

Forest fire and its management in Kudremukh National Park, Western Ghats, India using Remote Sensing and GIS

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Abstract:

Forest fires are a significant and increasing contributory factor for rapid depletion of forest resources. It has been well recognized that satellite data could be used effectively for the detection of active fires and fire-affected areas and also for rapid assessment and monitoring of the forest fires. The present paper focuses on the forest fire mapping and its management in Kudremukh National Park, Western Ghats, Karnataka and evaluated the role of existing fire-watch towers in detecting the frequently occurring fire affected areas. Two years satellite data has been used to study the occurrence of fire, its intensities and possible management aspects using GIS modeling. About 2,184.94 ha and 1,243.41 ha were affected by the forest-fire during the years 2001 and 2002, respectively, in Kudremukh National Park and major land cover types affected by the forest-fire are grasslands and the 'shola' type vegetation. The findings of the study revealed that frequent fire occurring areas could not be located with the existing fire-watch towers. Management aspects for detecting frequent fire-prone areas, efficacy of the fire-watch towers in detecting the fire affected areas have been discussed in the paper.

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Introduction

Forest fires are a significant and increasing contributory factor for rapid depletion of forest resources. It is the greatest enemy of the standing vegetation. Reports from the Ministry of Environment and Forests, Government of India, New Delhi, state that forest fires affect about 37 million ha and, around 50 - 55% of the country's forest area are being subjected to forest fire annually (Gubbi, 2003). Forest Survey of India has conducted a series of inventories since 1965 and documented the extent of forest fire and its intensity in a number of states in India (Anon., 1987a; b; 1995). In Karnataka, the inventory showed that 6-11% of the total area is burnt due to frequent fires and 31-51% of the area with occasional fires (Rai and saxena, 1997) and about 30% of the overall forest area is affected due to forest fires annually (Bahuguna and Singh, 2001). The source of forest fire in India is largely due to anthropogenic activity (Saha and Howe, 2001). Velez (1990) also observed that in Mediterranean region, people set majority of fires. Regulated or controlled fire is a very useful and legitimate tool in forestry practices for accomplishment of specific purposes. For instance, natural regeneration of teak (*Tectona grandis* L.f.), sal (*Shorea robusta* Gaertn.f.) and deodar (*Cedrus deodara* (D.Don) G. Don. f.) is intimately associated with the role of controlled fires. Uncontrolled fire, on the other hand, whether natural or manmade, can cause havoc, that too, in a short span of time. Small trees and regeneration are often affected very adversely. Ground fire destroys the organic matter, which is very necessary to maintain an optimum level of humus in the soil. Repeated annual fires might decrease the growth of the grasses, herbs and shrubs, which intern cause in soil erosion and also facilitate encroachments.

Fire detection through conventional means suffer from practical problems. It has been well recognized that satellite data could be used effectively for the detection of active fires and fire-affected areas and also for rapid assessment and monitoring of the forest fires (Ranganath et al., 1994, Ajai et al., 2003). The repetivity of the satellite data helps in analyzing the frequency of forest fires of a particular area. Kimothi and Jadav (1998) estimated the severity and damage caused by the forest fire in central Himalayan region using remote sensing in conjunction with Geographical Information System (GIS). Vadrevu et al. (2006) used spot satellite data for analyzing the distribution and causes of forest fire in Andhra Pradesh. Jaiswal et al. (2002) mapped the fire risk zones in Madhya Pradesh, which enabled the forest department to minimize the frequency of forest fires. Sastry et al. (2002) integrated remote sensing, meteorological and topographical data for forest fire risk area mapping in Gir forest area. In the Western Ghats, Hegde et al. (1998) studied the mechanisms by which forest fire altered the vegetation. Kodandapani et al. (2004) studied the fire frequency in Madhumalai wildlife sanctuary and pointed out the effect of fire on vegetation and their recovery pattern. Frequent fires contribute to the rapid invasion of exotic fire adopted species. Species like Lantana camara and Chromolaena odorata colonized regions, which are targeted by frequent fires (Kodandapani, 2001). Most studies focused on the mapping of the extent and severity of forest fire but not much emphasis is made on the management practices that prevent further spread of fires and its control. Studies conducted by Roman-Cuesta and Martinez-Vilalta (2006) indicated that fire incidence and burnt areas are significantly higher in protected areas than surrounding buffer areas and they suggested the participation of local people and ecotourism as effective means of mitigating fire incidence. Kushlin and Goldammer (2003) emphasized on the improvement of ground-based fire prevention and fighting, including systems of look-out stations in the mountainous terrain while addressing new approaches for forest fire management at an ecoregional level in the Far East region of the Russian Federation.

Keeping this in mind, the present study aimed at identifying the areas affected by forest fire using the satellite data of the year 2001 and 2002 and also the frequency with which burning has taken place over an area. The efficacy of the existing fire watch towers in the early detection of fire, using viewshed analysis and management practices that could reduce the fire hazards in the park, by rapid spreading of fire, are discussed herewith.

Materials and Methods:

The area selected for the study is "Kudremukh National Park", situated in the Western Ghats region in Karnataka (Fig. 1). This is one of the largest and the most recently (1987) declared National Park in Karnataka (Lal et al., 1994) and also probably one of the largest reserves of high altitude grasslands in the Western Ghats. Nayar (1996) identified the park as one of the hot-spots of endemic plants in India. It covered three state forests, viz., Tungabhadra, South Bhadra and Narasimha Parvatha State Forests and two reserve forests viz., Naravi and Andar Reserve Forests. The park extends over three districts, Dakshina Kannada, Udupi and Chikmagalur. It has an latitudinal range of 130 011 to 130 291 N and longitudinal range of 750 001 to 750 251 E.

The extent of forest fire and its frequency of occurrence in the national park were mapped using the dry season satellite data. The forest fires are active and more proliferating during the dry season (end of March to the beginning of May) of the year (Kodandapani, 2001). The satellite data used in the present study are IRS 1D LISS III data of the year 2001 (Path 97 Row 64, March 24) and 2002 (Path 97 Row 64, April 3). The infrastructural details such as locational details of existing fire watch towers and road network were obtained from the national park authorities.

Since the study area is mountainous, relief displacement in the satellite data has been removed by ortho-rectification with precise digital elevation model and ground control points. The satellite data was ortho-corrected using OrthoBase utility of the software Erdas Imagine by consulting 1:50,000 Survey of India topographic sheets (48 O/3, O/4, O/7 and O/8) of the area. This was used to generate planimetrically true "ortho images" which are corrected for the displacement of objects due to sensor or camera orientation, terrain relief and other errors associated with the acquisition of images and processing. The end output was an ortho image, which has the geometric characteristics of a map and the image qualities of a photograph. The corrected images served as the base for data collection for the GIS.

The supervised classification method was used to categorize fire-affected pixels from the rest of the pixels in the satellite data. Area statistics of fire-affected region was generated and tabulated for both these years. The frequency of the forest fire was analyzed using the classified data from year 2001 and 2002 and it was categorized into recurrent fire and occasional fire based on its occurrence in the these two years and, also on information of previous records.

The extent of viewability of the fire-affected region with the existing fire watchtowers in the park was determined. The 'viewshed analysis' tool of **Erdas Imagine 8.5** software was used to create the extent of the viewing area considering the terrain complexity (direction and degree of slope) with DEM, height of the fire watch tower and viewing range of a person from the watch tower at different topographical regions. Viewshed analysis is the study of visibility between points on a terrain surface, which computes the visibility of every cell from the observer cell. The viewshed algorithm works outwards from this point computing those areas of the landscape that are visible at each distance. Thus, areas in which fire might be visible are readily identified. There are five fire watch towers existing in the park and these towers are about 25 to 30 m in height. One can view as much as 5 to 6 km radius of an area in the open grassland locations. If the tower is in the valley the viewing area will be decreased to a range of 2 to 3 km (personal discussion with park authorities). Keeping this in mind, viewability of the fire watch towers were determined.

Results and Discussion:

Figure 2 shows the extent of fire and its frequency in Kudremukh National Park during the year 2001 and 2002. About 2184.94 and 1243.41 ha of area was burnt in the year 2001 and 2002, respectively (Table 1). Recurrent fire affected areas were observed in the southern part of the park to the extent of 473.88 ha and rest is occasional, burnt either in the year 2001 or 2002.

The viewshed analysis indicated that the major recurrently fire-affected areas could not be located for fire with the existing towers (Fig. 3). Only -% of fire affected area could be observed with the fire watch towers. Major fire breakout could not be viewed through the existing towers.

The nature, amount and spatial distribution of ignitable fuel largely govern the character of the fire in any forest location (Goldammer, 1990). The major land cover type prone to regular forest fire in the park is the hilltop grasslands. The thick mass of ferns present amidst the grassland in the southern part of the park might facilitate in rapid spread of fire and burn more area recurrently. The result of the present study corroborates with that of Pascal (1988) and Chandran (1997) on forest fires in Kudremukh region and they also recorded grasslands as the major land cover in that area affected by fire. In Kudremukh region, regular forest fire might have resulted in the restriction of grasslands from expanding surrounding the montane ('shola') forests. Supporting the entire earlier observation Meher-Homji (1984) pointed out that in the Western Ghats only the grasslands associated with montane forest are the fire-maintained ecosystem. In many ecosystems, fire is a part of the natural regeneration process stimulating the germination of certain species, clearing space for the invasion and growth of others and, releasing a periodic flush of nutrients into the soil (Dawson et al., 2002). In the Western Ghats, Hegde et al. (1998) studied the mechanisms by which forest-fires altered the vegetation. Kodandapani et al. (2004) studied the fire frequency in Madumalai Wildlife Sanctuary and pointed out the effect the fire on the vegetation types and their recovery pattern. The frequent fires contribute to the rapid

invasion of exotic fire-adapted species. Species like *Lantana camara* and *Chromolaena odorata* colonized regions that are exposed to frequent fires (Kodandapani, 2001).

The high wind speed in the hilltop resulted in the easy spread of the fire in a short time. It is a difficult and laborious job for the local forest officials to contain the spreading fire. Remote sensing coupled with GIS helps to identify the fire affected areas and also the frequency with which the same area has been burnt over a period. Kremasa (2002) used remote sensing to identify and control the forest fire in Mexican forests. Sastry et al. (2002) used remote sensing and GIS to map the fire risk areas and categorized them into high fire risk and no fire risk zonations in Gir forests, which helped the forest department to monitor the forest fire in a more efficient way. Mycke-Dominko (2004) used remote sensing images to determine the forest fire danger rating and used the vegetation indices to categorize forest fire and its effect on natural vegetation.

A regular monitoring needs to be set up during the summer season to cut down on the spread of fire and further depletion of spectacular grassland-'shola' complex in Kudremukh region. The existing fire watch towers are not sufficient to locate frequent fires that occur in the park area (Fig. 3). The viewshed analysis of the present study provides vital information about the viewability of the existing fire watch towers and recommends the forest department to set up additional fire watch towers. Viewshed analysis is one of the powerful GIS functions. Viewshed analysis using digital Elevation Model (DEM) has long been considered as one of the standard functions of GIS. It provides the model with a computed surface, which can be either or not seen from a particular location. A visual field or isovist is defined as a visual area that is wholly visible across the system from a defined vantage point (Benedict, 1979). Sentürk (2003) used viewshed analysis technique in Turkey to determine locations for fire lookout towers and overlay analysis to evaluate the existing planned fire roads. Cheng and Shih (1998) used viewshed analysis for validating the viewable areas of fire-affected region in Taiwan. They found this technique to be useful in terrain regions to find the viewability and this could effectively be used for management purposes. Che-Bin and Ahuja (2004) used viewshed analysis for vision based fire detection system. They found this useful for obtaining viewability area. Maichak and Schuler (2004) used viewshed analysis for detecting maximum viewable area for bison census. They opined that viewshed analysis provides a more accurate estimation of area visible from census routes and the resulting population estimations than conventional surveys.

Government of India is seriously thinking of setting up of a National Institute of Forest-fire Management equipped with satellite centers in different parts of the country to bring the latest forest-fire fighting technologies to India through proper research, training of personnel, and technology transfer on a long term basis (Bahuguna and Singh, 2001).

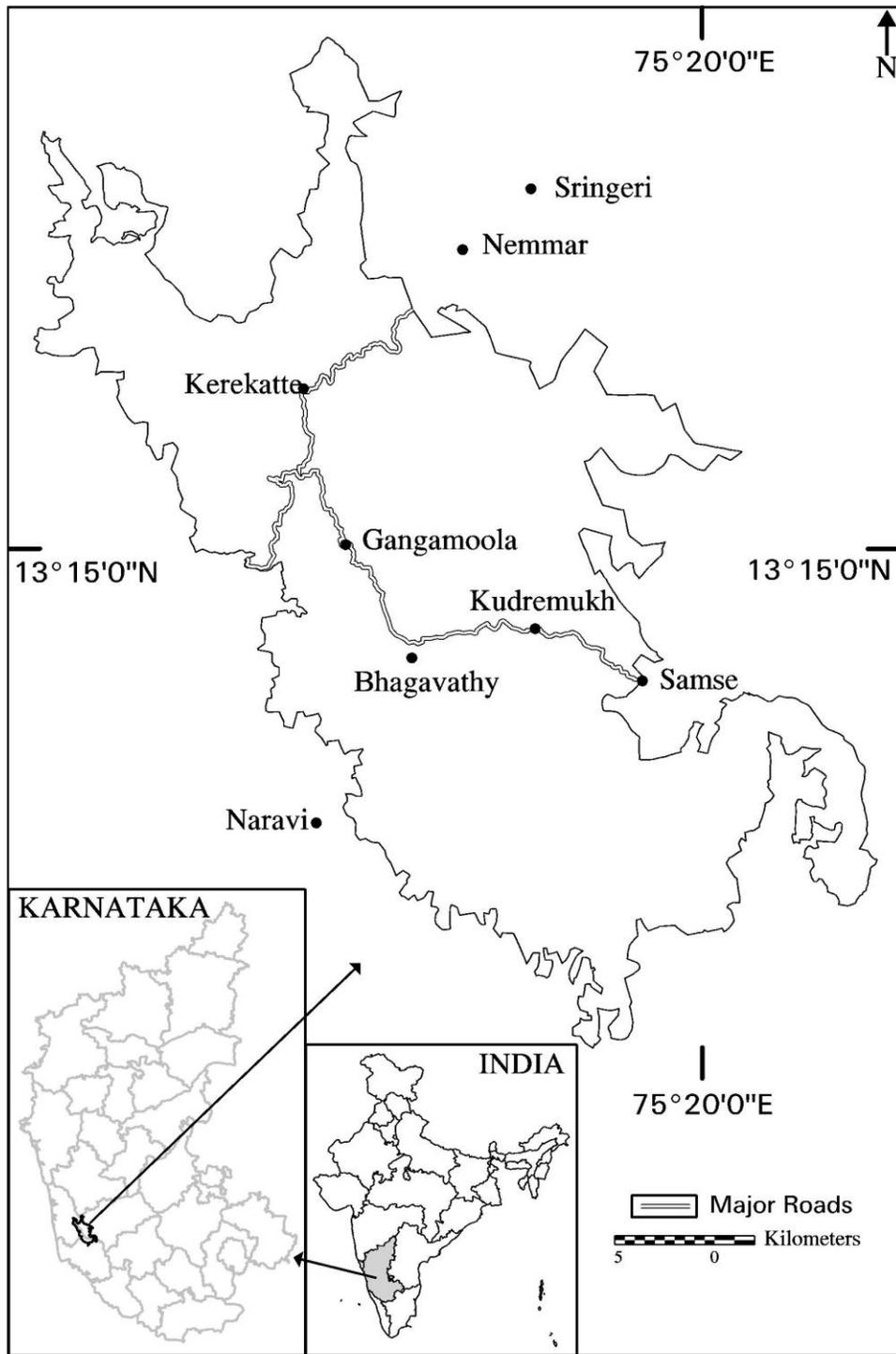


Fig:1 - Location map of the study area – Kudremukh National Park in the Western Ghats, Karnataka

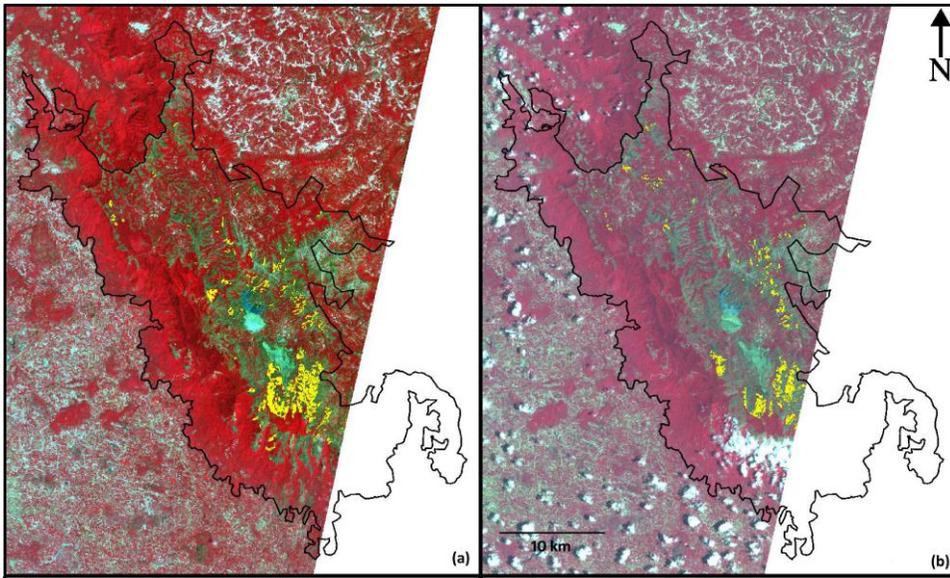


Fig. 2: Forest fire mapping, its frequency and loss of land cover in Kudremukh National Park (a & b - mapping of fire affected regions of the year 2001 and 2002, respectively).

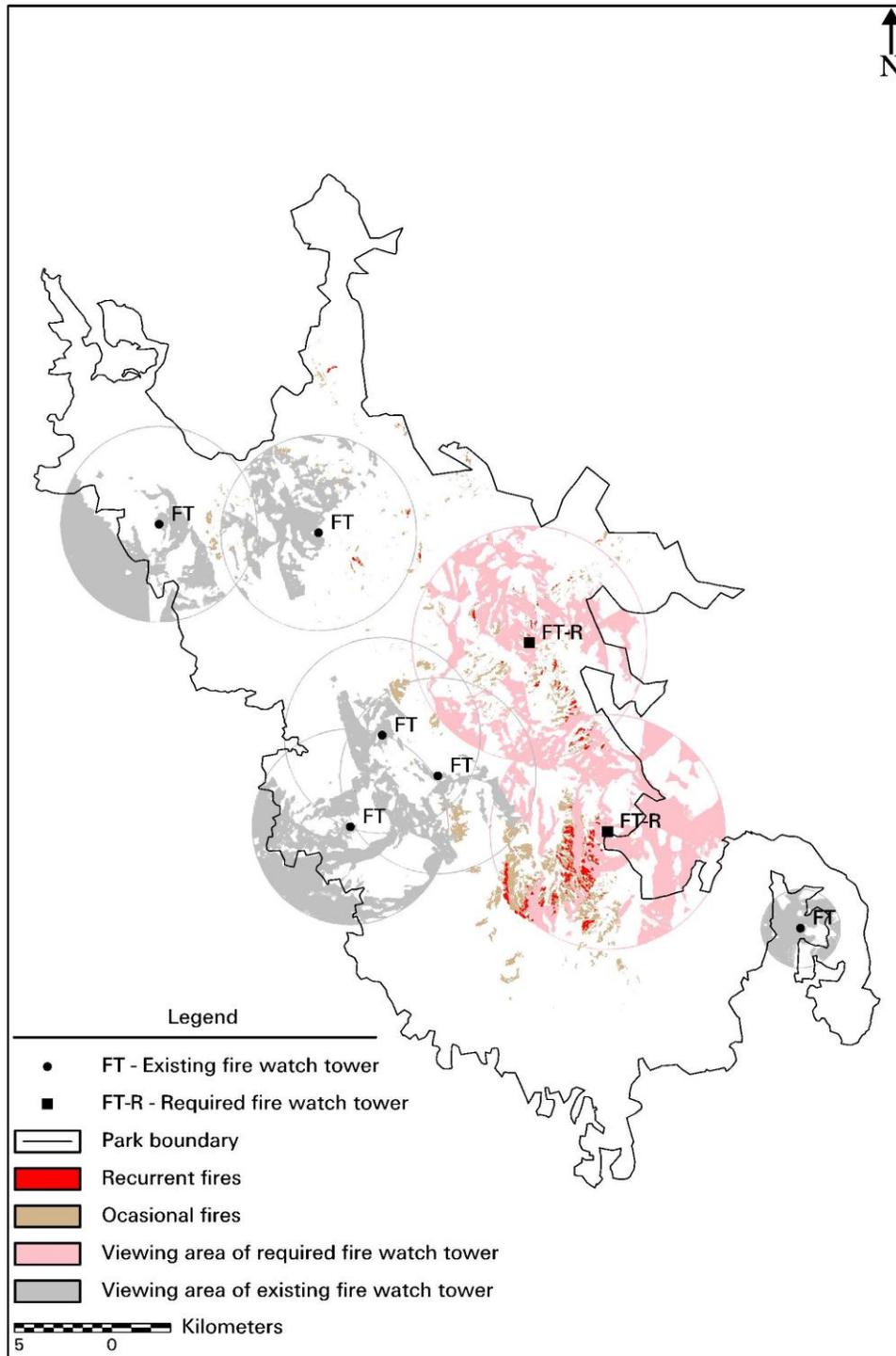


Fig:3 - Viewability of existing fire lookout towers and fire lookout towers required to monitor and control fire in Kudremukh National Park

Table 1
Area affected, loss of land cover and the frequency of forest fire in Kudremukh National Park.

Categories	Area (ha)
Area affected by fire in the year 2001	2,184.94
Area affected by fire in the year 2002	1,243.41
Loss of land cover types	
Grassland	2,003.85
'Shola' and other land cover types	127.07
Frequency of fire	
Frequent	473.88
Occasional	2,480.60

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