MAPPING OF FOREST FIRE RISK ZONES IN PEECHI-VAZHANI WILDLIFE SANCTUARY, THRISSUR, KERALA, INDIA: A STUDY USING GEOSPATIAL TECHNIQUES

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

Received: 01.02.2016 / Accepted: 25.03.2017

Abstract: Fires are one of the most common disasters occurring in forests, which adversely affect forest resources, biodiversity and endanger lives. The present study area, Peechi-Vazhani Wildlife Sanctuary is also prone to forest fires, where a total of 22 forest fires occurred during the last decade. The aim of this study is to demarcate the fire risk zones in Peechi-Vazhani Wildlife Sanctuary using geospatial techniques. Factors such as land-cover type, slope, distance from settlement, distance from road, and elevation are selected for the study. The Fire Risk Index method is used to demarcate the risk zones. The area of the final map is grouped into five risk zones *viz.* very low, low, moderate, high, and very high. The final fire risk zone map is validated with the fire incidence points collected from the records of the Forest Survey of India, which shows good reliability. This study shows that majority of the forest fire incidences in this sanctuary are of anthropogenic origin. From the study it is clear that the methodology is sound and can be applied to other areas with similar conditions.

Keywords: anthropogenic origin, Fire Risk Index, forest fire, geospatial techniques

Introduction:

Forest fires are one of the major natural hazards, which cause environmental, ecological and economic losses in the tropical forests of India. Uncontrolled severe fires can result in loss of forest resource, biodiversity, as well as human and animal life. In India, wildfires are the main reason for forest degradation and deforestation. Forest fires can be induced by both lightning strikes and human activities. The Peechi-Vazhani Wildlife Sanctuary is a part of the Western Ghats – a UNESCO World Heritage Site and a biodiversity hotspot in southwest India. This region is home to many rare and endemic floral and faunal species and is prone to forest fires, especially during the hot summer months. Any disturbance in this region will adversely affect the rich and unique assemblage of flora and fauna. Therefore all possible precautions along with

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): ajinares@gmail.com

fire prevention and mitigation action plan must be designed and developed.

Geospatial techniques (Remote Sensing and Geographic Information System) have been used by many researchers (Jaiswal et al. 2002; Dong et al. 2005; Vadrevu et al. 2010; Chavan et al. 2012; Ghobadi et al. 2012; Eskandari et al. 2013; Malik et al. 2013; Singh and Ajay 2013; Ajin et al. 2014a; 2014b, 2015, 2016a, 2016b, 2016c; Sivrikaya et al. 2014; Vinod et al. 2016) to demarcate the forest fire risk zones. Remote Sensing (RS) and Geographic Information System (GIS) are cost-effective and time-saving techniques, which can be efficaciously employed in risk assessments. Suryabhagavan et al. (2016) identified the fire risk zones of Harenna forest in Ethiopia using RS and GIS techniques. Factors such as elevation, slope, aspect, vegetation type, proximity to settlements and distance from roads were selected for the study. Using the same techniques Adab et al. (2013) delineated the fire risk zones in northeast Iran. The factors selected were vegetation moisture, slope, aspect, elevation, distance from roads, and vicinity to settlements. Sowmya and Somashekar (2010) demarcated the forest fire risk zones in Bhadra wildlife sanctuary using RS and GIS techniques. The factors selected were vegetation, slope, distance from roads, and proximity to settlements. Mahdavi et al. (2012) demarcated the wildfire risk zones of Ilam Township in western Iran. Factors such as elevation, slope, aspect, precipitation, temperature, distance from rivers, distance from roads, land cover, and population density were selected for the study.

The objective of this study is to delineate the forest fire risk zones in Peechi-Vazhani Wildlife Sanctuary using geospatial techniques. The factors selected are land cover type, slope, distance from settlement, distance from road, and elevation. The Fire Risk Index (FRI) method is used to delineate the risk zones.

Materials and methods:

Study area

The study area, Peechi-Vazhani Wildlife Sanctuary lies between 10˚27'0" and 10˚40'0"N latitudes and 76˚18'0" and 76˚29'0"E longitudes. This sanctuary is bounded by Thrissur forest division to the north and west, Nemmara forest division to the east, and Chalakkudy forest division and Chimmony Wildlife Sanctuary to the south. The sanctuary spans an area of about 125 Sq. Km. It is the catchment area of two reservoirs – Peechi and Vazhani. The study area map is shown in Figure 1.

The study area was delineated from the Survey of India topographic maps (58 B/6 and 58 B/7) of 1:50,000 scale. In order to 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 Landsat ETM+ image of 30 m resolution. ERDAS Imagine software was used for the supervised classification of the satellite 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 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. 2014b, 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 was calculated from the weight and rank (Index = Weight X Rank) (Tab. 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 using the fire

incidence points collected from the records of the Forest Survey of India (FSI). The flowchart of the methodology is displayed in Figure 2.

Figure no. 1 Study area map

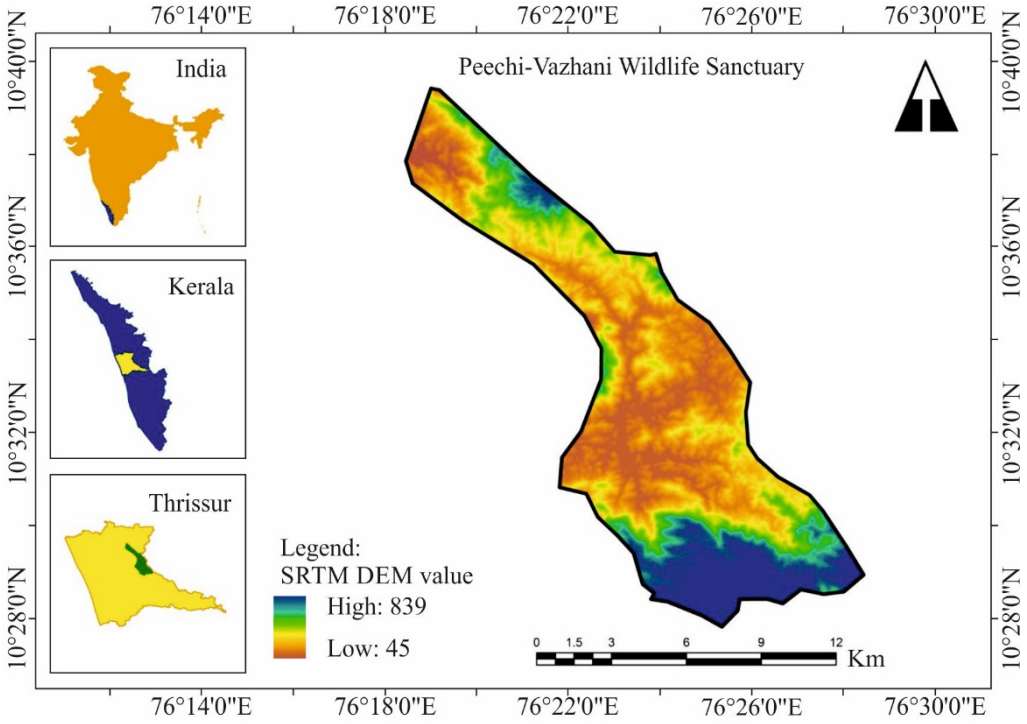


Figure no. 2 Flowchart of the employed methodology

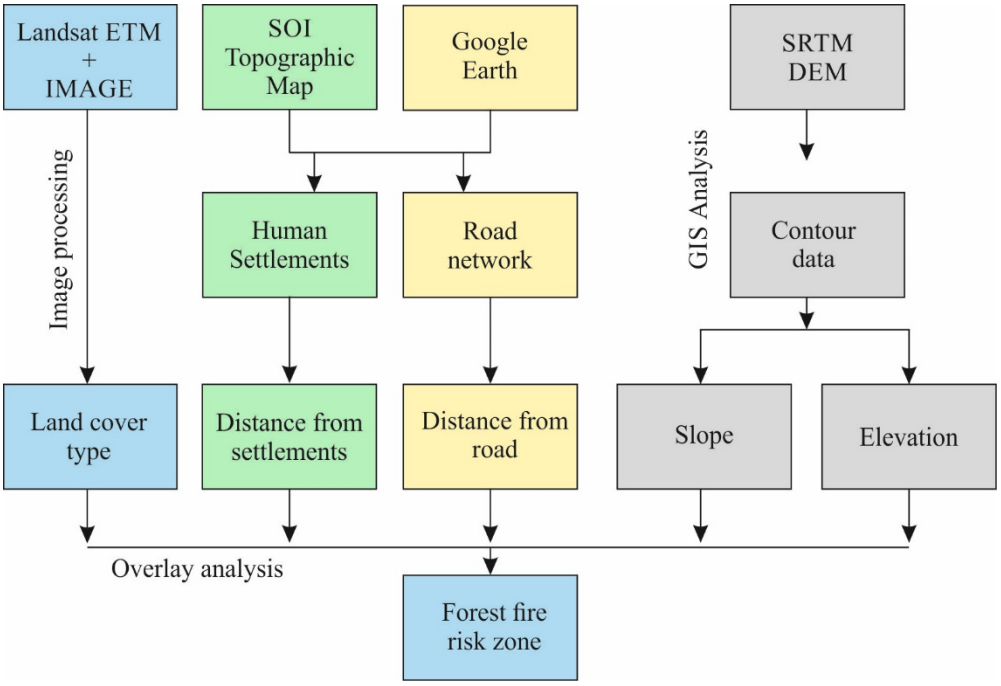


Table no. 1 Rank, weight and index assigned for different factors

Sl. no.	Factor	Class	Rank	Weight	Index
1	Land cover type	Deciduous forest	4	10	40
		Evergreen forest	3		30
		Agricultural land	2		20
		Water body	1		10
2	Slope (degree)	0 – 6.16	1	3	3
		6.16 – 11.58	2		6
		11.58 – 17.74	3		9
		17.74 – 25.40	4		12
		25.40 – 47.62	5		15
3	Distance from settlement (m)	0 – 1229	5	2	10
		1229 – 2695	4		8
		2695 – 4440	3		6
		4440 – 6739	2		4
		6739 – 10109	1		2
4	Distance from road (m)	0 – 1381	5	2	10
		1381 – 2762	4		8
		2762 – 4419	3		6
		4419 – 6748	2		4
		6748 – 10062	1		2
5	Elevation (m)	50 – 156	1	1	1
		156 – 276	2		2
		276 – 424	3		3
		424 – 600	4		4
		600 – 830	5		5

Results and discussion:

Land cover type

Land cover, the physical material present on the surface of the earth has a strong relationship with the forest fire occurrence. Vegetation is the most influencing land cover and is the fuel for forest fire. Different types of vegetation have different kinds of combustibility. Generally, the dry and dense vegetation is more prone to fire. The land cover types in this sanctuary are deciduous forest, evergreen forest, agricultural land and water body. In this sanctuary, the deciduous forests are more prone to fires. The land cover type map is shown in Figure 3.

Slope

Slope is the most important topographic factor, which influences the speed of fire spread. Fire moves most quickly up slope and least quickly down slope (Rothermel 1972). The steeper slopes are more prone to fire, as the convectional preheating and ignition rate are more effective in this area. The slope of the sanctuary is grouped into five classes' viz., 0 – 6.16^{o}, 6.16 – 11.58^{o}, 11.58 – 17.74^{o}, 17.74 – 25.40^{o}, and 25.40 – 47.62^{o}. The slope map is shown in Figure 4.

Distance from settlement

The areas closer to the human settlements are more prone to fires. The tribal settlements and eco huts constructed for the tourists pose threat to the forests. Carelessness in the livelihood practices of the forest inhabitants and recreational activities of travellers and tourists can cause forest fires, both intentional and unintentional. Based on the pattern of distribution of human settlements, the area has been grouped into five classes

viz., 0 – 1229 m, 1229 – 2695 m, 2695 – 4440 m, 4440 – 6739 m, and 6739 – 10109 m. The distance from settlement map is shown in Figure 5.

Figure no. 3 Land cover type map

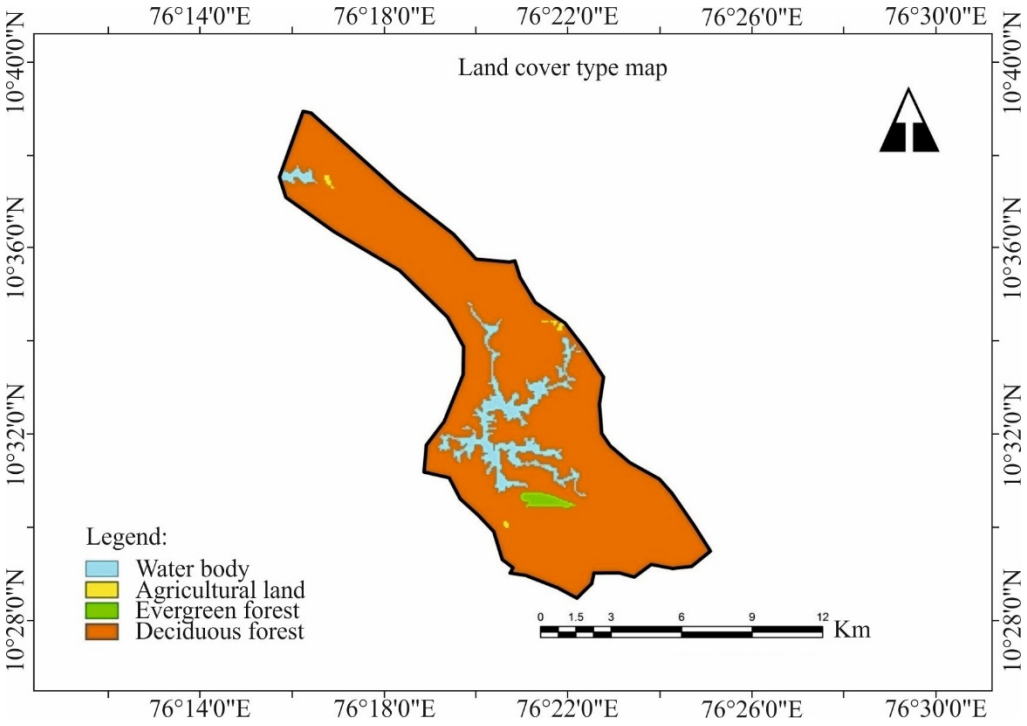


Figure no. 4 Slope map

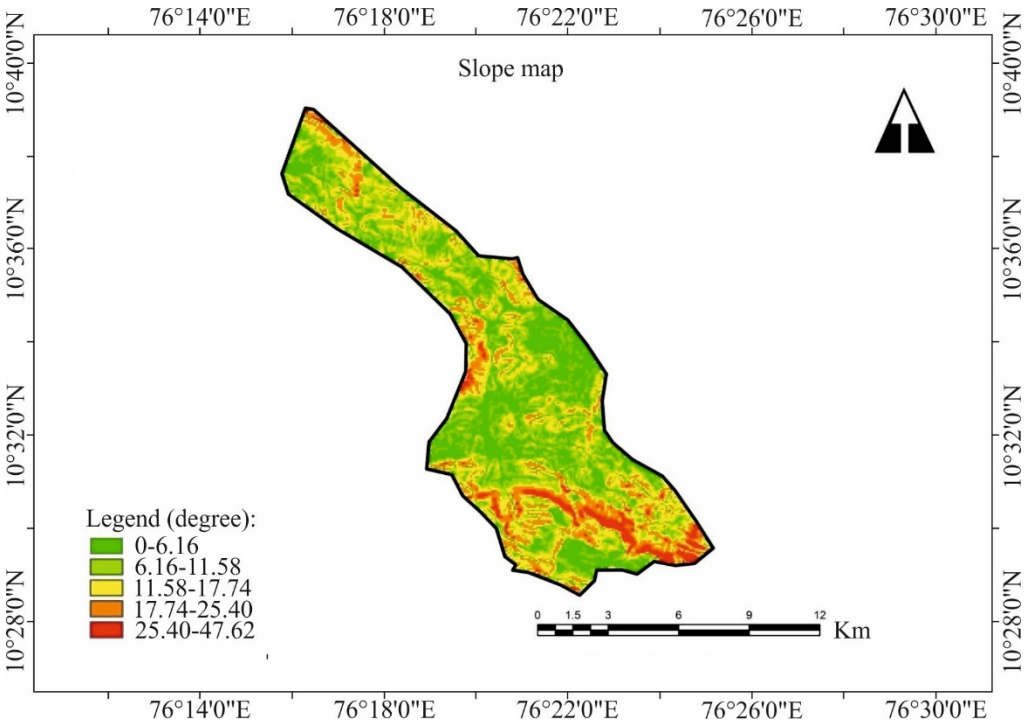
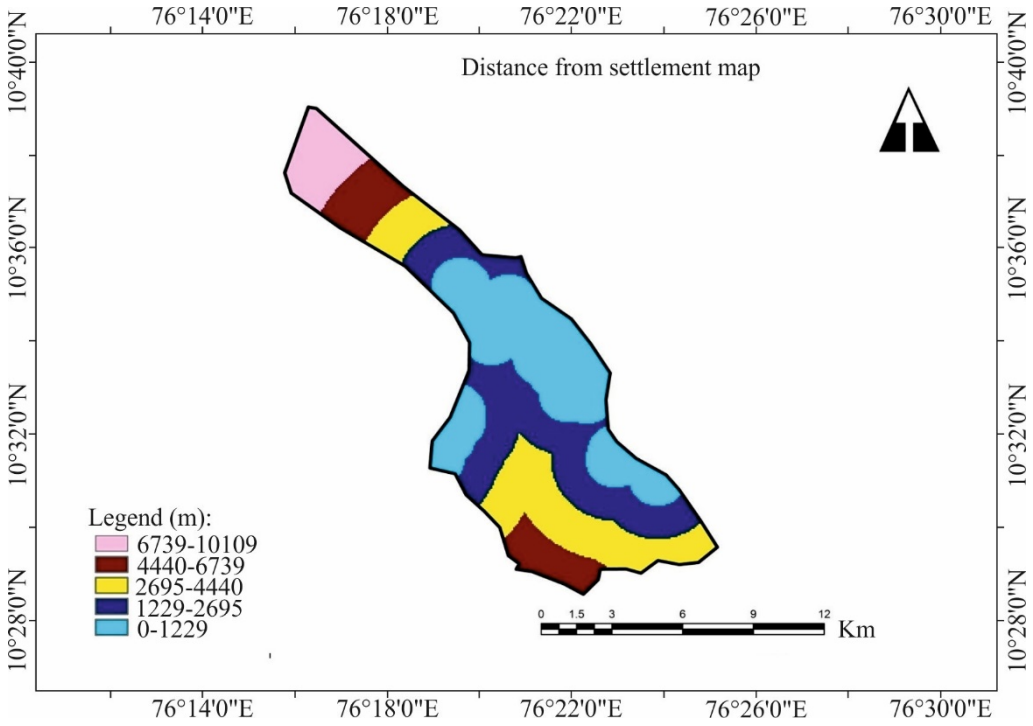


Figure no. 5 Distance from settlement map



Distance from road

The areas closer to the road networks are more susceptible to fires. The fires occurring in this zone are mainly due to some unintentional recreational activities. Roads allow tourists to go into forest areas and create ignitions. Based on the proximity to roads, the area has been grouped into five classes viz., 0 – 1381 m, 1381 – 2762 m, 2762 – 4419 m, 4419 – 6748 m, and 6748 – 10062 m. The distance from road map is shown in Figure 6.

Elevation

The areas with higher elevation are more prone to fires. Areas of higher elevation, where the incidences of lightning strikes are more, are also areas where the rate of advancement of forest fires is much higher. The elevation of the area is grouped into five classes viz., 50 – 156 m, 156 – 276 m, 276 – 424 m, 424 – 600 m, and 600 – 830 m. The elevation map is shown in Figure 7.

Forest fire risk zones

The forest fire risk zone map is prepared by overlaying 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. The area of fire risk zones is calculated and is shown in Table 2.

The most important part of the study is the validation of results. The prepared risk zone map is of no use, unless validated with real world datasets. In this study, the fire incidence points collected from the records of the FSI is used to validate the results. During the last decade 22 forest fires have occurred in the study area. The results show that 86.37% (19) of the incidences have occurred in the high and very high risk zones, 13.63% (3) occurred in the moderate risk zone, whereas no fires were reported in the low and very low risk zones.

Figure no. 6 Distance from road map

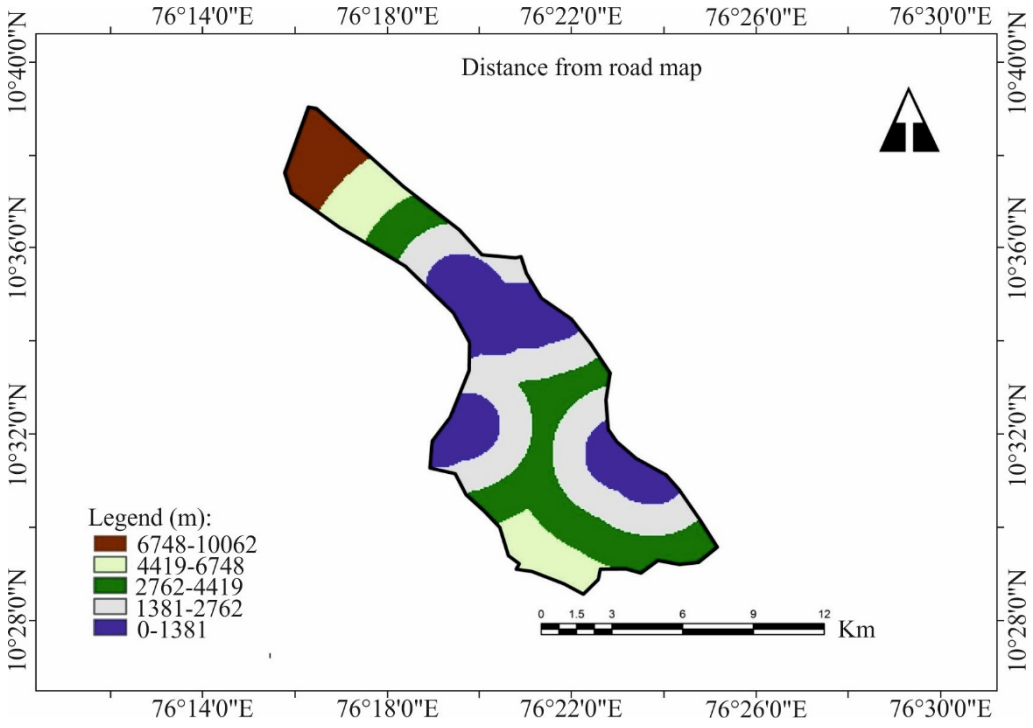


Figure no. 7 Elevation map

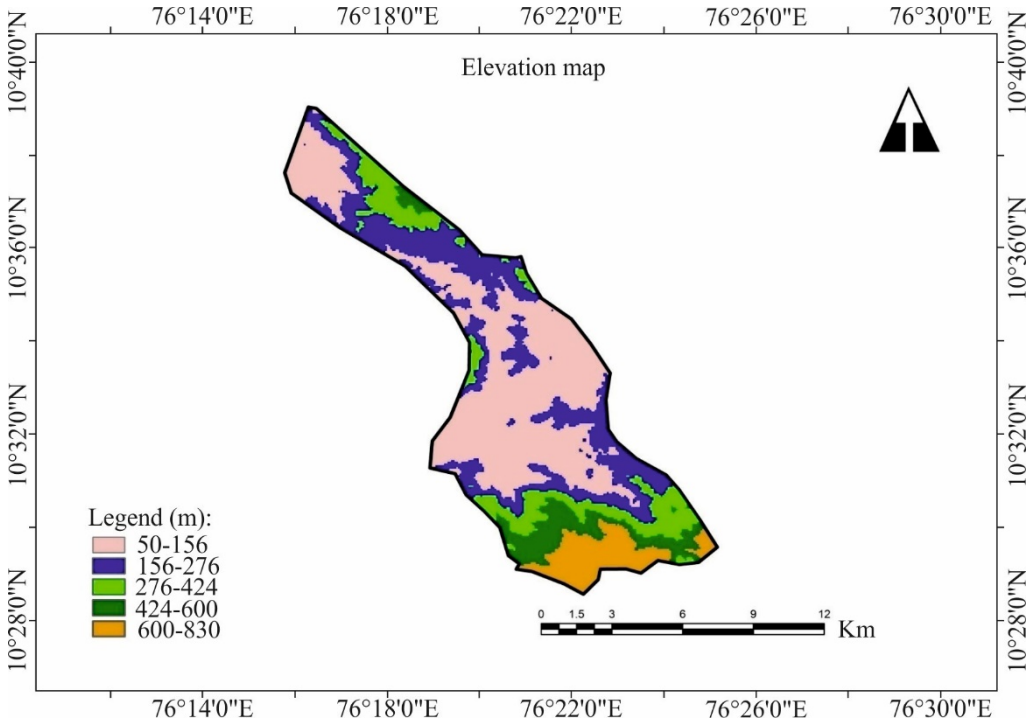
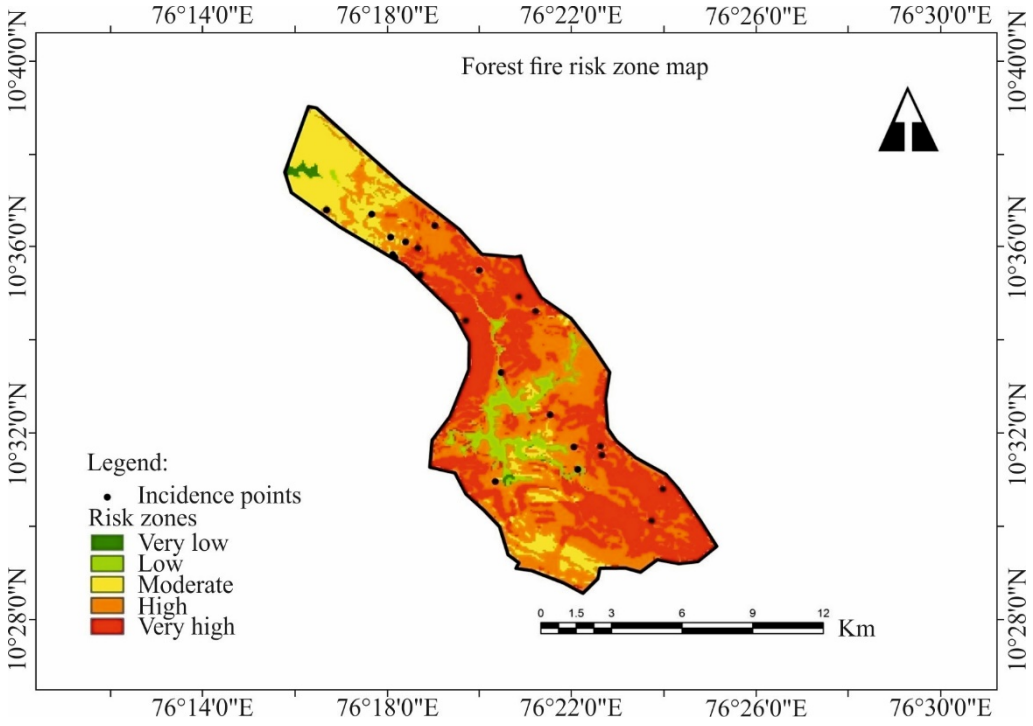


Table no. 2 Area of fire risk zones, number and percentage of fire incidences

Fire Risk Zones	Area (km^2)	Number of fire incidences	Percentage of fire incidences
Very Low	0.82	0	0
Low	8.25	0	0
Moderate	18.15	3	13.63
High	54.84	7	31.82
Very High	42.94	12	54.55
Total	125	22	100

The fires occurred in the months of February and March. The abundance of dry flammable fuel, prevailing winds, along with the hot and dry climate favour the occurrence and propagation of forest fires. The forest fire risk zone map is shown in Figure 8. The study shows that most of the fire incidence points fall spatially in the lower slopes and in the vicinity of roads and settlements. This confirms that the fires are induced by humans.

Figure no. 8 Forest fire risk zone map



Conclusions:

The present study is an attempt to delineate the forest fire risk zones in Peechi-Vazhani Wildlife Sanctuary using geospatial tools. The FRI method is employed to prepare the forest fire risk zone map and the study area is divided into five risk zones ranging from 'very low' to 'very high'. The validation of the results with the fire incidence points has shown that 86.37% of the forest fires occurred in the high and very high risk zones. Most of the fire incidence points fall spatially in the vicinity of roads and

settlements and also on the lower slopes; this confirms the anthropogenic origin of fires. The study shows that the present methodology based on RS and GIS techniques is reliable. The prepared forest fire risk zone map can help the forest managers and disaster management agencies to easily identify the high and very high fire risk zones and take preventive measures and reduce damage of natural resources and loss of life and property.

Rezumat:

CARTOGRAFIEREA ZONELOR DE RISC LA INCENDIU ÎN PĂDURILE DIN REZERVAȚIA NATURALĂ PEECHI-VAZHANI, THRISSUR, KERALA, INDIA: STUDIU DE CAZ PRIVIND UTILIZAREA TEHNICILOR GEOSPAȚIALE

Incendiile reprezintă unul dintre cele mai comune dezastre care apar în păduri, afectând negativ resursa forestieră, biodiversitatea și punând în pericol viețile oamenilor. În zona studiată, Rezervația Naturală Peechi-Vazhani, pădurile sunt predispuse la incendii, în ultima decadă având loc un număr de 22 de incendii. Scopul acestui studiu este de a cartografia zonele de risc la incendiu în Rezervația Naturală Peechi-Vazhani, utilizând tehnicile geospațiale. Factori ca tipul de acoperire a terenului, panta, distanța față de așezări, distanța față de drum și altitudinea au fost folosiți pentru acest studiu. Metoda Indexului de Risc la Incendiu a fost folosită pentru a cartografia zonele de risc. Harta arealului a fost împărțită în cinci zone de risc, respectiv, foarte redusă, redusă, moderată, mare și foarte mare. Harta finală a zonelor de risc a fost validată cu punctele de incidență la incendiu selectate din înregistrările FSI (Forest Survey of India), indicând o concordanță foarte bună. Prin acest studiu s-a putut preciza că majoritatea incendiilor din pădurile rezervației au o origine antropogenă. Din rezultatele obținute prin acest studiu se poate spune că metodologia este sigură și poate fi aplicată și în alte zone cu condiții similare.

References:

ADAB H., KANNIAH K.D., SOLAIMANI K. (2013), Modeling forest fire risk in the northeast of Iran using remote sensing and GIS techniques, *Natural Hazards* 65: 1723-1743.

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.

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., LOGHIN A.M., KARKI A., VINOD P.G., JACOB M.K. (2016a), Delineation of forest fire risk zones in Thenmala forest division, Kollam, Kerala, India: A study using geospatial tools, *Journal of Wetlands Biodiversity* 6: 175-184.

AJIN R.S., LOGHIN A.M., VINOD P.G., JACOB M.K. (2016b), RS and GIS based forest fire risk zone mapping in the Periyar Tiger Reserve, Kerala, India, *Journal of Wetlands Biodiversity* 6: 139-148.

AJIN R.S., LOGHIN A.M., VINOD P.G., JACOB M.K. (2016c), Forest fire risk zone mapping in Chinnar Wildlife Sanctuary, Kerala, India: A study using geospatial tools, *Journal of Global Resources* 3: 16-26.

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.

ESKANDARI S., GHADIKOLAEI J.O., JALILVAND H., SARADJIAN M.R. (2013), Detection of Fire High-Risk Areas in Northern Forests of Iran Using Dong Model, *World Applied Sciences Journal* 27 (6): 770-773.

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.

MAHDAVI A., SHAMSI S.R.F., NAZARI R. (2012), Forests and rangelands' wildfire risk zoning using GIS and AHP techniques, *Caspian Journal of Environmental Sciences* 10 (1): 43-52.

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.

ROTHERMEL R.C. (1972), A mathematical model for predicting fire spread in wildland fuels, *USDA Forest Service Research Paper INT – 115*, Ogden, Utah, USA.

SINGH R.P., AJAY K. (2013), Fire Risk Zone Assessment in Chitrakoot Area, Satna MP, India, *Research Journal of Agriculture and Forestry Sciences* 1 (5): 1-4.

SIVRIKAYA F., SAĞLAM B., AKAY A.E., BOZALI N. (2014), Evaluation of Forest Fire Risk with GIS, *Polish Journal of Environmental Studies* 23 (1): 187-194.

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.

SURYABHAGAVAN K.V., ALEMU M., BALAKRISHNAN M. (2016), GIS-based multi-criteria decision analysis for forest fire susceptibility mapping: a case study in Harenna forest, southwestern Ethiopia, *Tropical Ecology* 57 (1): 33-43.

VADREVU K.P., EATURU A., BADARINATH K.V.S. (2010), Fire risk evaluation using multicriteria analysis — a case study, *Environmental Monitoring and Assessment* 166: 223-239.

VINOD P.G., AJIN R.S., JACOB M.K. (2016), RS and GIS based spatial mapping of forest fires in Wayanad Wildlife Sanctuary, Wayanad, North Kerala, India, *International Journal of Earth Sciences and Engineering* 9 (2): 498-502.