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# Application of remote sensing and geographical information system in mapping forest fire risk zone at Bhadra wildlife sanctuary, India

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***Abstract:*** *Fire is the most spectacular natural disturbance that affects the forest ecosystem composition and diversity. Fire has a devastating effect on the landscape and its impact is felt at every level of the ecosystem and it is possible to map forest fire risk zone and thereby minimize the frequency of fire. There is a need for supranational approaches that analyze wide scenarios of factors involved and global fire effects. Fires can be monitored and analyzed over large areas in a timely and cost effective manner by using satellite imagery. Also Geographical Information System (GIS) can be used effectively to demarcate the fire risk zone map. Bhadra wildlife Sanctuary located in Karnataka, India was selected for this study. Vegetation, slope, distance from roads, settlements parameters were derived for a study area using topographic maps and field information. The Remote Sensing (RS) and Geographical Information System (GIS)-based forest fire risk model of the study area appeared to be highly compatible with the actual fire-affected sites. The temporal satellite data from 1989 to 2006 have been analyzed to map the burnt areas. These classes were weighted according to their influence on forest fire. Four categories of fire risk regions such as Low, Moderate, High and Very high fire intensity zones were identified. It is predicted that around 10.31% of the area falls under moderate risk zone.*

***Key words:*** *Forest fire, Risk zone, Weightage, Remote sensing, Wildlife sanctuary*
*PDF of full length paper is available online*

## Introduction

Land and forest degradation process is considered to be one of the major environmental problems, which has lead to a variety of environmental disasters that adversely affect human life. Traditional land use practices and changes in weather patterns have affected the incidence of fires over a period of time. In tropical deciduous forests, fire is a natural factor due to high levels of water stress during summer. Frequent occurrence of fire is one of the reasons for the degradation of forests in India. Annual fires may decrease the growth of the grasses, shrubs and forests, which may result in increased soil erosion (Kandya *et al.,* 1998). Fires cause negative effects on the stability of nutrients, flora and fauna, the structure of the soil and on the ecological stability as well can contribute to global climatic changes. Of late, the occurrence of forest fires increase every year for a number of reasons, which could be both, social and economical. Fire occurrences in turn depend on accumulation of fuels, moisture content and ignition incidence. Fuel accumulation in turn depends on production and decomposition, which varies among the vegetation types.

Forest fires are considered to be a potential hazard with physical, biological, ecological and environmental consequences (Jaiswal *et al.,* 2002). According to FAO, forests in 47 nations (accounting for 53.9% of world forest areas) the average fire affected area every year was 6.73x106 ha from 1881 to 1990, accounting for 0.47% of world forest areas (Kong *et al.,* 2003). In India, forest fires are initiated by nature as well as by man. Majority of induced fires in the Indian forests are mainly caused for timber harvesting, Land conversion, agriculture, cattle grazing, fodder and creating access to forest interiors. Fires set on farmlands, to clear agricultural residues, sometimes spread into the forests. As such this paper deals with preparing the forest fire risk zone map of Bhadra Wildlife Sanctuary to facilitate to minimize the frequency of fire by taking appropriate fire prevention measures, avert damage *etc.*

Satellite remote sensing provides the only practical means of monitoring and acquiring information about the spatial distribution of fire scars and fire activity. Understanding the behaviour of forest fires, the factors that contribute to making an environment fire prone and the factors that influence fire behavior is essential for forest fire risk zone mapping (Chuvieco *et al.,* 1989).

Satellite remote sensing has opened up opportunities for qualitative analyses of forest and other ecosystems at all geographic and spatial scales. Geospatial technology, including Remote sensing (RS) and Geographic Information Systems (GIS), provides the information and the tools necessary to develop a forest fire susceptibility map in order to identify, classify and map fire hazard area. This study is also an attempt to exploit the capabilities of remote sensing and GIS techniques and to suggest an appropriate methodology for forest fire risk zone mapping.

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**Study area:** Bhadra Wildlife Sanctuary is situated in the midst of Western ghats region of Narasimha Raja Pura and Tarikere taluks of Chikamagalur district and Bhadravathi taluk of Shimoga district. The sanctuary is situated between 75°15' and 75°50' E, and between latitude 13°25' and 13°50' N, located within Chickmagalur and Shimoga district (Fig. 1). It lies at the foot of the Bababudangiri hill range (rising from the Deccan Plateau) and is bound by the river Bhadra, and its associated reservoir. The area was declared as "Jagara Valley Wildlife Sanctuary" during 1951, covering an area of 20059.46 ha. After a systematic survey, the sanctuary was redelineated in 1974, as "Bhadra Wildlife Sanctuary", covering an area of 492.46 $km^2$. The Bhadra Wildlife Sanctuary has been divided into four ranges namely Muthodi, Hebbe, Lakkavalli and Thanigebail. The area consists of most undulating terrains with valleys and steep hillocks and the altitude varies from 650 to 1875 m MSL. The temperature ranges from 10°C in winter to 32°C in summer with hot and humid weather. The average rainfall varies from 1200 to 2600 mm. The sanctuary is covered with moist deciduous, dry deciduous, evergreen, semi evergreen, scrub, plantations, grass land and dominated by moist deciduous type to a great extent.

The fauna consists carnivorous animals like tigers, leopards, jungle cats, wild dogs, and hyena. The sanctuary has some of the rare animals like the giant malbar squiarrel, flying squirrel, pangolin besides rare birds like malbar, grey, hornbill great block, wood pecker, golden backed wood pecker, green pigeon.

## Materials and Methods

The 12 yr Satellite data between 1989 to 2006 was obtained from National Remote Sensing Agency (NRSA), Hyderabad for the study area. IRS-LISS (Indian Remote Sensing - Linear Imaging and Self-Scanning Sensor) imageries selected for the summer seasons of April-1989, April 1994, April 1997, March 1998, March 1999, March 2000, February 2001, March 2002, March 2003, April 2004 and March 2005 were used for defining and identifying the burnt area. Besides the satellite data topographic maps 48 O (06,07,09,10,11,14) of 1:50,000 scale were used.

Standard topographic maps of a scale 1:50,000 were used to prepare administrative boundaries such as State, District, Taluk, transportation network, drainage and canal digitized and fine tuned with respective satellite images. The major settlement location was also extracted as point coverage. The Forest administrative boundaries extracted from the working plan and wildlife management plan of the Forest Department were transferred onto topomaps and different wildlife administrative boundaries like division, range, section, beat, and boundary *etc.*, were generated along with reserve forest boundary.

Satellite images were rectified and processed, for preparing different thematic maps *viz.*, land use, land cover, forest type and vegetation mapping etc. using ERDAS 9.0.

During field work, measuring tape was used to measure crown diameter, Global Positioning System (GPS) was used to locate the sample plots and clinometers were used for measuring slope. The burnt area estimation was carried out for summer season using satellite images between 1989 and 2006. The procedure followed for preparing forest fire risk map is given in Fig. 2.

The data was collected by visiting burnt areas. Considering all these factors, satellite images were brought to a common data base and further processed to estimate spatial extent. A combination of multispectral thresholding and supervised classification using minimum distance criteria was adopted to discriminate and delineate burnt areas.

Vegetation mapping was done using VAX 11/780 based image processing system (Somashekhar *et al.,* 2009*).* The data has been georeferenced to the survey of India topomaps. The park boundry was digitised to generate the digital mask and extract the study area. A supervised approach is adopted for mapping of vegetation types. The training sets were defined interactively based on the ground information collected during the field work. The spectral statistics of the training sets were computed separately and analysed using bivariate frequency distribution and divergence matrix computation was carried out in order to evaluate the degree of class seperability in the multidimensional domain. The classification accuracy of the training set was ascertained by generating the confusion matrix. Maximum likelihood algorithm was applied to classify different vegetation types. The vegetation map types, *viz.*, moist deciduous, dry deciduous, evergreen, semi evergreen, teak plantation, scrub and water bodies. The map was further subjected to accuracy evaluation by selecting sample plots using simple random sampling, to asses the actual land cover versus digitally classified category. A two- way categorization (Somashekhar *et al.,* 2009) table was formed and accuracy for each class was evaluated using:

$$C = (Bj/Aj) \times 100$$

Where C= Class, j = Number of classes, Aj = Number of observation of class j from ground, Bj = Number of observation on digitally classified image.

In order to obtain accurate and more effective conclusions, mathematical operations in the GIS analysis were formed. The input information on forest fire influencing factors indicates the weights in the fire risk in an area. The different factors in the thematic maps were labeled separately based on their sensitivity to forest fire as very high, high, moderate and low. The factors were analyzed in the following order of importance: vegetation type, distance from roads, proximity to settlements and slope. A higher rating indicates that the factor has a high degree of influence on the fire risk. Then suitable weights were assigned to each factor using the AHP method (Yin Hai-Wei *et al.,* 2004).

In the analysis for vegetation parameter has been given the first highest "weightage of five "keeping in view the fact that a forest fire cannot occur unless inflammable material is present. Each class of forest type was rated according to its species composition. The proximity to settlement factor was assigned the second highest

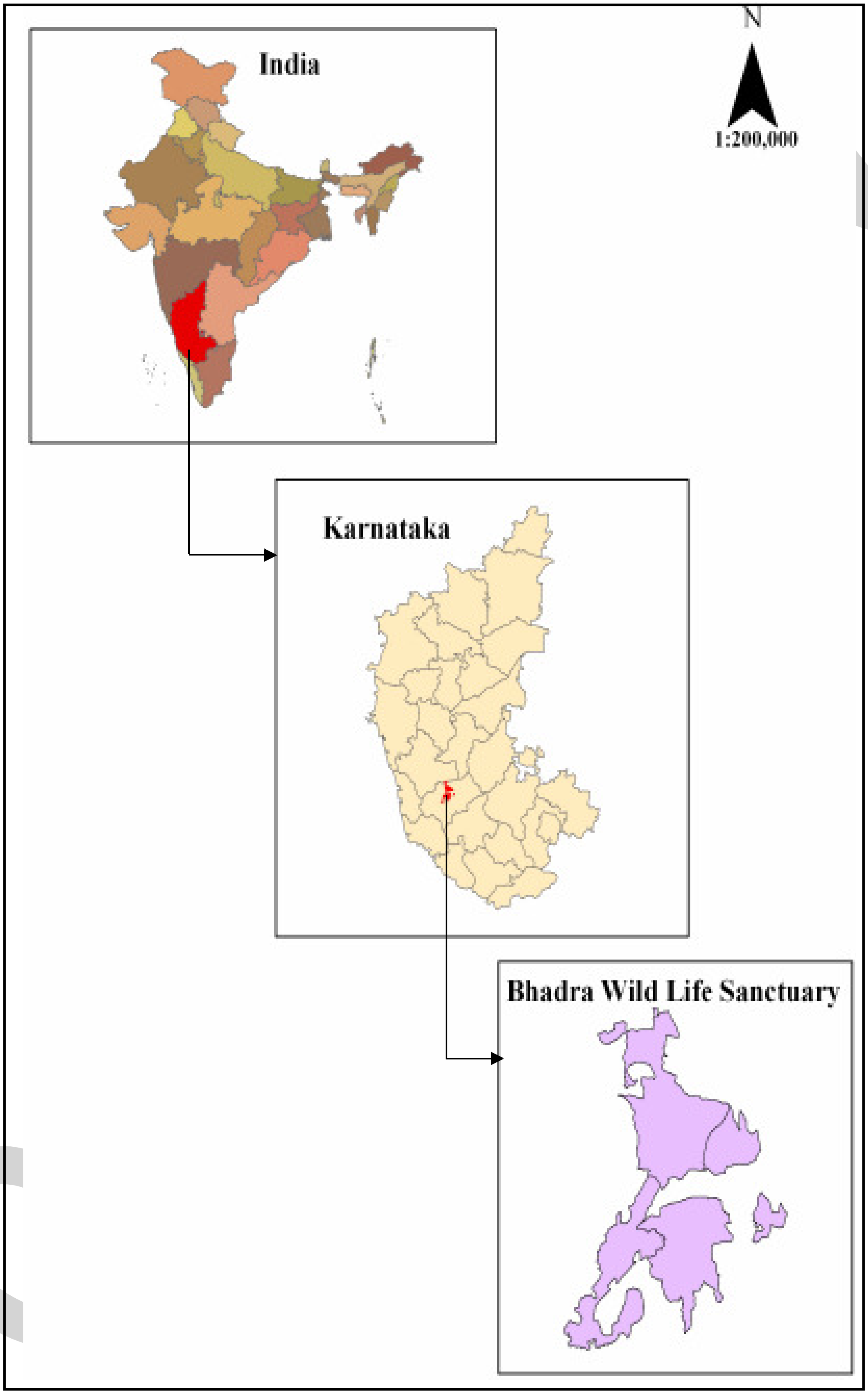


**Fig. 1:** Location map of Bhadra Wildlife Sanctuary, Karnataka

weightage, as man-made anthropogenic actions are the main causes for fire and also roads inside the forest provide possible access routes. So distance from roads also assigned equal "weightage of four". Slope does not necessarily influence the probability of an ignition but has a strong influence on the behaviour of fire and also plays a role in the consequent suppression operation. Slope was assigned the third highest "weightage of three". All the thematic maps (layers) were then integrated, and the forest fire risk index was calculated using the following equation:

$$FFR = [(V_I*WT) + (S_I*WT) + (D_R*WT) + (P_S*WT)]$$

Where FFR is the forest fire risk index, $V_I$ is the vegetation variable, $S_I$ indicates slope factor, $D_R$ indicates distance from road, $P_S$ indicates proximity to settlement, WT is the weightage given to the factors.

Finally, criterion-based analysis was carried out to create fire risk zone map (Fig. 3).

## Results and Discussion

In the process of identification of fire prone areas vegetation map plays an important role and it was prepared using satellite data, Vegetation mapping was done using VAX 11/780 based image

**Table - 1:** Classification of fire risk zones at Bhadra Wildlife Sanctuary, Karnatka

| Fire risk zones | Degree of fire risk | Area (ha) | Proportion to study area (%) |
|---|---|---|---|
| 1 | Very high | 3005.83 | 6.59 |
| 2 | High | 1695.31 | 3.72 |
| 3 | Medium | 14732.71 | 32.34 |
| 4 | Low | 22572.46 | 49.55 |
| 5 | Built up land | 24.28 | 0.05 |
| 6 | Water | 3518.90 | 7.72 |

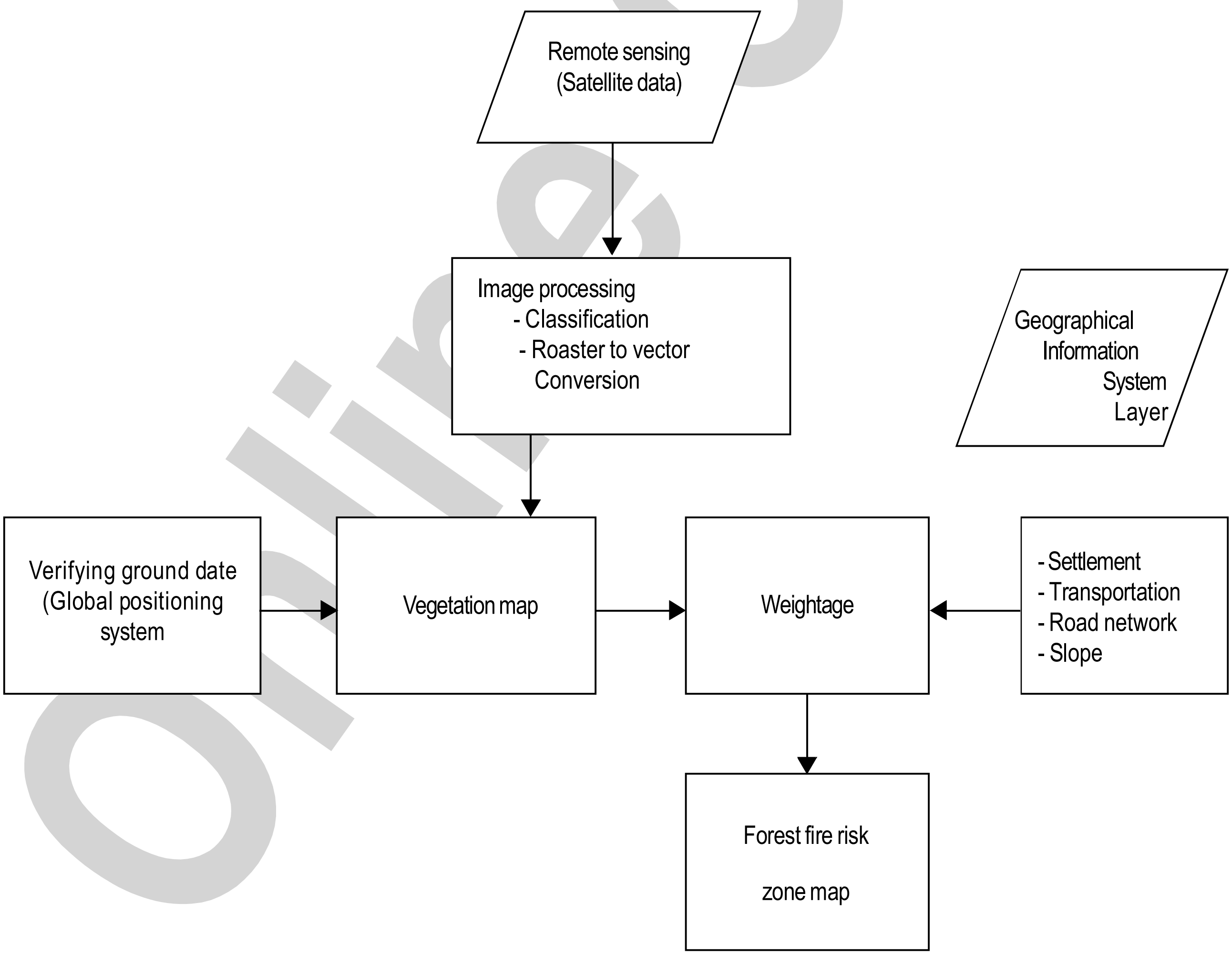


**Fig. 2:** Flow chart of the procedure followed for preparing forest risk map in Bhadra Wildlife Sanctuary, Karnataka

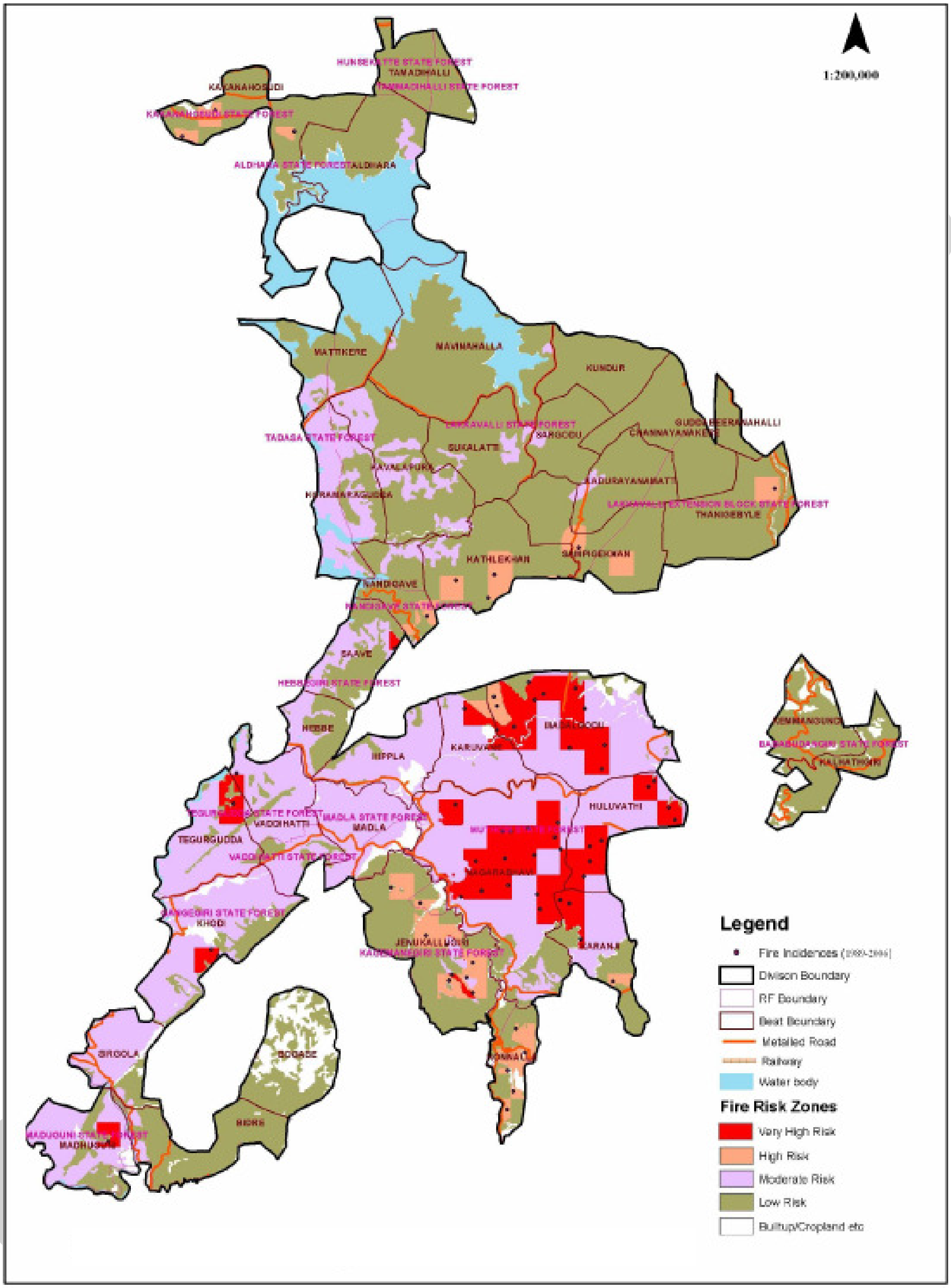


**Fig. 3:** Fire rich zonation map Bhadra Wildlife Santuary, Karnataka

processing system. The vegetation map types observed where moist deciduous, dry deciduous, evergreen, semi evergreen, teak plantation, scrub and water bodies has been classified. The moist deciduous occupied major forest area in all the four ranges. The moist deciduous forest of density category 10-40% covers major part of the sanctuary followed by dry deciduous forests. It is apparent that the fire occurrences are very high in moist deciduous forests. The burnt area assessment was carried out for the years 1989 to 2006 using IRS satellite data.

The forest fire risk zones were delineated four classes: Low, moderate, high, very high (Table 1). Water bodies and Built up area were assigned zero weightage and intersect with the resultant map, these were classified separately on the final forest fire risk zone map. It is clear that vegetation types that come under very high fire intensity zone belong to moist deciduous and dry deciduous, also moist deciduous and dry deciduous present in the high intensity, while dry deciduous, evergreen and teak plantation present in moderate intensity and the area having less forest, plantation, agriculture comes under the low fire intensity. The fire risk in the study area reflects both the likelihood of ignition and the risk of spreading. The slope, distance from roads and proximity of settlement, also influence the risk of spreading. An interesting feature of the model is that it explains fact that even if a forest type has a low risk weighting, the probability of a forest fire occurring there can be moderate due to other factors.

Table 1 describes the fire risk zones and degree of fire risk. In the study area, 6.59% area falls in the "very high" fire risk, followed by 3.72% in "high" fire risk, 32.34% in "medium" fire risk, 49.55% in "low", 7.72% and 0.05 in water and built up area respectively. Similarly in Gorna subwatershed in Madhya Pradesh large area comes under low fire risk (Jaiswal *et al.,* 2002). Also, a similar work has been done for Madumalai Wildlife Sanctuary for 1990 to 1995 (Ranganath *et al.*, 1994) also for Bandipur National park for 1997 to 2006 (Somashekhar *et al.,* 2009). Finally, the fire risk zone map was compared with the actual sites affected by fire, it was found that the area near to settlements, and roads prone to fire are, most of the fire predicted areas from the model are located in actual burnt areas. This comparison shows that the approach and the fire risk zone map have high reliability, which can be used by foresters to prepare effective fire prevention policies. The Bhadra Wildlife Sanctuary suffering from fire at frequent intervals. Most of the fires representing burnt areas were located in the low and medium fire risk zones in the study area. Comparing the entire thematic layer, it is suggested that (i) "Very high" degree of fire risk areas are dominated by moist deciduous and dry deciduous, bamboo, more than 35% slope nearer to settlement and at less than 100 m from the roads." (ii) "High" degree of fire risk areas are moist, dry deciduous and bamboo, less than 1000 m far from the settlement, 100-200 m from the roads and 5-10% slope., (iii) "Medium" degree of fire risk are with dry deciduous, evergreen and teak plantation, 1000-2000 m far from settlement, 200-300 m from the roads with 3-5% slope. (iv) "Low" degree of fire risk areas are less in forest, coffee, agriculture and plantation, 2000-3000 m far from settlement, 300-400 m from the roads and 1-3%, 0-1% slope.

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