RS AND GIS BASED FOREST FIRE RISK ZONE MAPPING IN THE PERIYAR TIGER RESERVE, KERALA, INDIA

Article · February 2016

CITATIONS
0

READS
84

4 authors, including:

Ajin R S
University of Madras
14 PUBLICATIONS **8** CITATIONS
SEE PROFILE

Ana-Maria Loghin
Gheorghe Asachi Technical University of Iasi
11 PUBLICATIONS **2** CITATIONS
SEE PROFILE

Vinod P G
GeoVin Solutions (P) Ltd.
22 PUBLICATIONS **16** CITATIONS
SEE PROFILE

RS AND GIS BASED FOREST FIRE RISK ZONE MAPPING IN THE PERIYAR TIGER RESERVE, KERALA, INDIA

R.S. Ajin, Ana-Maria Loghin, P.G. Vinod and Mathew K. Jacob

Received: 23.09.2015 / Accepted: 26.12.2015

Abstract: Forest fires are the most common natural disturbance occurring in the Western Ghats, especially during the summer season. The present study area is also prone to forest fires. In this study, an attempt has been made to locate and map the potential fire risk zones in the Periyar Tiger Reserve using geospatial techniques. The factors selected in this study are land cover type, slope, distance from settlement, distance from road, and elevation. The forest fire risk zone map is generated using the developed Fire Risk Index model. In the prepared map, the area has been classified into five risk zones *viz.* very low, low, moderate, high, and very high. The result has been validated with the fire incidence points for the past 10 years. The risk zone map of the Periyar Tiger Reserve is to be helpful for natural resource managers or planners in the management and environmental protection of resources.

Keywords: Fire Risk Index, forest fire, Periyar Tiger Reserve, Western Ghats

Introduction:

Forest is one of the most important natural resources and fundamental necessity for human survival and social development (Jinzhu et al. 2007). Forests can absorb atmospheric carbon, maintain a certain degree of humidity in the atmosphere, regulate rainfall, moderate the temperatures, restrain soil erosion and also form the basis for the conservation of fauna and flora (Morancho 2003). But most of the forests in the Western Ghats, a biodiversity hotspot in India are under serious threat, especially from fires. In India, the estimated total fire prone area in the recorded forest area (771,821 sq. km) is 53.91% (FSI 2013). Forest fire can cause loss of ecosystem, depletion of wildlife, deforestation, global warming, and adverse health impacts. Deforestation can result in soil erosion and floods. In this regard, forest fire risk zone mapping is essential for better forest management.

Remote Sensing (RS) and Geographic Information System (GIS) techniques have been used by many researchers to delineate the forest fire risk zones (Jaiswal et al. 2002; Sowmya and Somashekar 2010; Ghobadi et al. 2012; Malik et al. 2013; Ajin et al. 2014a; Ajin et al. 2014b; Ajin et al. 2015). Dong et al. (2005) delineated forest fire risk zones of

R.S. Ajin and **P.G. Vinod:**
Geomatics Division
GeoVin Solutions Pvt. Ltd.
Thiruvananthapuram, Kerala, India

Ana-Maria Loghin:
Faculty of Hydrotechnical Engineering
Geodesy and Environmental Engineering
Gheorghe Asachi Technical University of Iasi
Iasi, Romania

Mathew K. Jacob:
Post Graduate Department of Geology
Sree Narayana College, Sivagiri
Kerala, India
e-mail (for all authors):
drmathewkjacob@gmail.com

Baihe Forestry Bureau in China using RS and GIS techniques. The factors selected for the study were vegetation, slope, aspect, altitude, distance from roads, distance from farmlands, and distance from settlements. Using the same techniques Chavan et al. (2012) delineated forest fire risk zones in Huynial watershed. The factors considered were fuel type, slope, aspect, habitation, drainage, and road. Manavalan and Jayalakshmi (2013) demarcated forest fire risk zones in Nilgiri district forest area using RS and GIS tools. Factors such as slope, aspect, temperature, distance from roads, distance from settlements, Normalized Difference Vegetation Index (NDVI), and Normalized Difference Water Index (NDWI) were selected for the study.

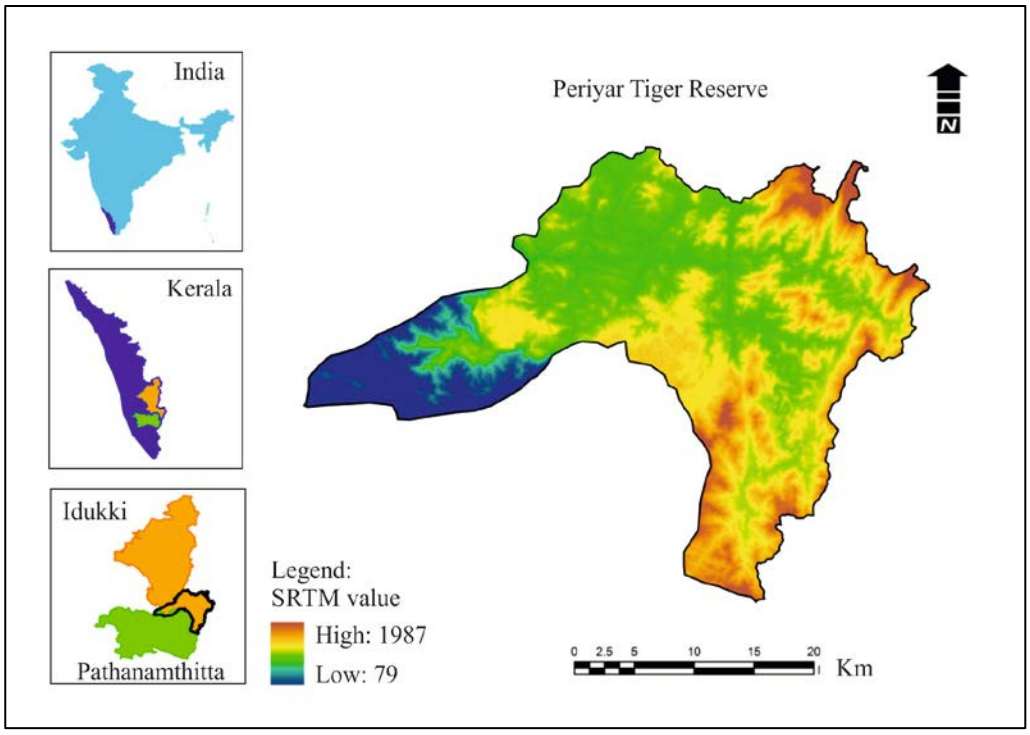
The objective of this study is to demarcate the forest fire risk zones in the Periyar Tiger Reserve using RS and GIS techniques. A Fire Risk Index (FRI) model is developed to delineate the risk zones. The factors selected are land cover type, slope, distance from settlement, distance from road, and elevation.

Materials and methods:

Study area

The Periyar Tiger Reserve (PTR) is located between 76° 55' 0" and 77° 25' 0" E longitudes respectively 9° 16' 0" and 9° 38' 0" N latitudes. This area is bordered by Kottayam forest division to the west and northwest, Ranni forest division to the south and south-west, and the state of Tamilnadu to the north, east and south-east. The total area of the PTR is 777 sq. km. The temperature in this area varies from 15 °C to 31 °C and the annual average rainfall is 1700 mm. The major rivers flowing through this area are Mullayar and Periyar. The study area map is shown in Figure 1.

Figure no. 1 Study area map



The study area, PTR was delineated from the Survey of India topographic maps (58 C/15, 58 G/2, 58 G/3, 58 G/6, and 58 G/7) 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 cover type map was derived from the IRS-P6 LISS-III image of 23.5 m resolution. The ERDAS Imagine software was used for the supervised classification of the LISS-III 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 Cartosat 1 DEM of 30 m resolution. ArcGIS spatial analyst and 3D analyst tools were employed to prepare the slope and elevation maps from the 20 m interval contour data. A FRI model was developed for the demarcation of forest fire risk zones. These 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 assigned to each thematic map layer according to their capacity on fire ignition and spreading. The Index (Tab. 1) was derived 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 with the fire incidence points. The flowchart of the methodology is shown in Figure 2.

Figure no. 2 Flowchart for delineating forest fire risk zones

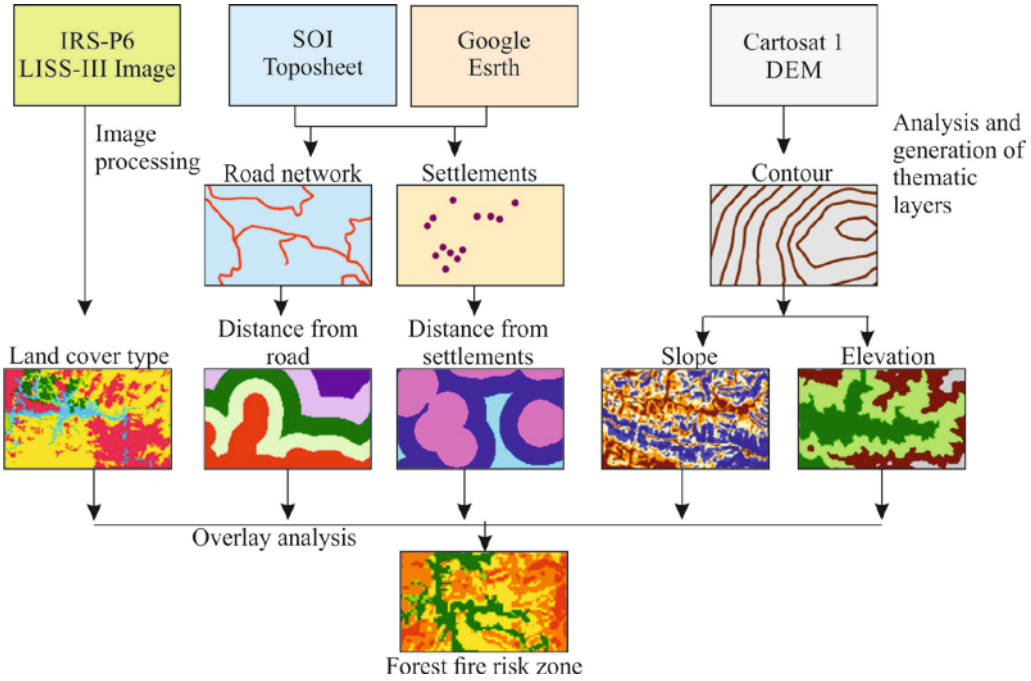


Table no. 1 Rank, weight and index assigned for different factors

Factor	Class	Rank	Weight	Index
Land cover type	Deciduous forest	7	10	70
	Grassland	6		60
	Forest plantation	5		50
	Evergreen forest	4		40
	Built-up area	3		30
	Wetland	2		20
	Water body	1		10
Slope (degree)	0 - 5.64	1	3	3
	5.64 - 10.95	2		6
	10.95 - 16.43	3		9
	16.43 - 22.94	4		12
	22.94 - 43.65	5		15
Distance from settlement (m)	0 - 2723	5	2	10
	2723 - 5231	4		8
	5231 - 8313	3		6
	8313 - 12685	2		4
	12685 - 18275	1		2
Distance from road (m)	0 - 1006	5	2	10
	1006 - 2181	4		8
	2181 - 3490	3		6
	3490 - 5000	2		4
	5000 - 8557	1		2
Elevation (m)	90 - 639	1	1	1
	639 - 1006	2		2
	1006 - 1186	3		3
	1186 - 1408	4		4
	1408 - 1951	5		5

Results and discussion:

Land Cover Type

The vegetative covers in forests are the fuel for fire. The proneness of an area to forest fire depends on the type of fuel present. The dry and dense vegetation is more prone to fire. The land cover types in the study area are deciduous forest, grassland, forest plantation, evergreen forest, built-up area, wetland, and water body. In this area, the deciduous forest and grassland are more liable to fire. The zones in the study area, where forest regeneration is not possible, are characterised by built-up areas, wetland and water body. These areas are not prone to fire. The land cover type map is shown in Figure 3.

Slope

In steeper slopes, the intensity of heat generated and the rate of advancement of fire can be much higher than on horizontal levels. The lateral migrations as well as the uphill and downhill movement of fire are also influenced by slope (Rothermel and Richard 1972). Steep slopes in the windward side enhance the intensity of fire, especially due to the generation of strong upward convective movement of extreme hot air. The slope of this area is grouped into five classes (Tab. 1; Fig. 4).

Figure no. 3 Land cover type map

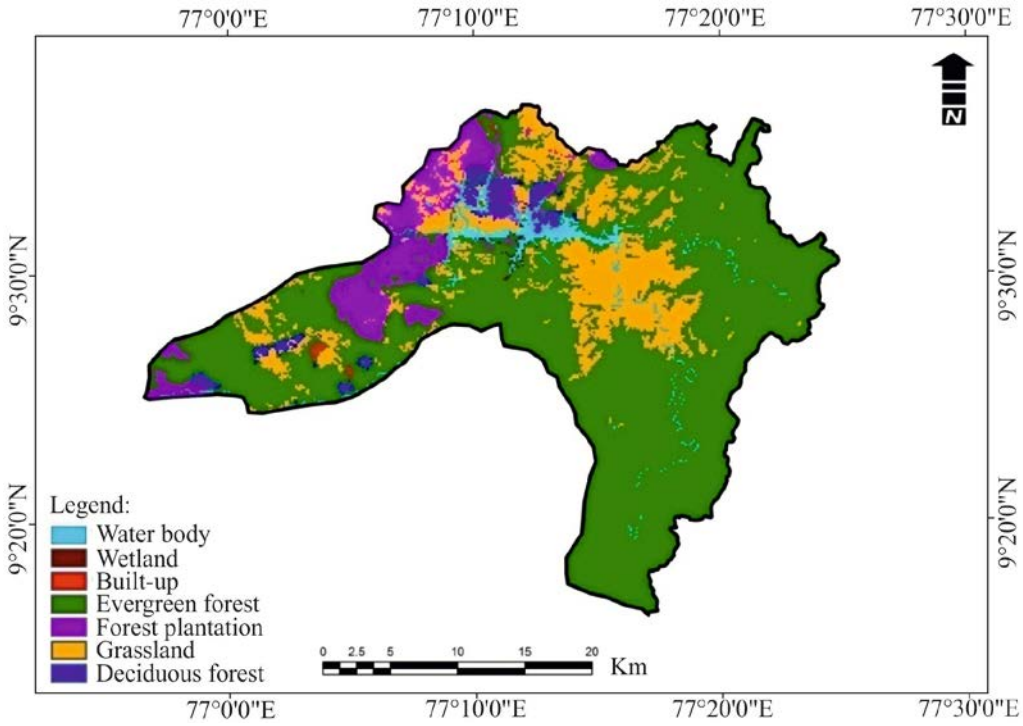
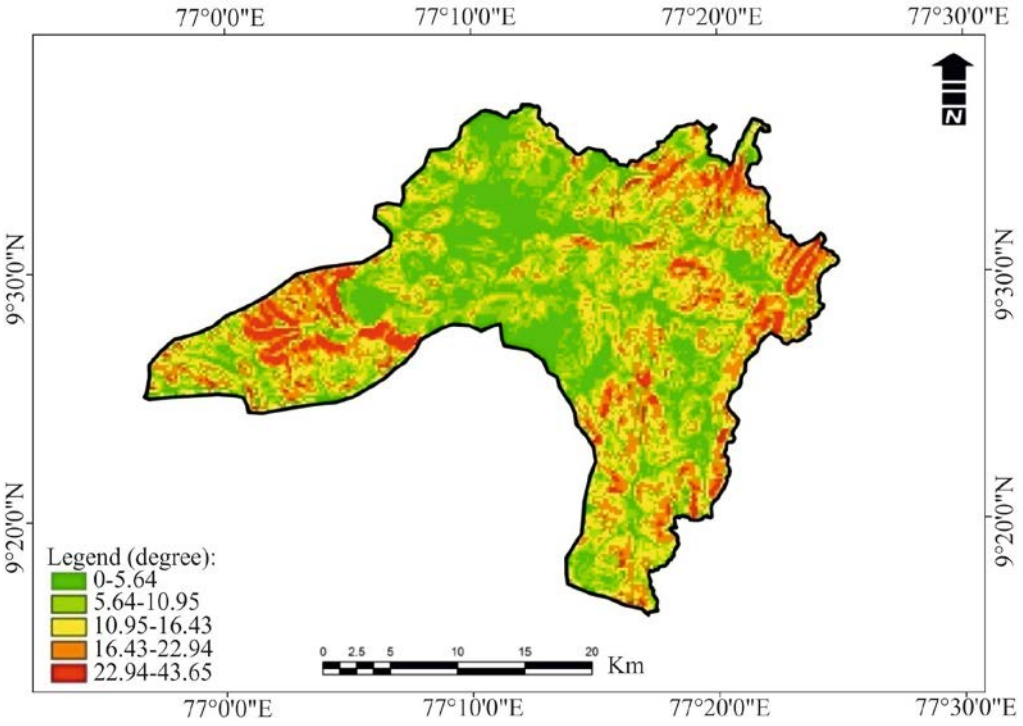


Figure no. 4 Slope map



Distance from settlement

The areas closer to the human settlements are more prone to fire. The forest fire caused by the presence of human settlements can be due to deliberate or accidental intervention. The fires set to promote forest regeneration, clear forest path, encroach upon the forest land, conceal the tree stumps of illicit felling, and as a part of tribal customs can result in deliberate forest fire. The accidental forest fire can occur from the fire set by the villagers to drive away wild animals, collect Non Timber Forest Products (NTFP), burn the farm residues, or from the sparks released during cooking, and thrown lighted cigarette butts. In protected areas, where ecotourism is promoted, the accidental fires can occur from the campfires set by the tourists. The distance from settlement classes is grouped into five classes (Tab. 1; Fig. 5).

Distance from road

The areas close to the roads are more prone to fire. In this zone, the fires occur mainly due to accidental causes. The sparks from vehicle exhaust, cooking near the forest roads, fires released during the heating of coal tar for road construction, thrown unextinguished cigarette butts etc. can be the possible reasons. The distance from road classes is grouped into five classes (Tab. 1; Fig. 6).

Figure no. 5 Distance from settlement map

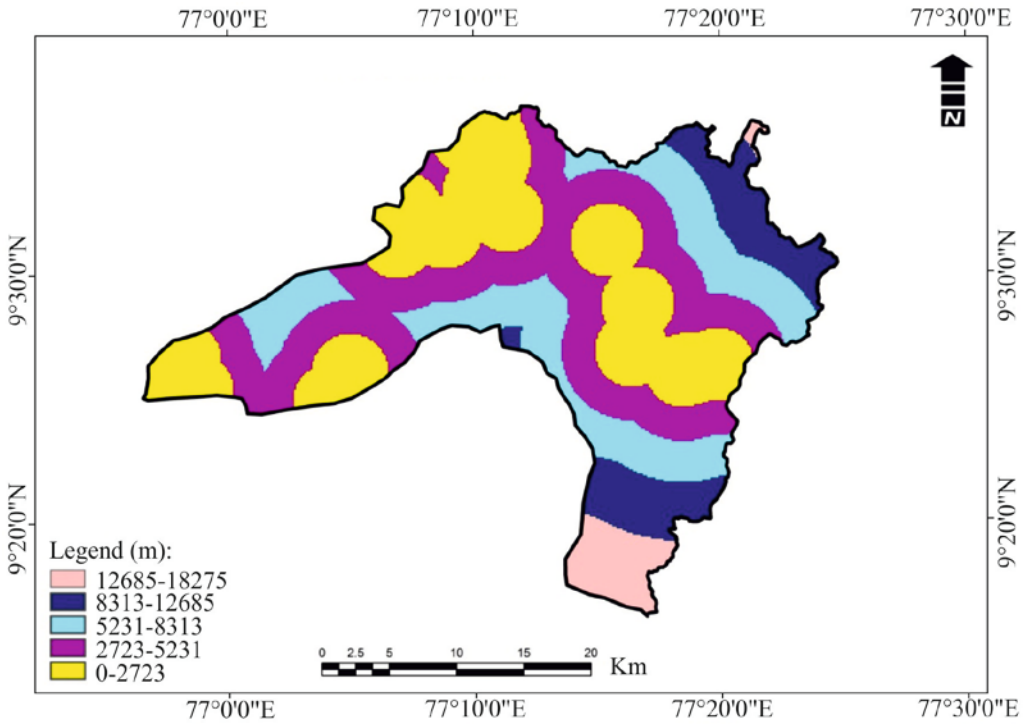
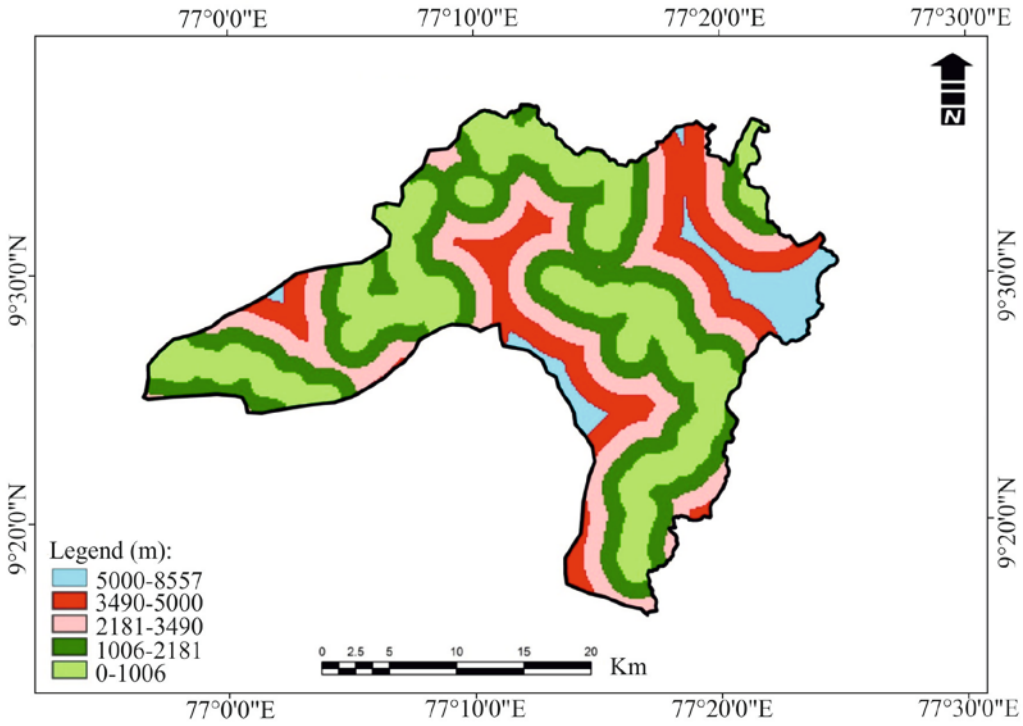


Figure no. 6 Distance from road map



Elevation

The forests located at higher elevation are more prone to fire disaster. At high elevation areas, hours of sunshine increase greatly during summer with high intensity of heating resulting in frequent fires. Also, in regions with a higher elevation the frequency of lightning strikes is higher, which can trigger forest fires. The elevation of this area is grouped into five classes (Tab. 1; Fig. 7).

Forest Fire Risk Zones

The forest fire risk zone map is prepared by combining the index map layers using GIS tools. In the prepared map, the area has been classified into five risk zones *viz*. very low, low, moderate, high, and very high. The risk zone map is validated with the fire incidence points collected from the Forest Survey of India (FSI). This study shows that the PTR is prone to forest fire, where a total of 31 forest fires occurred during the years from 2004 to 2014. Results show that out of the 31 forest fires, 25 (80.64%) forest fires occurred in the high and very high risk zones, 4 (12.90%) occurred in the moderate risk zone and 2 (6.45%) occurred in the low and very low risk zones. The study also conveys that most of the fire incidence points fall spatially close to the roads and settlements, which confirm an anthropogenic origin. The forest fire risk zone map is shown in Figure 8. The area and percentage under each fire risk zone is summarized in Table 2.

Table no. 2 Percentage and area of fire risk zones

Fire Risk Zones	Percentage (%)	Area (Km^2)
Very low	3	23.31
Low	34	264.18
Moderate	36	279.72
High	10	77.7
Very high	17	132.09

Figure no. 7 Elevation map

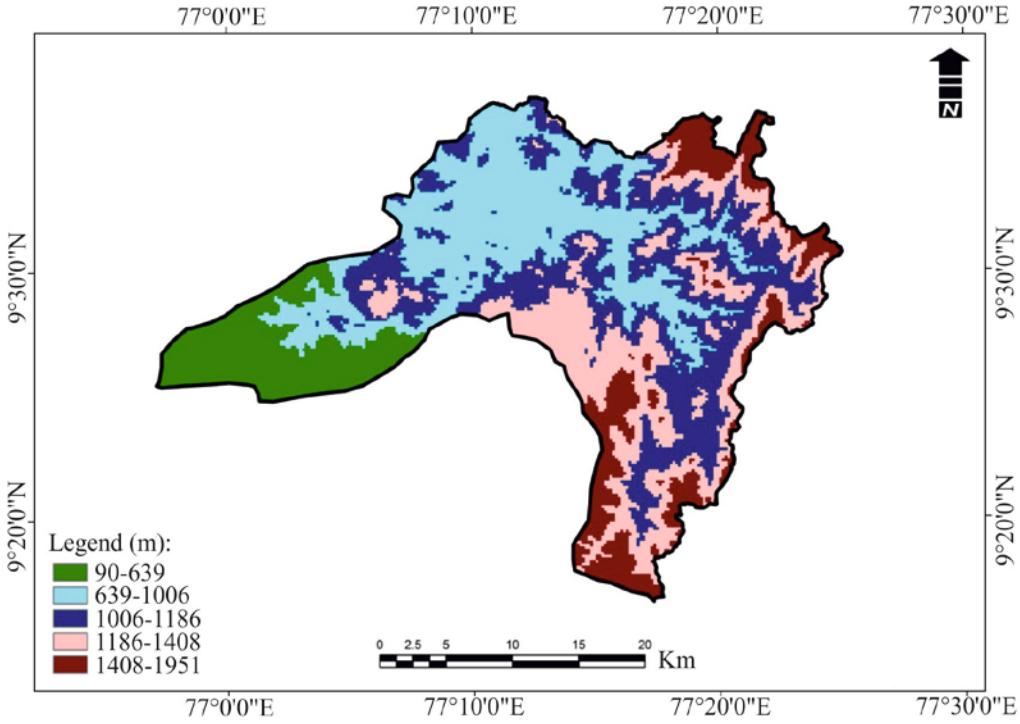
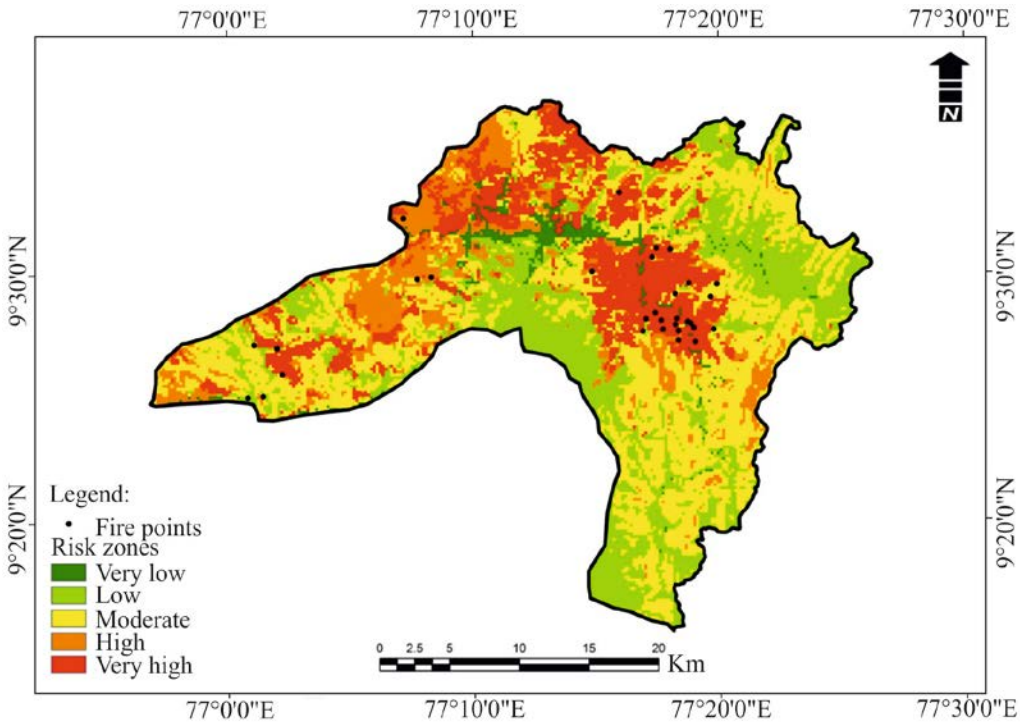


Figure no. 8 Forest fire risk zone map



Conclusions:

In the present study, in order to prepare the forest fire risk zone map of the PTR, a method integrating RS and GIS techniques has been used. These tools are very effective and offer a major help in the mapping of forest fire risk zones, especially when the difficulty in accessing the irregular terrains appears. In order to minimize the occurrence and the frequency of forest fires, it is very important to have a forest fire risk zone map of each area. The results show that 80.64% of the forest fires occurred in the high and very high risk zones, which together represents 27% area of the PTR. This shows that the present methodology based on RS and GIS techniques is reliable and can be efficaciously used in the process of delineation of the forest fire risk zones. The study confirms that the majority of the forest fires occurred in areas closer to road networks and human settlements. This point out that most of the forest fires are induced by the people. The methodology presented in this study becomes an excellent tool used to obtain a classification of the risk zones, necessary for the analysis, study and forest fire risk assessment in order to prevent and to reduce their frequency. The final forest fire risk zone map of the PTR is to be helpful for natural resource managers or planners in the management and environmental protection of resources.

Rezumat:

FOLOSIREA RS ȘI GIS ÎN CARTOGRAFIEREA ZONEI DE RISC A INCENDIILOR DE PĂDURE ÎN REZERVAȚIA PERIYAR TIGER, KERALA, INDIA

Incendiile de pădure reprezintă dezastrul natural cel mai frecvent care se petrece în Ghats-ul de Vest, în special în timpul verii. Zona de studiu selectată este, de asemenea, predispusă la incendii de pădure. În studiul prezent s-a încercat localizarea și cartografierea zonelor predispuse la incendiu în rezervația Periyar Tiger, folosind tehnici geospațiale. Factorii selectați au fost: tipul de acoperire al terenului, panta, distanța față de așezări, distanța față de drum și altitudinea. Harta zonelor de risc a fost generată folosind modelul Indexului de Risc la Incendiu. În harta realizată, aria de studiu a fost împărțită în cinci zone de risc: foarte înaltă, înaltă, moderată, joasă și foarte joasă. Rezultatul a fost confirmat pe baza punctelor de incendiu din ultimii 10 ani. Harta zonei de risc a rezervației Periyar Tiger trebuie să fie un instrument util pentru managerii de resurse naturale sau planificatorii în management, în vederea includerii unor măsuri de precauție pentru protecția resurselor naturale.

References:

AJIN R.S., CIOBOTARU A., VINOD P.G., JACOB M.K. (2015), Forest and Wildland fire risk assessment using geospatial techniques: A case study of Nemmara forest division, Kerala, India, *Journal of Wetlands Biodiversity*, 5: 29-37.

AJIN R.S., JACOB M.K., MENON A.R.R., VINOD P.G. (2014a), *Forest fire risk analysis using geo-information technology: A study of Peppara Wildlife Sanctuary, Thiruvananthapuram, Kerala, India*, Proceedings of the 2nd Disaster Risk and Vulnerability Conference, Thiruvananthapuram, India: 160-165.

AJIN R.S., VINOD P.G., MENON A.R.R. (2014b), *Forest fire risk analysis using GIS and RS techniques: An approach in Idukki Wildlife Sanctuary, Kerala, India*, Proceedings of the 24th Swadeshi Science Congress, Tirur, India: 406-413.

CHAVAN M.E., DAS K.K., SURYAWANSHI R.S. (2012), Forest fire risk zonation using Remote Sensing and GIS in Huynial watershed, Tehri Garhwal district, UA, *International Journal of Basic and Applied Research*, 2: 6-12.

DONG X., LI-MIN D., GUO-FAN S., LEI T., HUI W. (2005), Forest fire risk zone mapping from satellite images and GIS for Baihe Forestry Bureau, Jilin, China, *Journal of Forestry Research*, 16(3): 169-174.

FSI (Forest Survey of India) (2013), *Important Characteristics of India's Forests*, India State of Forest Report, p. 57-70.

GHOBADI G.J., GHOLIZADEH B., DASHLIBURUN O.M. (2012), Forest fire risk zone mapping from Geographic Information System in Northern Forests of Iran (Case study, Golestan province), *International Journal of Agriculture and Crop Sciences*, 4(12): 818-824.

JAISWAL R.K., MUKHERJEE S., RAJU K.D., SAXENA R. (2002), Forest fire risk zone mapping from satellite imagery and GIS, *International Journal of Applied Earth Observation and Geoinformation*, 4: 1-10.

JINZHU Y., ZHONGKE F., WEI J., XIAOQIN Y. (2007), Risk management: A probe and study on forest fires, *Frontiers of Forestry in China*, 2(3): 335-339.

MALIK T., RABBANI G., FAROOQ M. (2013), Forest fire risk zonation using Remote Sensing and GIS technology in Kansrao forest range of Rajaji National Park, Uttarakhand, India, *International Journal of Advanced Remote Sensing and GIS*, 2(1): 86-95.

MANAVALAN R.N., JAYALAKSHMI S. (2013), Forest fire risk and degradation assessment using Remote Sensing and GIS, *Journal of Geomatics*, 7(2): 198-205.

MORANCHO A.B. (2003), A hedonic valuation of urban green areas, *Landscape and Urban Planning*, 66(1): 35-41.

ROTHERMEL P., RICHARD C. (1972), *A mathematical model for predicting fire spread in wild land fires*, USDA Forest Service Research Paper INT – 115, Ogden, Utah, USA.

SOWMYA S.V., SOMASHEKAR R.K. (2010), Application of remote sensing and geographical information system in mapping forest fire risk zone at Bhadra wildlife sanctuary, India, *Journal of Environmental Biology*, 31(6): 969-974.