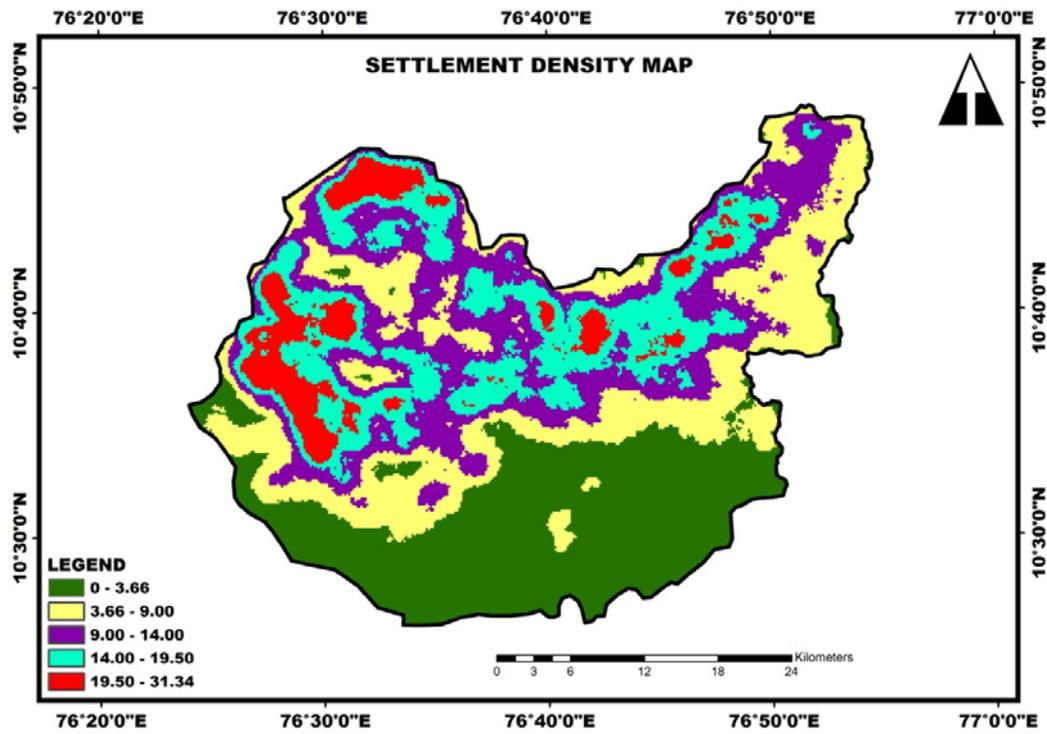
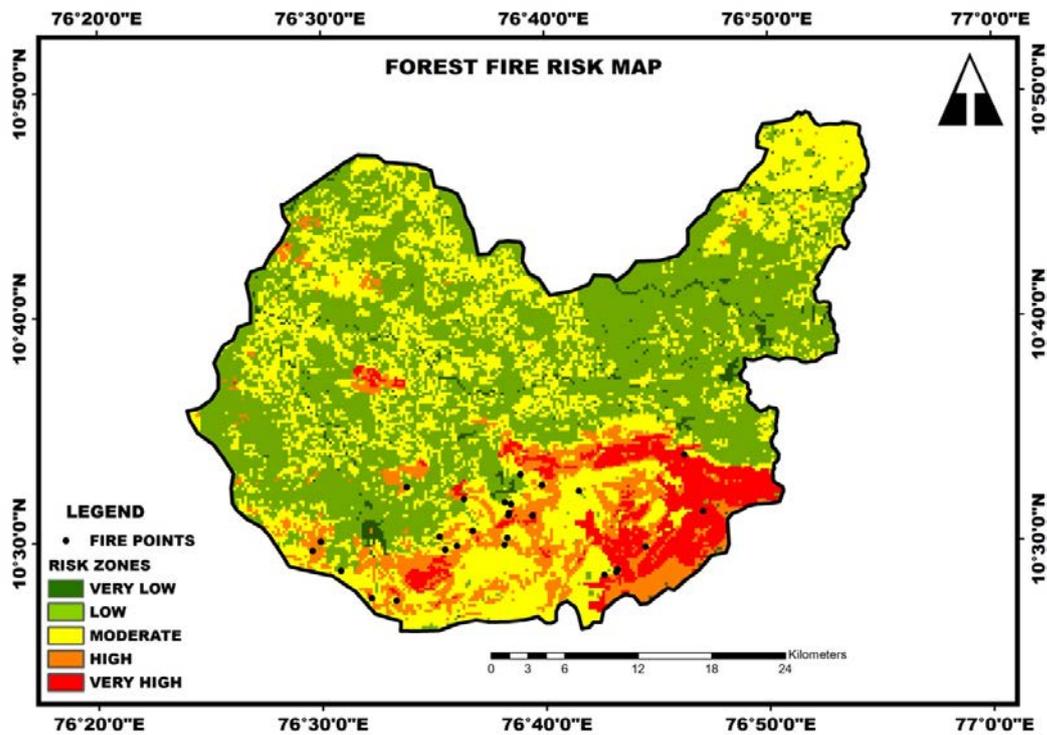


Figure no. 7 Forest fire risk map



Conclusions:

Disasters and hazards due to forest fires are common in the Nemmara Forest Division of Palakkad district. This area is geomorphologically characterised by steep slopes in south and gentle slopes to the north. It has been observed that the disaster and losses are more frequent in the southern part. This is confirmed during this study using geospatial techniques.

In this area forest fire outbreaks are more due to natural causes. The regions near human settlements and access are comparatively speaking safe zones. This may be due to preventive measures taken by the Forest department implementing latest forest fire preventing strategies jointly with creating public awareness for forest protection and conservation. The records of past forest fires, as maintained by the Forest Survey of India concur well with the present study employing geospatial techniques.

Rezumat:

**PĂDUREA ȘI EVALUAREA
RISULUI DE INCENDIU FOLOSIND
TEHNICILE GEOSPAȚIALE:
STUDIUL DE CAZ PENTRU
GRUPUL DE PĂDURE NEMMARA,
KERALA, INDIA**

Izbucnirea incendiilor în pădure reprezintă unul dintre evenimentele majore naturale din vestul regiunii Ghats din Kerala. Scopul studiului nostru este de a demarca zonele de risc pentru incendiu în grupul de pădure Nemmara. Această regiune se confruntă frecvent cu incendii spontane în ținuturile sălbatice și păduri. În acest studiu s-a folosit o combinație între senzorii de control și tehnologia GIS pentru a dezvolta un model de Index al Riscului de Incendiu. Variabilele folosite au fost tipul combustibilului, panta, înălțimea, densitatea drumului și a amplasamentului. În selectarea variabilelor s-

a ținut cont de ponderea lor în apariția incendiilor. În realizarea hărților cu zonele de risc la incendiu au fost utilizate programele software Imagine 9.2 și ArcGIS 9.3. În urma cartografierii hărților de risc la incendiu din pădurea Nemmara, aria a fost clasificată în cinci zone de risc: foarte mare, mare, moderat, scăzut și foarte scăzut. Pentru validarea hărții rezultatele au fost comparate cu punctele de incendiu din pădure deja inventariate.

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Annexes:**Table no. 1** Rank, Weight and Index assigned for different factors

Factor	Class	Rank	Weight	Index
Fuel type	Deciduous forest	9		90
	Evergreen forest	8		80
	Forest plantation	7		70
	Grassland	6		60
	Crop plantation	5	10	50
	Mixed vegetation	4		40
	Built up	3		30
	Wetland	2		20
	Water body	1		10
Slope (degree)	0-3.9	1		3
	3.9-10.9	2		6
	10.9-19.1	3	3	9
	19.1-29.6	4		12
	29.6-52.5	5		15
Elevation (m)	40-134.9	1		1
	134.9-361.9	2		2
	361.9-682.4	3	1	3
	682.4-955.8	4		4
	955.8-1587.2	5		5
Road density (km/sq. km)	0-0.33	1		2
	0.33-0.78	2		4
	0.78-1.19	3	2	6
	1.19-1.70	4		8
	1.70-3.34	5		10
Settlement density (Km/sq. km)	0-3.66	1		2
	3.66-9.00	2		4
	9.00-14.00	3	2	6
	14.00-19.50	4		8
	19.50-31.34	5		10