GEOSPATIAL APPROACH FOR FOREST FIRE RISK MODELING: A CASE STUDY OF TARADEVI RANGE OF SHIMLA FOREST DIVISION IN HIMACHAL PRADESH, INDIA

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Introduction

Forest fires controlled or uncontrolled have profound impacts on the physical environment including land cover, land use, biodiversity, climate change and forest ecosystem. It also has enormous implication on human health and on the socio-economic system of affected countries. A study made by the Forest Survey of India reveals that 51% of the forest area in Assam and Gujarat, 93% in Arunachal Pradesh, 67% in Bihar, 69% in H. P., 46% in J & K, 45% in Karnataka, 76% in M. P., 94% in Meghalaya and Orissa, 87% in Nagaland, 58% in U. P. and 33% In West Bengal Is subject to repeated annual fires (Bahuguna and Lal, 1989). India has a population exceeding 1000 million, and increasing at an annual rate of more than 2 %. with increase in population. The pressure on the forests is enormous and the forest cover of the country is deteriorating. Along with various factors, forest fires are a major cause of degradation of Indian forests (Roy, 2000). About 6% of the forests are prone to severe fire damage. The normal fire season in India is from the month of February to mid-June. India witnessed the most severe forest fires during the summer of 1995 in the hills of Uttaranchal and Himachal Pradesh in the Himalayas in the northern part. Forest fire risk zones are the locations where a fire is likely to start and from where it can easily spread to other areas.

A precise evaluation of forest fire problems and decisions on solutions can only be satisfactory when a forest risk zone mapping is available to the management authority (Jaiswal *et al.,* 2002). People studied forest fire risk zone (FFRZ) with a variety of mapping methods. Most of them mapped forest fire risk zones by directly using remote sensing and geographic information systems (GIS) that contain topography, vegetation, land use, population, and settlement information (Chuvieco and Congalton, 1989; Chuvieco and Salas, 1996; Mariel *et al.,* 1996; Jaiswal *et al.,* 2002). A common practice was that forest fire risk zones were delineated by assigning knowledge base weights to the classes of all the layers according to their sensitivity to fire or their fire-inducing capability. The most important use of GIS is its 'modeling capability' i.e. constructing models of the real world from digital database. Modeling is a powerful tool for identifying factors, or for displaying the possible consequences of planning decisions or projects that affects them, or for displaying the possible consequences of planning decisions or projects that affect resource use and management.

Remote sensing and GIS techniques used to analyze the vast amount efficiently and statistical programs were used to

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maintain the specificity and accuracy. These techniques are being widely used for early warning, fire suppression resources planning and allocation. The information of forest in specific area can be searched, analyzed and managed through GIS and remote sensing. It makes possible for the forest fire forecasting system to predict and prevent forest fire in effective and scientific manner because it assume exact forest fire hazard index in real time and present in proper time. It makes possible for the forest fire forecasting system to predict and prevent forest fire in effective and scientific manner because it assume exact forest fire hazard index in real time and present in proper time.

Study Area

The region taken for study is Taradevi forest range (Himachal Pradesh), having an area of 1564.90 (ha) and spatial extent lies between 76^{0}59'12.66"E to 77^{0}11'16.96"E and 31^{0}01'15.59" N to 31^{0}10'45.42"N. The Taradevi Range has 3 Blocks and 11 Beats *Viz.* Taradevi Block, Tutu Block and Jubarhatti Block. All the Blocks and Beats are covered as part of the study area. The area has mountainous terrain with the elevation ranging between 900-2200m and covered with thick forest which constitutes mainly chirpine (*Pinus roxburghii*), bluepine (*Pinus wallichiana*), ban oak (*Quercus incana*) and deodar (*Cedrus deodara*) with variety of broad leave trees like jamun (*Syzygium cumini*), khair (*Acaccia catechu*), pipal (*Ficus religiosa*) etc. along with shrubs and grasses. The relative humidity remains high around 80%. Temperature ranging from a maximum of 28^{0}C and minimum of 15^{0}C in summers and a max of 8^{0}C and a low of 0^0 C or even low in winters. The average total annual precipitation is 1520 mm.

Methodology

Data used in the present study include IRS-P6 LISS-III imagery of November 2004, SRTM (Shuttle RADAR Topographic Mission) data of 90mt and SOI (Survey of India) Toposheets on 1/50000 scale along with the secondary data sources collected from the Shimla Forest Division's office. Forest type and density maps were prepared using visual interpretation and ground truth. The overall methodology used in the study is shown in (Fig. 1). Topographical maps (slope, elevation, aspect) were prepared using SRTM data.

Spatial modeling to acquire combined effect of settlement index, road index, elevation index, aspect index, slope index and fuel type index with weightage assigned on the basis of relative weight of variables was done on the basis of previous study in Corbett National Park India (Sharma, 1995) and in Motichur range of Rajaji National Park by (Porwal *et al.*, 1997). Roads and settlements, elevation, slope, aspect, and fuel type are the base layers used for the generation of fuel type index, elevation index, slope index, aspect index, road index and settlement index maps. These layers were classified according to their fire sensitivity. Higher values represent high-risk places and lower values represent the low risk or no risk places. Every class with its weightages is given in Table 1.

Aspect and elevation index maps were created as the sunrays directly falls on the slopes facing southward so fires break out easily and spread fast in the southern parts than and fire behavior tends to be low at higher elevations due to high rainfall. While generating the slope index map higher the slope higher will be the chances of fire occurrence and it decreases as we move towards the lower slopes due to accessibility. Fuel type index map was made according to their flammability which plays an important role on ignition and forest fire spread. Finally for the calculation of fire risk zonation each index maps again classified according to the equation-1.

$$FRI: = 1*ELI + 2*SLI + 3*ASI + 1*SI + 1*RI + 4*FUI \quad \text{..........................Equation-1}$$

Here:

FRI: is fire risk index value of forest fire risk zone map

ELI: Elevation index, SLI: Slope index, ASI: Aspect index,

RI: Road index, SI: Settlement index and

FUI: Fuel type index .

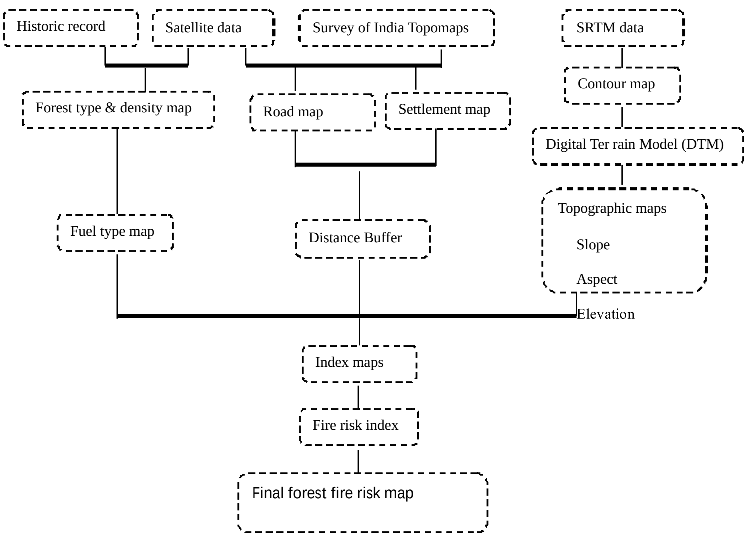
Fire risk indexed map created on the basis of statistics of different classes and reclassified into five classes as very high, high, moderate, low and very low. Finally the generated fire risk zonation map validated using secondary data sources i.e. Working Plan for Shimla and Theog Forest Division, ground truth data and Fire Management Plan of Shimla Division for fire occurrences in the area.

Results and Discussions

Forest fire risk index (FRI) map has ranked in five classes using following layers like fuel type, slope, aspect, elevation, road and settlements. Multi criteria analysis and weighted sum (knowledge based) method was used to the creation of index map of the base layers and finally to model forest fire risk zonation map (Figs. 3 and 4).

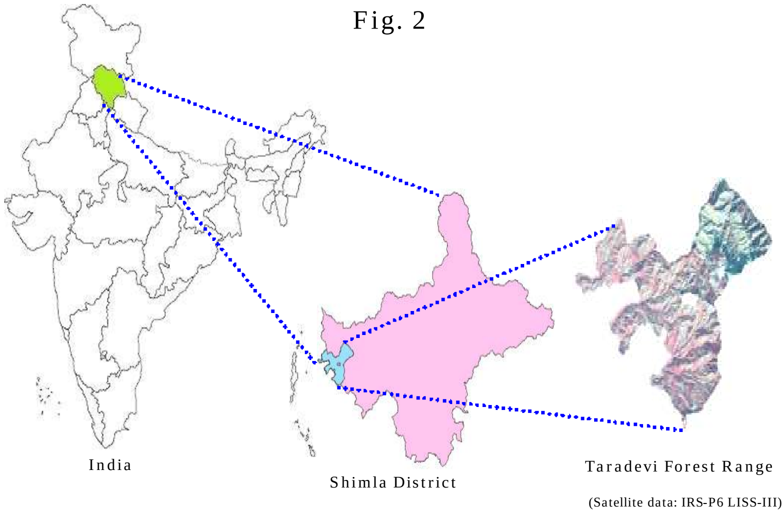
In the study area 5% (0.57 km^2) area of total area falls under very high risk prone area, 22%(2.61 km^2) area is under high risk prone, 38% (4.52 km^2) area is under moderate risk, 32% (3.75 km^2) under low

Fig. 1



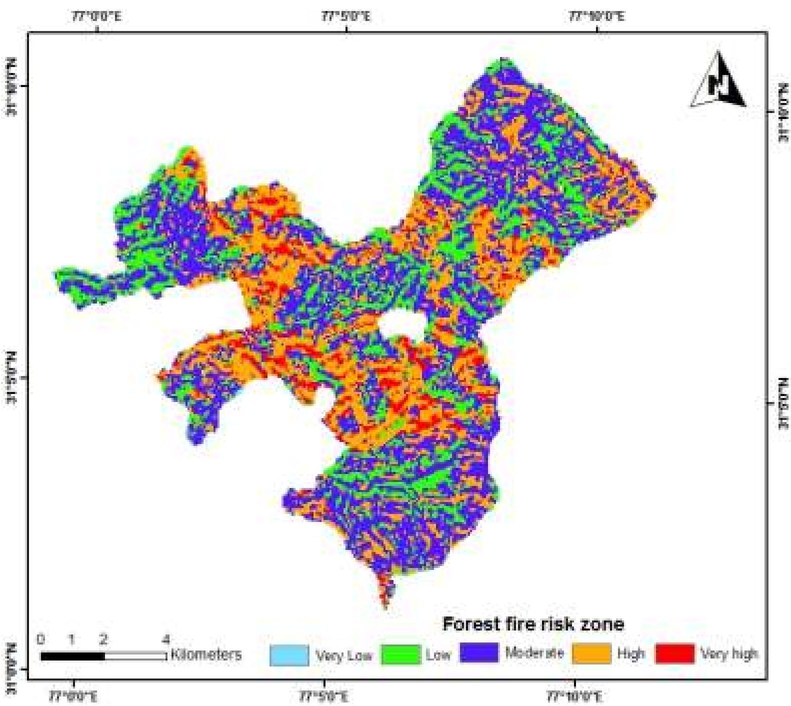
Methodology adopted for fire risk assessment.

Fig. 2



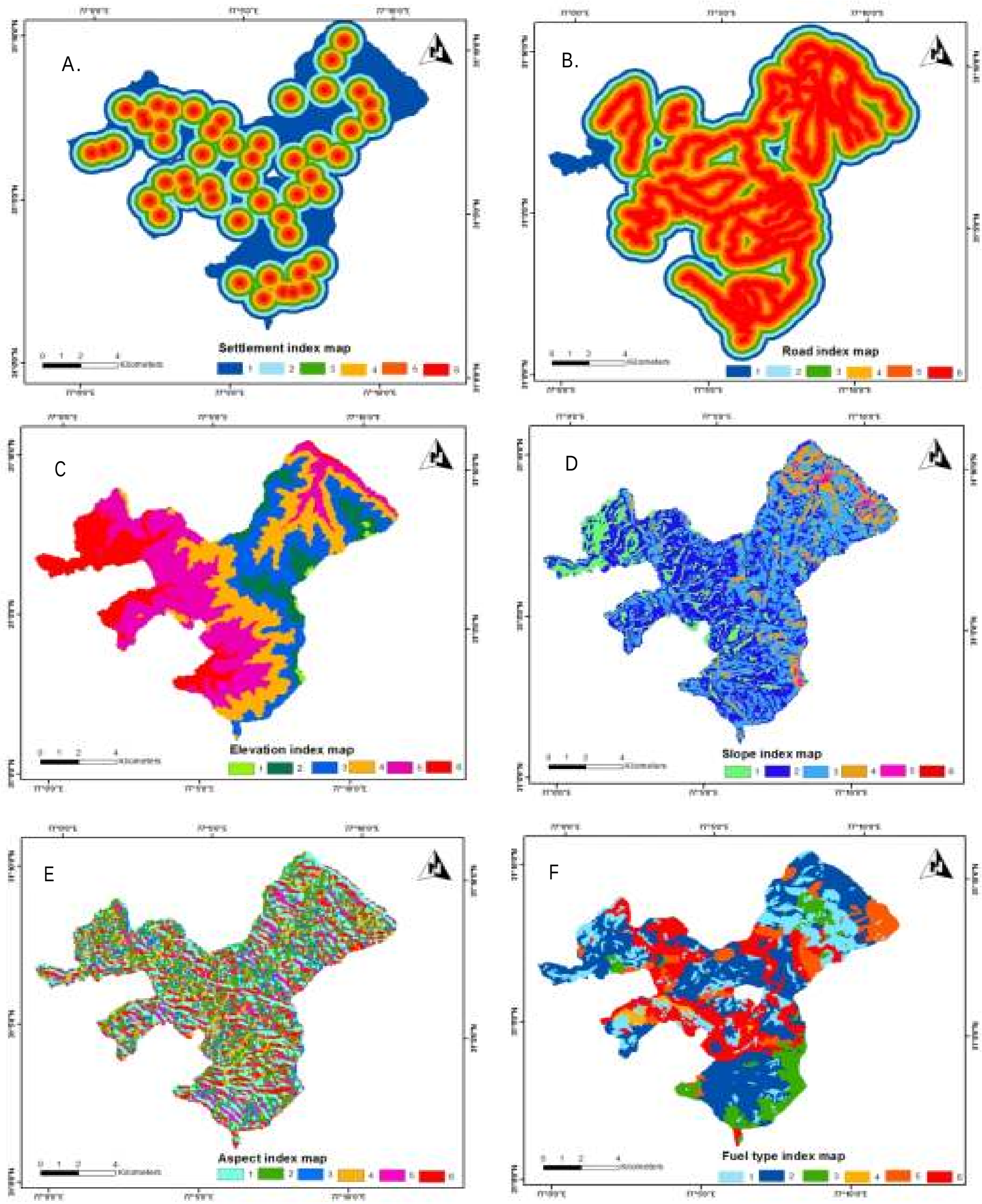
Location Map of Study Area

Fig. 3



Zonation map for Taradevi forest range.

Fig. 4



(A, B, C, D, E and F)
Index maps for Taradevi forest range.

Table 1
Weightages and parameters in determination of fire risk modeling.

Parameters	Weights	Classes	Fire Rating Class	Index Values
Distance from Settlement	1	1000m – 1200m	Very low	1
		800m – 1000m	Low	2
		600m – 800m	Moderate	3
		400m – 600m	Moderate High	4
		200m – 400m	High	5
		0 – 200m	Very High	6
Distance from Road	1	1000m – 1200m	Very low	1
		800m – 1000m	Low	2
		600m – 800m	Moderate	3
		400m – 600m	Moderate High	4
		200m – 400m	High	5
		0 – 200m	Very High	6
Elevation	1	2050m - 2150m	Very low	1
		1850m – 2050m	Low	2
		1650m - 1850m	Moderate	3
		1450m – 1650m	Moderate High	4
		1250m - 1450m	High	5
		950m - 1250m	Very High	6
Slope	2	0^0 - 10^0	Very low	1
		10^0 - 20^0	Low	2
		20^0 - 30^0	Moderate	3
		30^0 - 40^0	Moderate High	4
		40^0 - 50^0	High	5
		50^0 - 60^0	Very High	6
Aspect	3	North	Very low	1
		North-East	Low	1
		West & North-West	Low	2
		East	Moderate	3
		South-East	Moderate High	4
		South-West	High	5
		South	Very High	6
Fuel Type	4	Scrub, Agriculture & Settlement	Very low	1
		Rocky waste & Land with Scrub	Very low	1
		Land without Scrub	Very low	1
		Deodar & Mixed Forest	Low	2
		Plantation Deodar & Oak	Moderate	3
		Platn. Chirpine Oak & Platn. Oak	Moderate High	4
		Bluepine & Plantation Chirpine	High	5
		Chirpine	Very high	6

risk and 3% (.35 km^2) under very low risk. Maximum forest fire risk prone area found in the Jubbarhatti and Taradevi block whereas fire risk prone area is comparatively low in the Tutu block. Fire Risk zone generated by giving different inputs (slope, aspect, forest density, forest types etc.), if utilized will serve as Decision Support System to management authority of forest department official in Taradevi forest range in taking spatial decisions. As per the result of study the recommendations for future fire management can be suggested for enhancement of existing conventional fire control measures.

The results reveal that Remote Sensing, GIS and GPS collectively play an important role in forest fire risk assessment and management. A method incorporating remote sensing and GIS with knowledge based concepts are incorporated in this paper. Satellite images and topographic data were analyzed and the results showed that the methods are suitable for forest fire risk modeling. It can be applied successfully for managing forest fires for forest departments. As the study area is hilly and due to hard topographical conditions forest fire managers can find high-risk places easily and take proper actions to minimize frequency of forest fires and avoid damage.

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SUMMARY

Forest fires are calamity that causes damage to the forest economy which is considerably greater than all damages caused by the harmful insects and diseases. Its cause's substantial damage whether caused by natural or anthropogenic factors. Therefore the problem of controlling forest fire is making its important place in issue of economy development. The study area is prone to fire because of the presence of dominant species of pines which are highly susceptible to fires due to the presence of resins. The greatest danger from fire occurs during the month of April to June in higher temperatures periods. Satellite images were interpreted and classified to generate fuel type layer and land use layers. Topographic layers (slope, aspect and altitude) were derived from SRTM data. The thematic and topographic information was analyzed by using ARC/INFO GIS software. Forest fire risk zones were delineated by assigning subjective weights to the classes of all the layers (vegetation type, slope, aspect, elevation and distance from roads, and settlements) according to their sensitivity to fire or their fire-inducing capability. Five categories of forest fire risk ranging from very high to very low were derived on knowledge based information.

Key words: Forest fire Risk Model, Geospatial Approach.

वन में लगती आग का जोखिम प्रतिरूपित करने की भूक्षेत्रीय दृष्टि: हिमाचल प्रदेश भारत के शिमला मण्डल के तारादेवी परिक्षेत्र का एक विशेष अध्ययन

श्रुति काँगा, लक्ष्मीकान्त शर्मा, एम.एस नाथवत व एस.के. शर्मा

सारांश

वनों में लगती आग ऐसी आपदा है जो वन आर्थिकी को इतनी हानि पहुँचाती है जिसे हानिप्रद कीड़ों और रोगों से पहुंचने वाली सभी क्षतियों से कहीं बढ़कर माना जाता है। इससे काफी हानि होती है चाहे वह आग प्राकृतिक कारणों से लगी हो या मानव जाति

कारणों से। इसीलिए वनों में लगने वाली आग की रोकथाम करना अर्थव्यवस्था के विकास की समस्याओं में महत्वपूर्ण स्थान लेता जा रहा है। अधीत क्षेत्र आग के प्रति प्रमाण्य है क्योंकि इसमें चीड़ की जातियों का बाहुल्य है जो इसमें लीसा होने के कारण अत्यधिक आग प्रभविष्ट हैं। आग लगने का सबसे ज्यादा खतरा अप्रैल से जून के महीने में रहता है। जिनमें तापमान ज्यादा रहता है। ईधन रूपी स्तर और भूमि उपयोग स्तर तैयार करने के लिए उपग्रह आंकड़ों का निर्वचन और वर्गीकरण किया गया। भूमिगत स्तरों (ढलान रूख और ऊंचाई) को SRTM आंकड़ों से लिया गया। विषयगत और भूमि वर्णन जानकारी का विश्लेषण ARC/INFO GIS साफ्टवेयर से किया गया। सभी स्तरों (वनस्पति रूप, ढलान, रूख ऊंचाई और सड़क तथा बस्तियों से दूरी) की श्रेणियों को उनकी आग के प्रति संवेदयता या आग प्रेरण क्षमता के अनुरूप व्यक्तिनिष्ठ भार देकर आग लगने के जोखिम वाले क्षेत्रों का चिन्हित किया गया। बहुत ज्यादा से बहुत कम तक की सीमा वाले आग लगने के जोखिम वाली पांच श्रेणियां जानकारी पर आधारित सूचनाओं से तैयार की गई।

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