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DELINEATION OF FOREST FIRE RISK ZONES IN THENMALA FOREST DIVISION, KOLLAM, KERALA, INDIA: A STUDY USING GEOSPATIAL TOOLS

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Abstract: Forest fires represent one of the major natural disasters that are common in the tropical forests of India. The forests in Thenmala forest division are also prone to fires. The objective of this study is to demarcate the fire risk zones in Thenmala forest division using geospatial tools. A Fire Risk Index model has been developed considering the land cover type, terrain geomorphology (slope and elevation), and anthropogenic factors (distance from settlement and distance from road). The area of the prepared forest fire risk zone map is classified into five risk zones *viz.* very low, low, moderate, high, and very high. The high and very high risk zones jointly constitute 51.57% area of the forest division. Most of the forest fires in this region have an anthropogenic origin. The result of this study is validated by the fire incidence points for the years from 2004 to 2015. It shows very good reliability. This confirms the efficacy of the present methodology and can be used in any terrain of similar conditions. The prepared forest fire risk zone map is a valuable data for planners and decision makers for effective resource management and protection.

Keywords: anthropogenic origin, forest fire, natural disaster, risk zones

Introduction:

Forests are one of the most important natural resources which provide vital ecosystem goods and services such as food, water, shelter, and nutrient cycling among others, and play a fundamental role in the conservation of soil and biodiversity (Morales-Hidalgo et al. 2015). In the Indian tropical forests, this natural resource is seriously and recurrently affected by fires. As per the estimation of the Forest Survey of India (FSI), 53.91% of the recorded forest areas in India are prone to fires (FSI 2013). The present study area is also prone to forest fires, where a significant number of fires have occurred. These fires may be major or

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minor, and the real disaster occurs when it becomes uncontrollable. Uncontrolled forest fire can cause environmental, ecological, and economical loss.

Remote Sensing (RS) and Geographic Information System (GIS) techniques are cost effective and require only lesser time to locate the fire risk zones, when compared to the conventional methods. Also the conventional methods sometimes fail, because of the difficulty in accessing the rugged terrains. RS and GIS techniques have been used by many researchers to delineate the forest fire risk zones (Dong et al. 2005; Chavan et al. 2012; Ghobadi et al. 2012; Singh and Ajay 2013; Ajin et al. 2014a; Ajin et al. 2014b; Ajin et al. 2015). Ariapour and Shariff (2014) demarcated rangeland fire risk zones of Boroujerd rangelands in Iran using RS and GIS techniques. Factors such as land use, slope, aspect, rainfall, evaporation, temperature, road, village, and river were selected for the study. Sivrikaya et al. (2014) prepared the forest fire risk map of Yeşilova Forestry Enterprise in Turkey using GIS techniques. The variables selected for the study were species composition, stand crown closure, development stage, slope, insolation, distance from settlement and agricultural land, and distance from road.

This study is aimed at delineating the fire risk zones in Thenmala forest division using geospatial techniques. A Fire Risk Index (FRI) model has been developed to delineate the risk zones. The factors selected are land cover type, slope, distance from settlement, distance from road, and elevation.

Materials and methods:

Study area

The study area, Thenmala forest division is located between 76° 58' 0" and 77° 13' 0" E longitudes and 8° 51' 0" and 9° 3' 0" N latitudes. This forest division is bordered by Thiruvananthapuram forest division to the south, Shenduruny Wildlife Sanctuary to the southeast, the state of Tamilnadu to the east and north-east, and Punalur forest division to the north, north-west, west and south-west. The forest division covers an area of 159.47 sq. km. The location map of the study area is shown in Figure 1.

The flowchart of the employed methodology is shown in Figure 2. The present study area was delineated from the Survey of India topographic maps (58 C/16, 58 D/13, 58 G/4, and 58 H/1) of 1:50,000 scale. The thematic maps have been prepared using ArcGIS 9.3 and ERDAS IMAGINE 9.2 software tools. The land cover type map was derived from the Landsat ETM+ image of 30 m resolution. The ERDAS IMAGINE software was used for the supervised classification of the Landsat image. The road networks and human settlements were digitized from the topographic maps 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 generated from the SRTM DEM of 30 m resolution. The slope and elevation maps were prepared from the 10 m interval contour data using ArcGIS 3D analyst and spatial analyst tools. A FRI model was developed for the demarcation of forest fire risk zones. These thematic map layers were reclassified using the Equal Interval method. Rank was assigned to each class of the thematic map layers and weight was committed to each thematic map layer according to the risk potential. The index was derived from the weight and rank (Index = Weight x Rank), and is shown in Table 1. The forest fire risk zone map was prepared by overlaying the index map layers using ArcGIS tools. Finally, the risk zone map was validated with the forest fire incidence points for the years from 2004 to 2015, collected from the Forest Survey of India (FSI).

Figure no. 1 Study area map

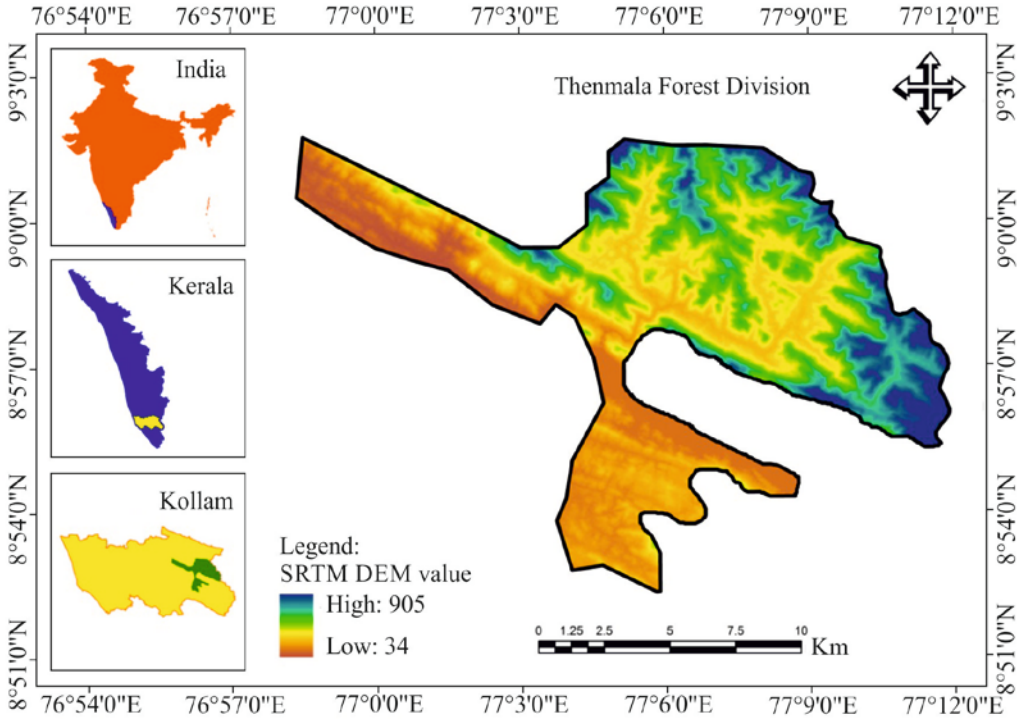


Figure no. 2 Flowchart for delineating the forest fire risk zones

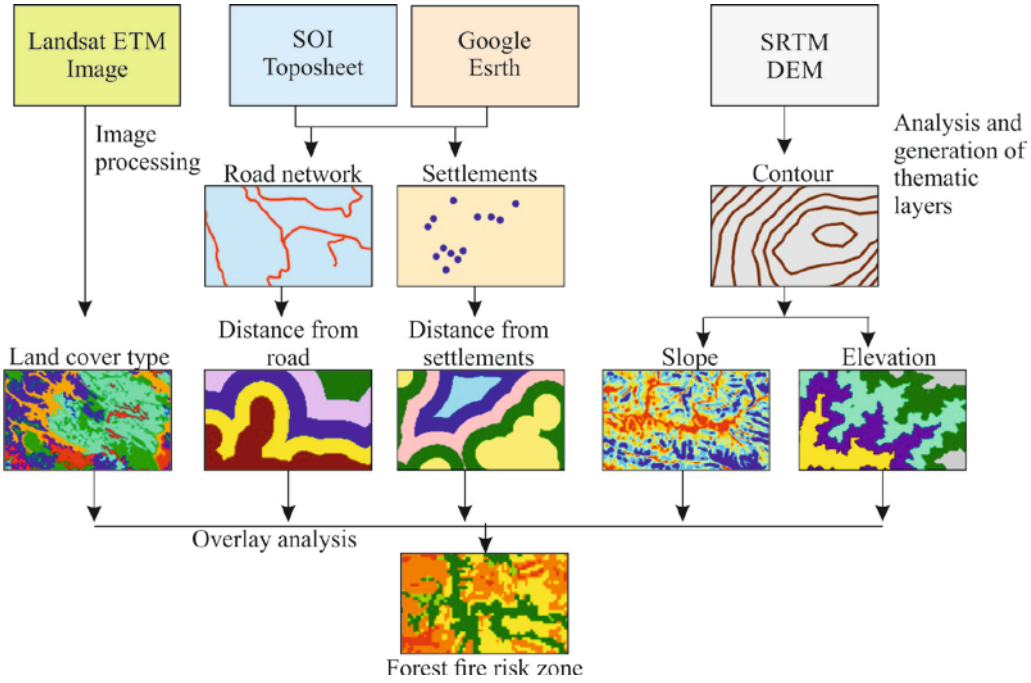


Table no. 1 Rank, weight and index assigned for different factors

Factor	Class	Rank	Weight	Index
Land cover type	Water body	1	10	10
	Built-up area	2		20
	Agricultural land	3		30
	Evergreen forest	4		40
	Forest plantation	5		50
	Deciduous forest	6		60
Slope (degree)	0 - 8.20	1	3	3
	8.20 - 16.41	2		6
	16.41 - 24.62	3		9
	24.62 - 32.83	4		12
	32.83 - 41.04	5		15
Distance from settlement (m)	0 - 707.48	5	2	10
	707.48 - 1414.96	4		8
	1414.96 - 2122.45	3		6
	2122.45 - 2829.93	2		4
	2829.93 - 3537.42	1		2
Distance from road (m)	0 - 429.98	5	2	10
	429.98 - 859.97	4		8
	859.97 - 1289.96	3		6
	1289.96 - 1719.94	2		4
	1719.94 - 2149.93	1		2
Elevation (m)	40 - 207.89	1	1	1
	207.89 - 375.78	2		2
	375.78 - 543.68	3		3
	543.68 - 711.57	4		4
	711.57 - 879.46	5		5

Results and discussion:

Land Cover Type

The most important triggering factor for forest fire is the land cover, the vegetative material present in the area. The severity of fires differs with respect to the nature of the vegetative material, mainly the density and moisture content. The lesser the moisture content, the higher the fire risk. Also the dry fire season enhances the forest fires in these regions. The land cover types in this study area are deciduous forest, forest plantation, evergreen forest, agricultural land, built-up area, and water body. In this area, the deciduous forest and forest plantation are more prone to fire. The land cover type map is shown in Figure 3.

Slope

Slope is another important factor that induces forest fires. Steeper slopes are more susceptible to fires. Slope morphology significantly influences the rate of upward and downward spread of forest fires (Rothermel and Richard 1972). Favourable wind can accelerate the upslope movement of forest fires. The slope of the area is grouped into five classes (Tab. 1; Fig. 4).

Figure no. 3 Land cover type map

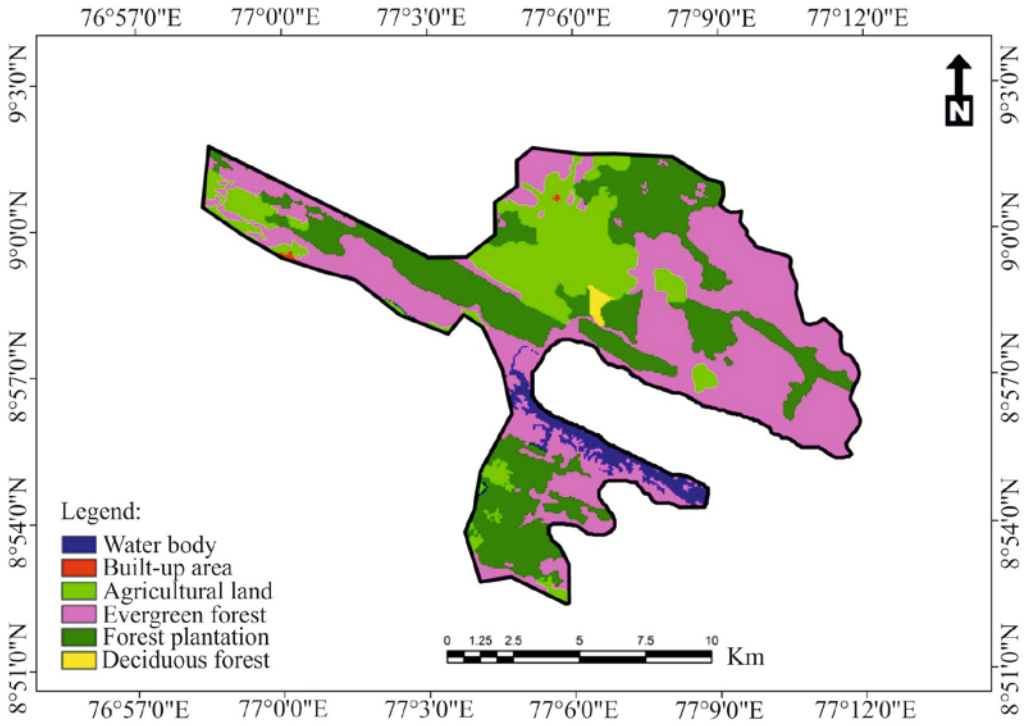
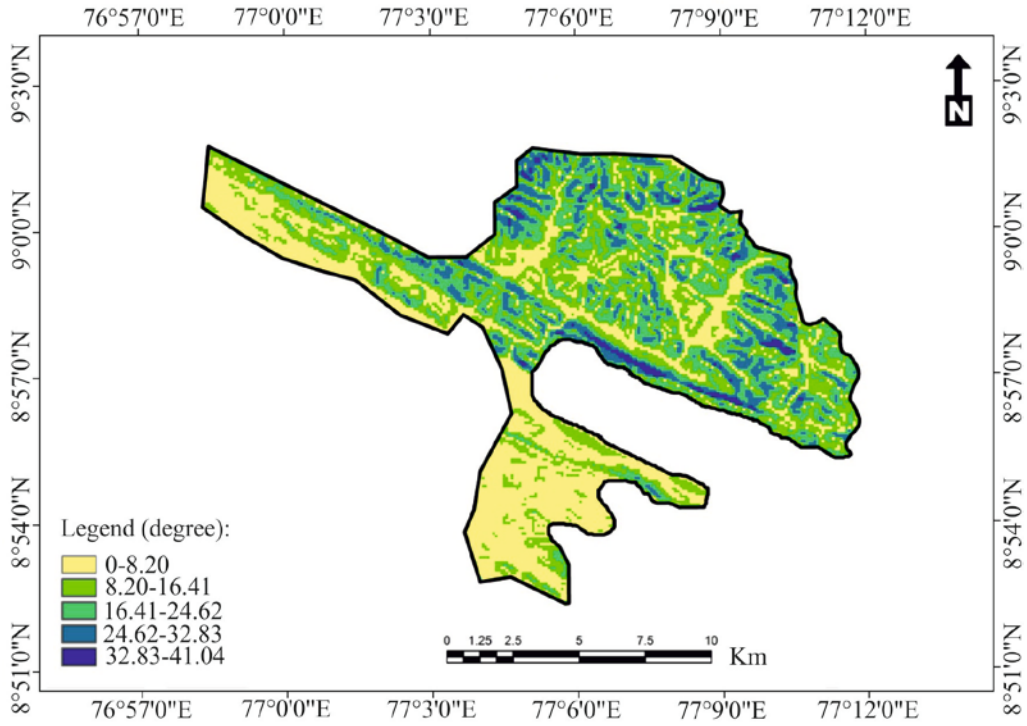


Figure no. 4 Slope map



Distance from settlement

Both accidental and deliberately caused fires could occur in the vicinity of settlements. Sometimes villagers may set fire to clear a forest path, to encroach upon forest land, to promote regeneration, as a part of tribal traditions or customs, and also timber smugglers so as to conceal the stumps of illicit felling. These are the reasons for forest fires caused due to deliberate human intervention. The fire set to collect Non Timber Forest Products (NTFP), to burn agricultural residues, to drive away wild animals, and for making charcoals may result in accidental forest fires. Also the sparks from thrown lighted cigarette butts, flames during cooking, and campfires set by the tourists can also induce accidental fires. The distance from settlement is grouped into five classes (Tab. 1; Fig. 5).

Distance from road

Accidental fires can occur in the proximity of roads due to multiple reasons. This type of fires is mainly induced by the tourists. The unextinguished cigarette butts thrown by the tourists, campfires set by the tourists, and sparks resulting while cooking near the forest roads are the major causes of accidental fire. Forest fires may occur rarely from the sparks of vehicle exhaust and while heating coal tar for road construction through the forests. The distance from road is grouped into five classes (Tab. 1; Fig. 6).

Figure no. 5 Distance from settlement map

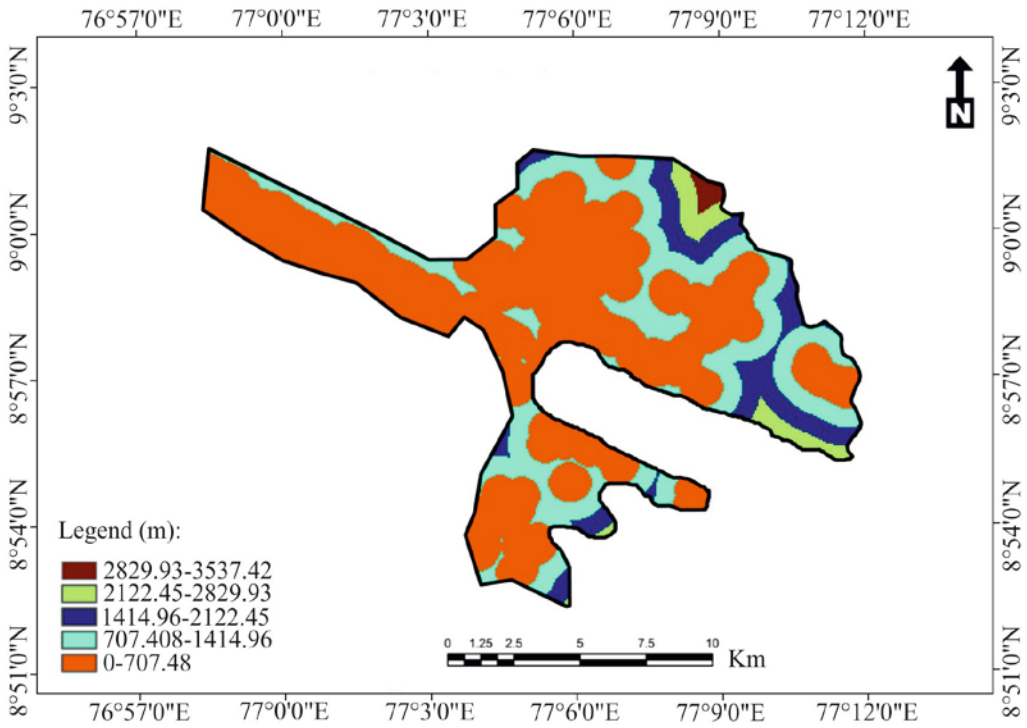
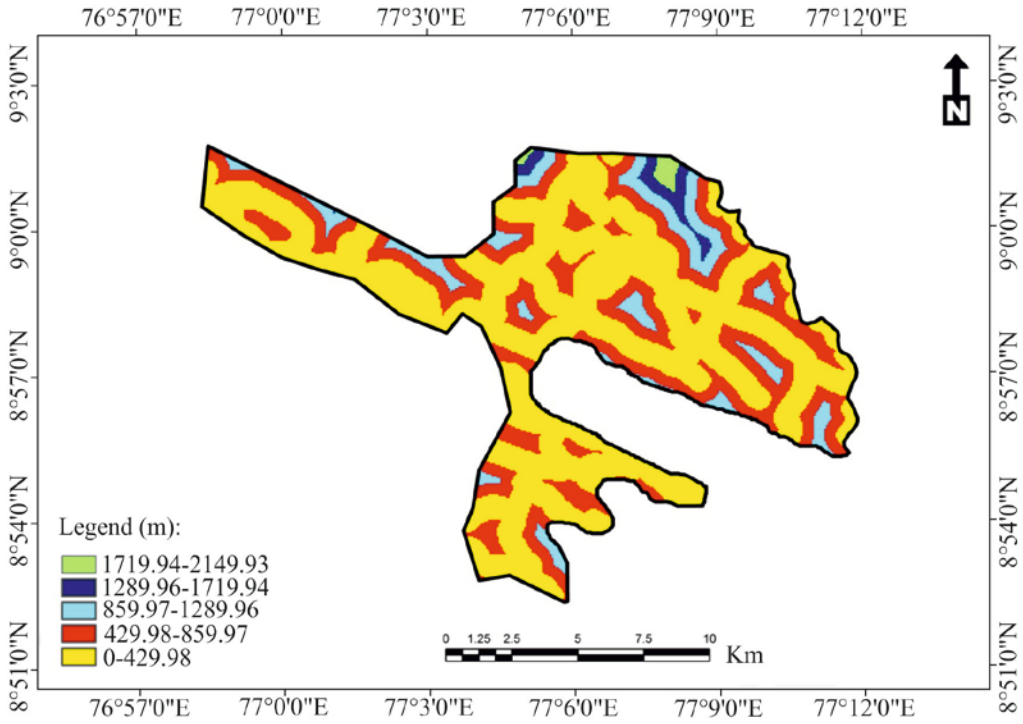


Figure no. 6 Distance from road map



Elevation

The higher elevation regions are more prone to forest fires. At higher elevations, the influence of the prevailing winds is high and the number of lightning induced ignitions is more. The elevation of this area is grouped into five classes (Tab. 1; Fig. 7).

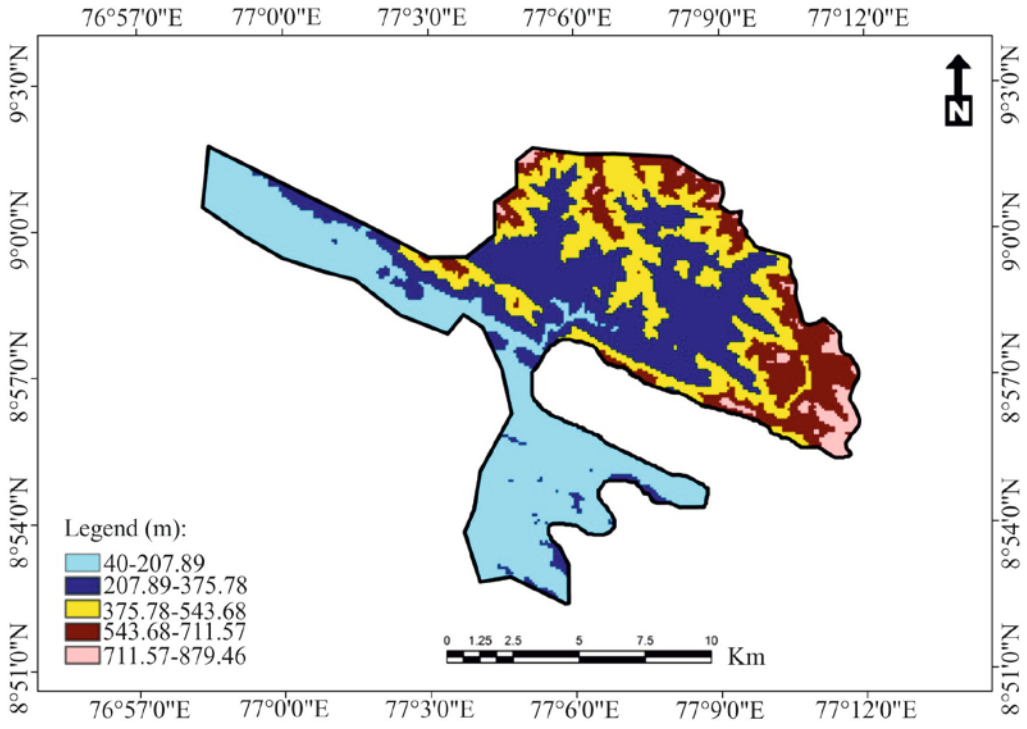
Forest fire risk zones

The forest fire risk zone map of Thenmala forest division is prepared by combining the index map layers of factors such as land cover type, slope, distance from settlement, distance from road, and elevation using GIS techniques. The study area is grouped into five risk zones *viz.* very low, low, moderate, high and very high. Finally, the fire incidence points collected from the FSI are overlaid on the forest fire risk zones. A total of 12 fire incidences are recorded during the years from 2004 to 2015. The study verified that out of the 12 forest fire incidence points, 11 (91.66%) fire incidence points fall spatially over the high and very high risk zones, 1 (8.33%) fall over the moderate risk zone, and no fire is recorded over the low and very low risk zones. Most of the fire incidence points fall spatially in the proximity of roads and settlements. Thus it is clear that the fires are human induced. The forest fire risk zone map is shown in Figure 8. The percentage and area of fire risk zones is shown in Table 2.

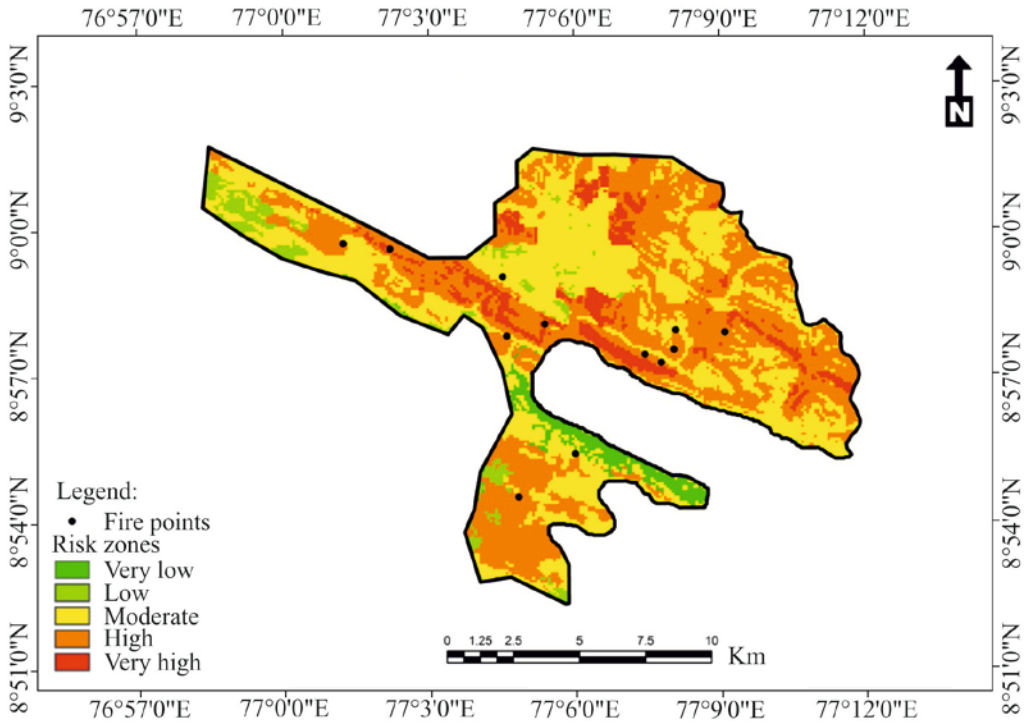
Table no. 2 Percentage and area of fire risk zones

Fire Risk Zones	Percentage (%)	Area (Km^2)
Very low	3.48	5.55
Low	4.16	6.63
Moderate	40.78	65.03
High	45.33	72.29
Very high	6.24	9.95

Figure no. 7 Elevation map



Figuer no. 8 Forest fire risk zone map



Conclusions:

In recent years, the natural environmental disaster by forest fire is found in many countries, including India, creating serious damage. Therefore, it is necessary to have a good evidence and control, especially over the terrains which are prone to forest fires. We cannot control the natural phenomenon of frequently occurring forest fires, but based on accurate statistical data, risk or hazard zone maps can be created, which are very useful for taking good disaster management decisions. In this study, A FRI model has been developed using the factors such as land cover type, slope, distance from settlement, distance from road, and elevation. The forest fire risk zone map is prepared using geospatial tools, and the area has been classified into five risk zones ranging from 'very low' to 'very high'. The study shows that more than 90% of the fire incidence points fall spatially over the high and very high risk zones, which together constitute 51.57% area of this forest division. This confirms the reliability of the present methodology. Another finding of the study is that most of the forest fires occurred in the vicinity of settlements and roads. This proves beyond doubt that the fires are induced by humans (anthropogenic origin). The study reveals that RS and GIS based methodology and techniques can give better results with minimum time and cost. The prepared forest fire risk zone map is a valuable data for planners and decision makers for effective resource management and protection.

Rezumat:

DESCRIEREA ZONELOR DE RISC LA INCENDIU ÎN SECTORUL PĂDURII THENMALA, KOLLAM, KERALA, INDIA: UN STUDIU FOLOSIND METODE GEOSPAȚIALE

Incendiile de pădure reprezintă unul dintre cele mai mari dezastre ce apar frecvent în pădurile tropicale din India. Pădurile din sectorul Thenmala sunt, de asemenea, predispuse la incendii. Obiectivul studiului a fost să desemneze zonele de risc la incendiu din sectorul pădurii Thenmala folosind metode geospațiale. Un index al riscului la incendiu a fost întocmit luând în considerare tipul de acoperire al terenului, geomorfologia terenului (pante și altitudine) și factorii antropogenici (distanța față de așezări și distanța față de drum). Harta ariilor cu risc de incendiu în pădure a fost împărțită în cinci zone, respectiv foarte înaltă, înaltă, moderată, joasă și foarte joasă. Majoritatea incendiilor de pădure din această regiune au o origine antropogenică. Rezultatele acestui studiu au fost confirmate de punctele de incidență din perioada 2004 - 2015. Acestea confirmă fiabilitatea metodologiei folosite care poate fi utilizată în orice teren având condiții similare. Zonele cu risc înalt și risc foarte înalt constituie împreună 51.57% din sectorul studiat. Harta riscului de incendiu este un instrument valoros pentru factorii de planificare și decizie în vederea protecției și managementului eficient al resurselor.

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