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MAPPING FIRE HAZARD IN RAJAJI NATIONAL PARK, FUTURE PERSPECTIVE OF WILDLIFE HABITAT CONSERVATIONBY USING REMOTE SENSING AND GIS

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***Abstract*— Forest fires lead to disastrous consequences such as huge economic and ecological losses in India. Apart from landslides and earthquakes, forest fires are one of the major natural risks in the Uttarakhand forests. It is impossible to control nature, but is possible to map forest fire risk zones for early action and thereby minimizing fire frequency. A study has been conducted in Rajaji National Park which is an important animal habitat because of its location at the meeting point of the lesser Himalayan foothills and the beginning of the vast Indo-Gangetic plains. Forest fire during summer months is a major problem in the park, which most of the times result into loss of fodder, habitats, as well as death of wildlife too.**

In the present study an attempt has been made to develop a Fire Hazard Map of Rajaji National Park where forest and wild land fires have been taking place historically, by using multi source data comprising cartographic documents, satellite imageries and statistical information about the fire history of the region. It is based upon a combination of remote sensing and GIS data. Parameters that affect fire such as Topography, Vegetation, Drainage, Settlements, Road network and Forest Guard Chowki were integrated within a GIS framework. Multi-temporal fire hot-spot data from MODIS were used as reference data. The relation between the occurrence of wild fires and the influencing factors was established. Each factor was converted into thematic layer and based upon the value of parameter at each Fire incidence location; a thematic hazard map was generated. The study area was divided into five hazard classes based upon the intensity of Hazard viz. Very high, High, Moderately, Low and Very Low. The results of the analysis were shown by maps, table and Chart. The evolved GIS-based forest fire hazard map of the study area was found to be in strong agreement with actual fire-affected sites. The resulting map can be of great use for the understanding of the fire problem and can be a good tool for the management of forest fire in the park. It also depicts the alert and alarming for wildlife conservation& its future perspectives.

***Index Terms*— Fire Hazard, Landsat, Forest Fire, Fire management, RS & GIS.** *(key words)*

I. Introduction

A forest fire whether it is caused by natural forces or anthropogenic activities could be the real ecological and environmental disaster (Saigal, 1989; Kandya *et al*., 1998). In India, about 2 to 3 % of the forest area is affected annually by fire and on an average over 34,000 ha forest areas are burnt by fire every year (Kunwar P. 2003). Fire hazard is physical event of certain magnitude in a given area and at a given time, which has the potential to disrupt the functionality of a society, its economy & its environment (Boonchut, 2005).

Fire serves as an important function in maintaining the health of certain ecosystems, but as a result of changes in climate and in human use and misuse of fire, fires have become a threat to many forests and their biodiversity (Dennis, Meijaard *et al.* 2001).

Forest fire research can be considered as one of the most appropriate areas, where Geographic Information System (GIS) approach can be effectively applied. GIS can take advantage of the computer’s capability in processing, storage and retrieval of immense data. The use of the GIS approach facilitates in integrating several variables in order to establish and focus on the problem. It has been stated that when it comes to spatial-decision aid, the analytical capability of the GIS has to be enhanced in respect of semi-structured problems involving subjective judgments (Beedasyl, *et.al.* 1999). This can be strengthened by any GIS application, which is most appropriate for that site-specific condition. Such type of study provides the scientific proof and prediction of hazardous situation for fauna and flora in wildlife. We can also predict by generating the model for movement pattern of wild animal like elephant and tiger (Panthera tigris). Animal can change their movement from hazardous place to easier one. This condition leads the chances of conflict and loss of man& nature both.

II. Geospatial Technology for Forest Fire Zone Mapping

Remote sensing has significant advance over a conventional method to map forest fire hazard, because of its continuity coverage over large areas. A GIS can take advantage of its capability to combine different source of information for modelling or mapping. However, for the optimum utilization of remote sensing and GIS to forest fire hazard model, the characteristic of remotely sensed data and GIS analysis, which are closely related to fuel type, terrain and human access, that have been known as a factor affecting spreading of fire need to be studied. However, this type of research is generally lacking in the tropical region compared to other regions (Darmawan; *et al.* 2001).

Monitoring techniques based on multi-spectral satellite acquired data have demonstrated potential as a means to detect, identify, and map fire danger in vegetation. Fire danger estimation demands frequent monitoring of vegetation stress. Vegetation moisture is particularly difficult parameter to estimate as it accounts for little spectral variation with respect to other environmental factors (Cohen 1991).

The Moderate-resolution Imaging Spectrometer (MODIS) is an instrument that is onboard two satellite platforms owned by NASA: Terra (launched December 18^{th}, 1999) and aqua (launched May 4^{th}, 2002). The MODIS instrument has 36 spectral bands available to view the earth. Each instrument has a viewing swath width of 2,330 km and views the entire surface of earth every one to two days. The image resolution used in detecting fires is 1 km.

III. Objectives and Study Area

The objective of this research is to develop a Fire Hazard Map of Rajaji National park using remote sensing and GIS.

The study was carried out in Rajaji National Park (Fig.1) (29^{o}50\`52" to $30^{o}$15\`11" North latitude and 78^{o} 00\`30" to $78^{o}$ 52\` 45" East longitude) located in north India and covers an area about 869 km^2. It extends over the Shiwalik Range from Dehradun-Saharanpur road in the north-west to the Rawasan River in the southeast, with Ganges dividing it into two parts. The eastern part, consisting of the Chilla and Gohri ranges, stretches from the left bank of the Ganges to Rawasan river in the east and Shyampur range of haridwar forest Division to the South. The northern boundary of the eastern portion of the park is defined by Laxmanjhula beat of Gohri range of the park. The western part of the park consists of the Ramgarh, kansaro, Motichur, Haridwar, Dholakhand and Chillawali Ranges. The area has an uneven topography, with elevation ranging from 242 m to 1362 m. The area is covered with thick green forest, mainly Sal, Teak, and other varieties of deciduous trees, along with grass and shrubs.

Based on the physiognomy and floristic composition, the permanent vegetation of the Park may be classified broadly under the Northern Tropical Moist Deciduous Forests and can be grouped into the following six types: a. Sal Forest b. Mixed Forest c. Riverine Forest d. Scrubland e. Grassland (savannah) f. Subtropical Pine Forest.

IV. Materials and Methodology

A. Data used

The data used is Landsat 8 of November 21, 2013 (spatial resolution 30m), Topo Sheet (SOI) No. 53 f/16, 53j/3,4,8 and 53k/1,5 on scale 1:50,000 with contour interval 20 meters, ASTER 30m. Garmin 76 GPS is used for field purpose. Historical Fire data for the period of 2000-2014 was downloaded from FIRMS website in the form of shapefile as point feature. Digital boundary of Rajaji National Park upto beat level was collected from IT Cell, PCCF office, Management plan of Rajaji National Park.

Software used: Erdas imagine 2013 for Digital Image Processing work & Arc GIS 10.1 for map composition.

Fig. 1. Study Area Map

B. Methodology

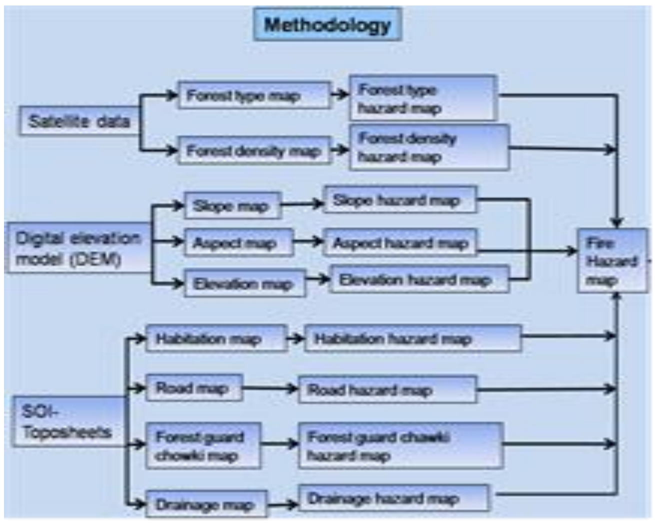

Fig. 2. Flowchart of Methodology

C. Generation of Fire Incidence Map

Digital boundary of Rajaji National Park was used to clip the fire points of study area. Total 760 fire incidences occurred during 15 years (2000-2014). The analysis shows that the park was severely affected in year 2010 due to highest number of fire incidences during 15 years followed by 2007. 2014 has reported 33 fire incidences. Chilla Range has maximum fire incidence followed by Haridwar and Ramgarh range during 15 year (2000-14). The fire incidence map of study area is shown in Fig. 3

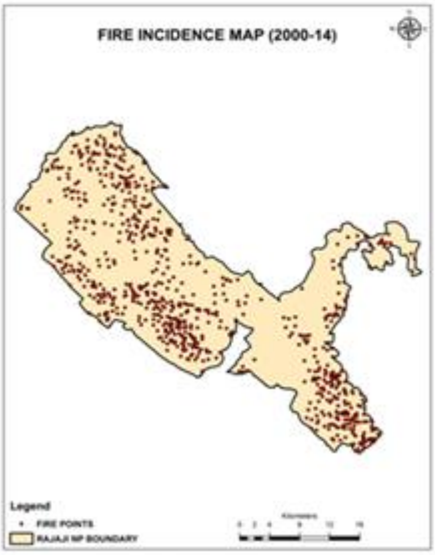

Fig. 3. Fire Incidence Map

D. Generation of Thematic Layers

For inputting spatial data in GIS, it is necessary that the resource information is in the form of map; hence the mapping of the thematic layers is one of the primary requirements. Remote sensing, coupled with limited ground checks, is the most ideal way for generating resource maps.

A. *Generation of Forest Type and Vegetation Density Type Layers*

Supervised classification approach was used for classification of Forest type (Fig.5) in which 30 training sets were taken from Google earth as ground control points. Based on the field visit the study area was classified into Sal Forest, Mixed Forest, Riverine Forest, Scrubland, Grassland (savannah) and Subtropical Pine Forest.

Unsupervised classification approach was used for Vegetation Density Mapping (Fig.7) using ERDAS imagine 2013 software. The study area was classified into 50 spectral classes using unsupervised image classification approach. Eventually the Vegetation of study area was stratified into four major types on the basis of density viz; VDF (very dense forest), MDF (moderately dense forest), OF (open forest) and Sc (Scrub) as per the fundamental criteria of Forest Survey of India (FSI) for Forest cover Mapping (FCM).

B. ***Generation of Slope, Aspect and Elevation from DEM (Digital Elevation Model)***

A subset of the ASTER 30m DEM of study area was clipped with the help of boundary vector layer. Slope (Fig.9), Aspect (Fig.11) and Elevation (Fig.13) map were generated with the help of Arc map 10.1.

C. ***Generation of Vector layer(Road, Drainage, Habitation and Forest Guard Chowki (FGC))***

Road (Fig.15), Drainage (Fig.17), Habitation (Fig.19) and Forest guard Chowki (Fig.21) were digitized from Survey of India toposheets at 1:5000 scale with the help of Arc map 10.1 software.

Data processing & Generation of Thematic Hazard Layers

For generating thematic hazard map of each thematic parameter (Slope, Aspect, Elevation, Forest Type and Vegetation Density) the value of parameters at each fire incidence location were extracted from these layers. For establishing the relation of fire incidence location *w.r.t.* Habitation, Road, Drainage and FGC layer "Near tool" was used to calculate the Distance from Fire incidence location. Inverse Distance weighted technique (IDW) has been used for generating thematic hazard map of each parameter.

The raster data products were reprojected with nearest neighbour resampling to maintain the pixel values, and resampled with 30m output pixel dimensions to reduce nearest-neighbour resampling pixel shifts (i.e. position errors) (Dikshit & Roy, 1996). Similarly, the vector data were converted into raster thematic layers with 30m output pixel dimensions.

A specific color code was assigned to each Hazard class for representing it in thematic hazard map. Hazard value of each Hazard class differs with the significance of parameter in Forest Fire. The color code used for each hazard class has been shown in Fig.4.

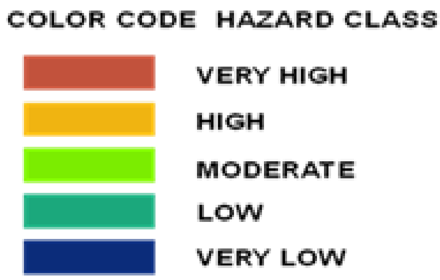

Fig.4. Hazard Class Colour Code

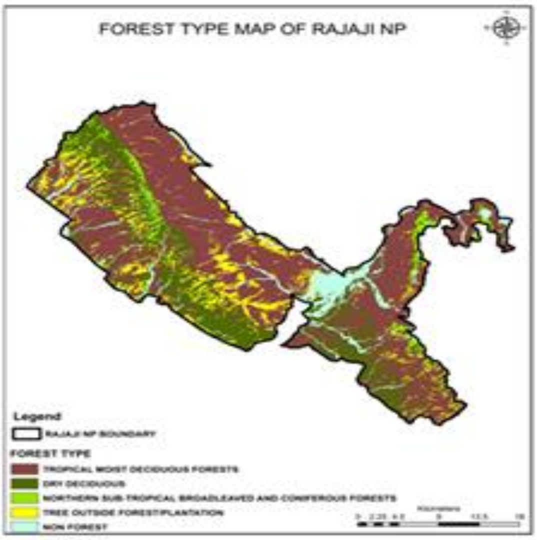

Fig. 5 Forest Type Map

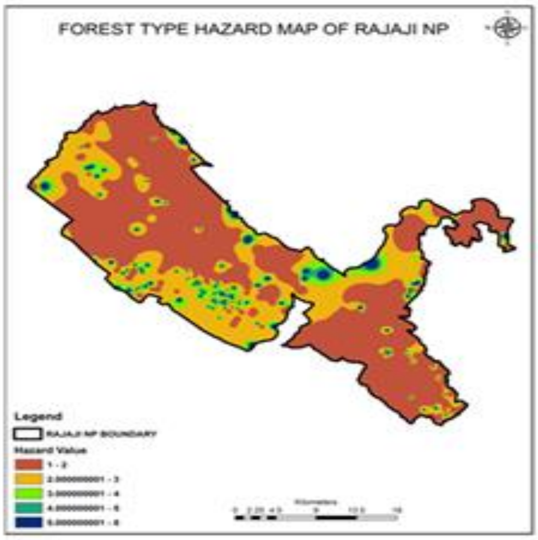

Fig. 6 Forest Type Hazard Map

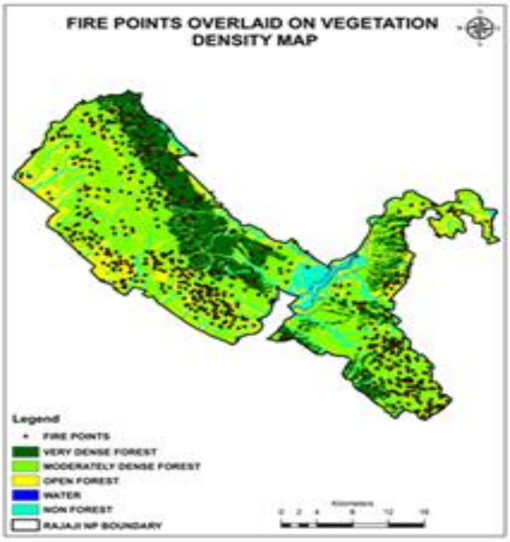

Fig. 7 Vegetation Density Map

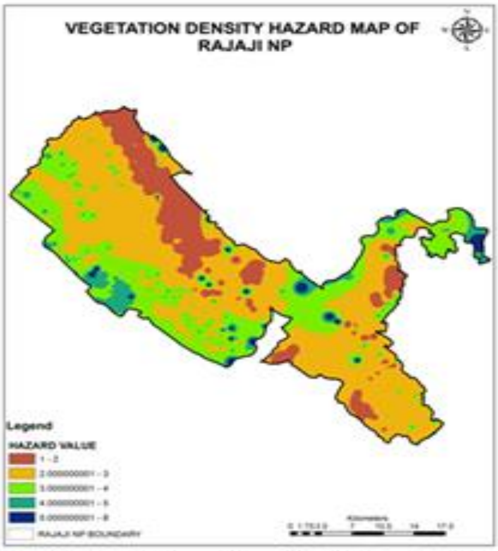

Fig. 8 Vegetation Density Hazard Map

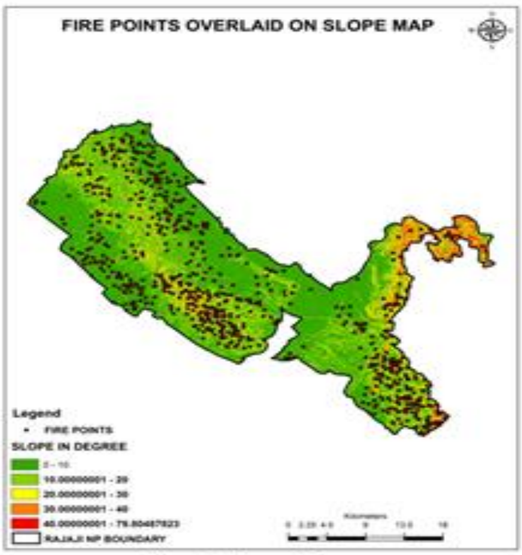

Fig. 9. Slope Map

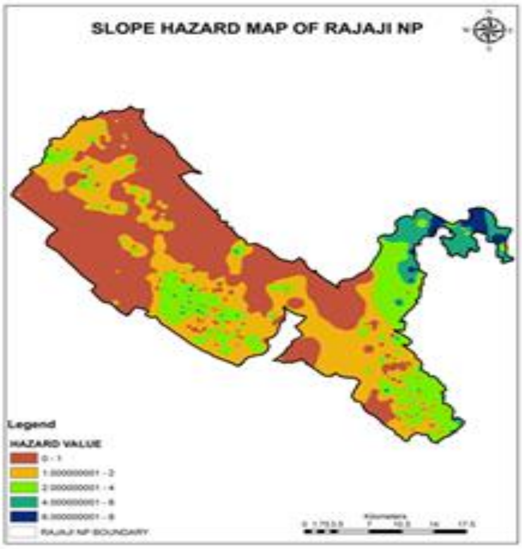

Fig. 10. Slope Hazard Map

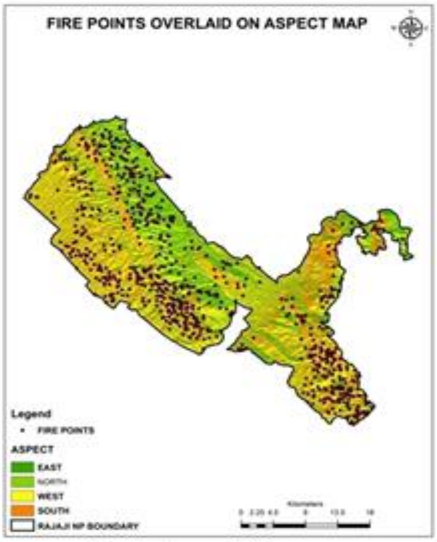

Fig. 11. Aspect Map

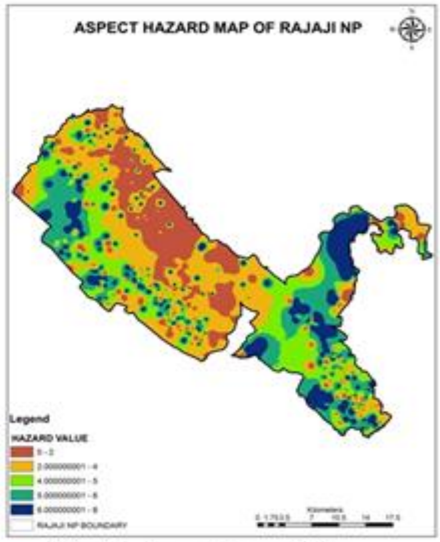

Fig. 12. Aspect Hazard Map

Fig. 13. Elevation Map

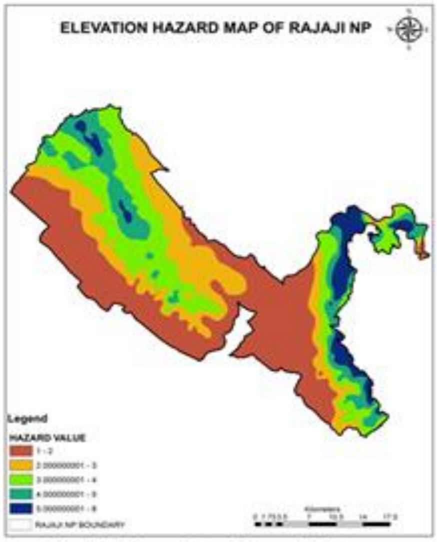

Fig. 14. Elevation Hazard Map

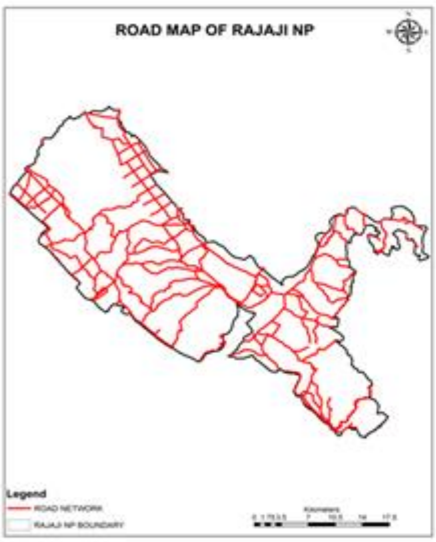

Fig. 15. Road Map

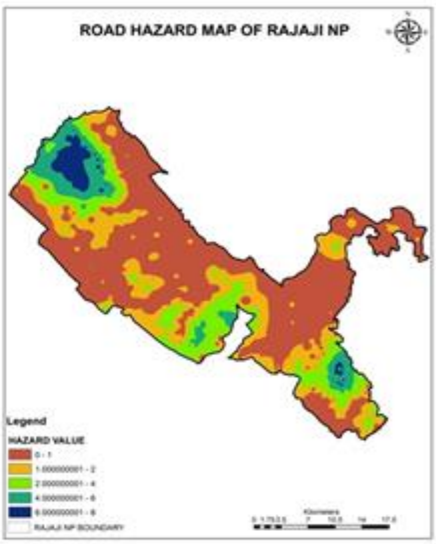

Fig. 16. Road Hazard Map

Fig. 17 Drainage Map

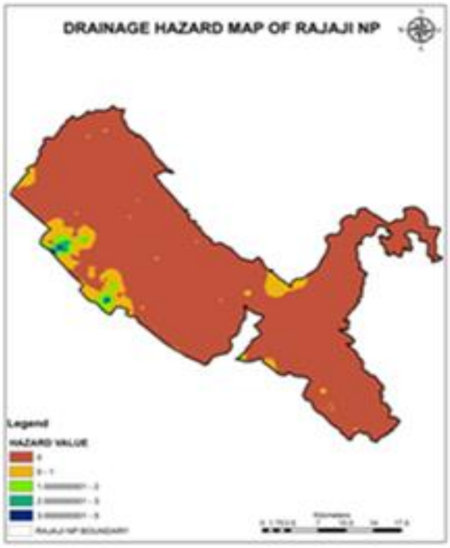

Fig18 Drainage HazardMap

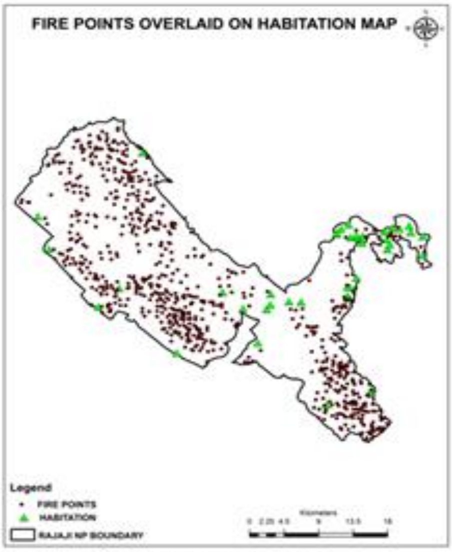

Fig. 19. Habitation Map

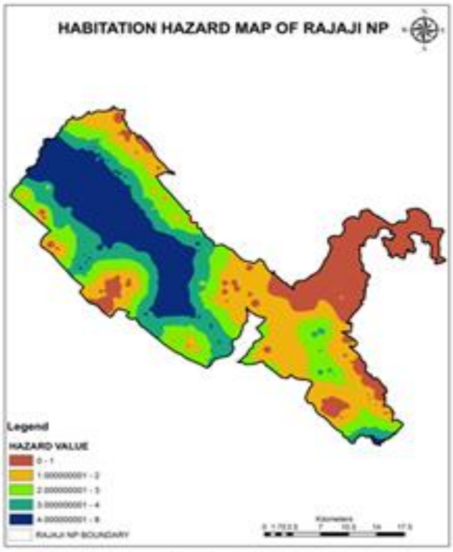

Fig. 20. Habitation Hazard Map

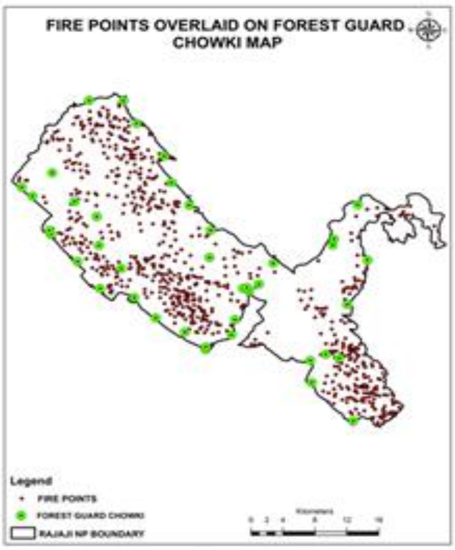

Fig. 21. Forest Guard Chowki Map

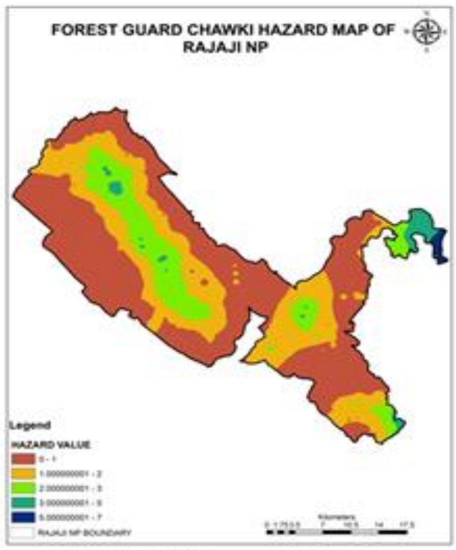

Fig. 22. FGC Hazard Map

V. Results & Discussion

A. Generation of Fire Hazard Map

Fire hazard map (Fig.23) has been generated by using Map Algebra tool in Arc GIS. Each thematic hazard layer Forest Type Hazard (Fig. 6), Vegetation Density Hazard (Fig. 8), Slope Hazard (Fig. 10), Aspect Hazard (Fig. 12), Elevation Hazard (Fig. 14), Road Hazard (Fig. 16), Drainage Hazard (Fig. 18), Habitation Hazard (Fig. 20), FGC Hazard (Fig. 22) with pixel size of 30m dimension has been added by using Raster calculator tool which Builds and executes a single Map Algebra expression using Python syntax in a calculator-like interface by adding the Hazard values of each pixel of thematic hazard layer one by one for generating Fire hazard map of Rajaji National Park. The hazard class with hazard value 0 is not playing any role in Fire Hazard map. The Hazard value in Fire Hazard Map varies from 6-42. This on further classification in five classes divides the hazard values in five different ranges. The area of each Hazard class was calculated in sq km (Table1).

Our methodology evaluated Fire Hazard Map for Rajaji National Park providing substantial improvement over frequency analysis method. In our study area Vegetation Density, Elevation, Aspect, Forest type, Road network, FGC and Habitation plays significant role in Fire with Hazard Value more than 0. The slope map reveals that most of the study area comes under gentle slope. So, it does not play a significant role in Fire Hazard Map as most of the study area comes under Very High and High Hazard class. Drainage is less significant parameter as the most of the area comes under Very High Hazard Class with Hazard value 0 (Fig.18) as the drainage is uniformly distributed in study area. Therefore, it does not play any role in Fire Hazard map.

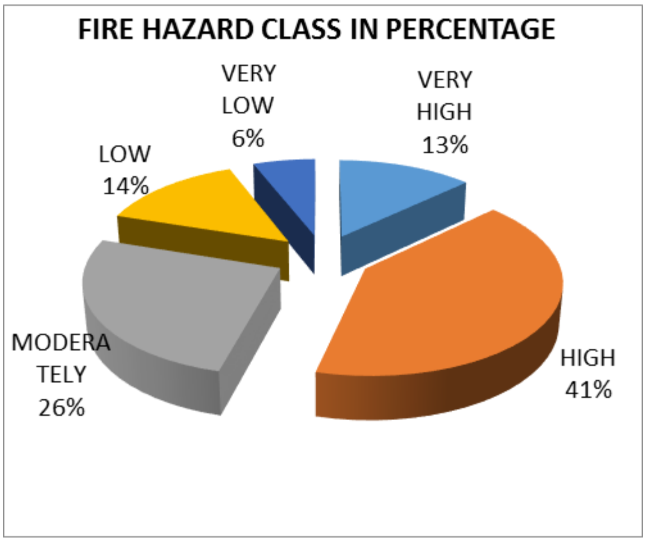

Table 1.Area (sq km) under different Hazard class

HAZARD CLASS	AREA IN SQ KM	PERCENTAGE
Very high	110	13%
High	357	41%
Moderately	228	26%
Low	124	14%
Very low	50	6%

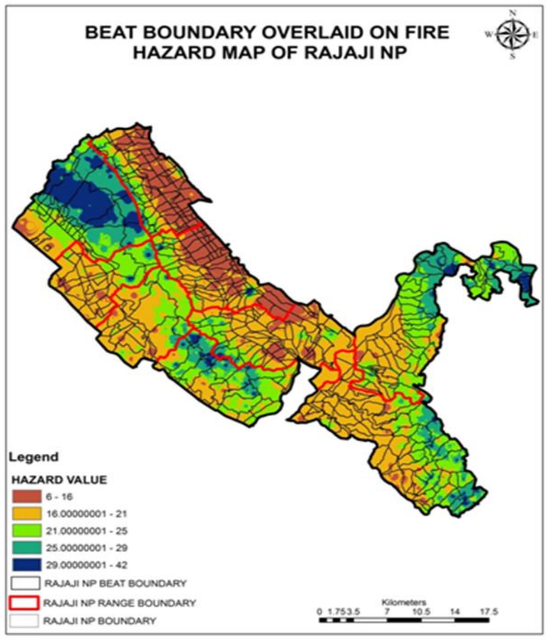

Fig. 23. Fire Hazard Map

VI. Conclusion

The present study relates the fire incidence location with parameters responsible for forest fire. From the above study we can conclude that the GIS can be used as a potential tool for Mapping Fire hazard areas based on historical fire data. The Hazard maps generated by using Raster interpolation method (IDW) show the level of significance of each parameter by assigning hazard value from 0-8. The Fire Hazard Map of occurrence shows that most of the study area comes under High Hazard followed by Very High Hazard. This study exemplifies the usefulness of Hazard Map of forest fire and offers a more effective way for management of forest fire and wildlife conservation.

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