Forest Fire Risk Zonation for Jammu District Forest Division Using Remote Sensing and GIS

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Key words: Geospatial, NDVI, Fire Risk Zonation, Digital Terrain Model and Expect knowledge

SUMMARY

The purpose of this paper is to presents the potential of Geospatial Technologies, implementation of developmental plans and developing the earlier alarmic strategies to evaluate unexpected and uncontrolled forest fire susceptibility which badly effects the local landscape, ample diversity of forests bloomed with rich array of floral, faunal life forms and economy. The Earth observation satellites are currently applied in bulk to detect burned area by means of remotely sensed images of vegetation index (NDVI) based on specific combination of red and near infra red bands which specially reflect back the amount of green vegetation and provide comprehensive information of forest fires whereas, the analysis as well as mapping of the damage caused by forest fire through Geomantic Technologies (GIS) contribute a lot in development and installation of "Fire Danger Rating System" and "Forest Fire Forecasting System". "Fire Risk Zonation" map has been developed additionally to determine the level of severity of forest hazards zone by accessing the relative importance between fire factors and location of fire ignition.

Digital Terrain Model (DTM) is prepared and same used to extract slope and aspect of the terrain, Soil type was extracted from soil database and dry month code from agro- climatic, also raster maps showing the index of flammability, and expect knowledge such as velocity and direction of the wind, altitude, drainage, fuel load, are used in large and all these information are put in a Geospatial Information System (GIS) to simulate and visualize the wildfire spread.

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INTRODUCTION

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. 1990). This can be strengthened by any GIS application, which is most appropriate for that site-specific condition.

This study mainly focus over the construction of restoration techniques, development of ecosystem and forest fires via the implementation of various techniques such as image composition, visualization of 3D model (DEM), correlation analysis between surface temperature in the mountainous area with biophysical variables, physical environment, NDVI and other potential factors including elevation (90% cases of forest fire happens at 100M above sea level). Slope (65% cases in the entire forest fire occurs between slope of zero and slope of 20 degree and decrease remarkably as slope increase). Aspect(related to amount of sunshine and probability of forest fires is more in the south rather than north because a southern exposure has higher vegetation which have the effect and play vigorously in the forest fires).

CONCEPTUAL BACKGROUND AND MOTIVATION

The incidence of forest fires in the country is on the increase every year. The major cause of this failure is the piecemeal approach to the problem. We have always looked at the problem from the perspective of addressing the same without going into the actual causes. Both, the scientific focus and technical resources required for sustaining appropriate mitigation strategy are deficient.

Forest fires imprint a significant effect in shaping the character and composition of forest vegetation. Study conducted by Forest Survey of India reveals that 46% of forest area of Jammu and Kashmir State is subjected to repeated annual fires. The major losses are suffered by chir pine crop. Coming to the fire characteristics, these move in all directions after ignition. They move rapidly with wind or uphill especially in Kalidhar region where the head fire flame is close to forest floor and preheats the fuel. Firstly, the fire starts from low vegetation as surface fire Further it gains intensity along the slopes and preheats the overstorey canopy, causing it to burn rapidly as crown fire, which generally burn foliage and small limbs of trees above forest floor.

Research Objective

The present study deals with the application of RS, GIS and DIP for the risk assessment and Zonation in forest division of Jammu district. (J&K), India

The main objectives of the study were:

1. To generate thematic layers in GIS domain.
2. To identify fire prone areas based on spatial modeling in GIS.

Geographical Background

Study area: Jammu is the south western district of Jammu and Kashmir state (India) lies between 32 º 27´ and 33º 50´ N latitude and to 75º 19´ and 75º 20´ E longitude, with an approximate geographical area of 2,942 sq km. The altitude varies from 320 m to 1,675 m above the sea level (Fig.1). It comprises four tehsils: Jammu, Akhnoor, Ranbir Singh Pura and Bishnan.

Climate: Jammu district, situated in subtropical part, has markedly periodic climate, characterized by dry and increasingly hot season from March to June, a warm humid monsoon season from July to September and dry and cold weather from October to December.

Vegetation: The forests of Jammu district represent typical subtropical vegetation. The lower altitudinal Zonation is dominated mainly by shrubs with a few scattered patches of broad-leaved trees. On moderate elevation these shrubs are found to be mixed with broad-leaved and chir pine communities, while high elevations are dominated exclusively by chir pine patches.

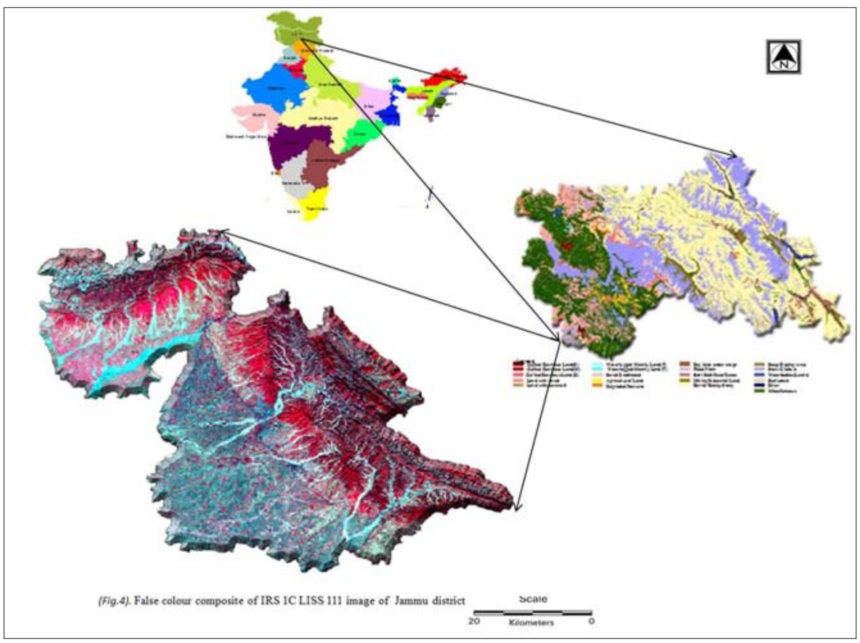


Figure1: study area

Satellite dataset and material used

Primary data consisting of digital dataset of IRS-1C LISS-III sensor of October 8, 1998 with spatial resolution 23.5 was procured from NRSA (Fig.1) along with its support to study the other land base information are collected from SOI (Survey of India topographic map) of study area with 1:50,000 scale. These Topo Maps serve the purpose of registration of Satellite data, ground truth studies, authentification of various cultural features on satellite imagery and also the generation of vector layers such as contours and road network layers.

METHODOLOGY

Data Conversion

Satellite Imagery in available is raster digital format where as the secondary data (Topographic Map and Guide Map) were available in analogue format. Road maps were scanned to convert the analogue map into raster digital format. All the raster data are then registered in the required projection system i.e. UTM (Universal Transverse Mercator) and Datum WGS84 so that digitized output is achieved in real ground units. Satellite images are digitized in the different layers depending upon the variety of features available on the ground. Topologies of the various features digitized are created so that actual attribute information of the corresponding features on the ground can be like to it.

Ground surveys, are conducted to update the features, which are not visible on the satellite imageries such as the actual names of the rods etc. Finally the ground survey data are integrated with the attribute table of the corresponding features. The general methodology is shown in figure 2

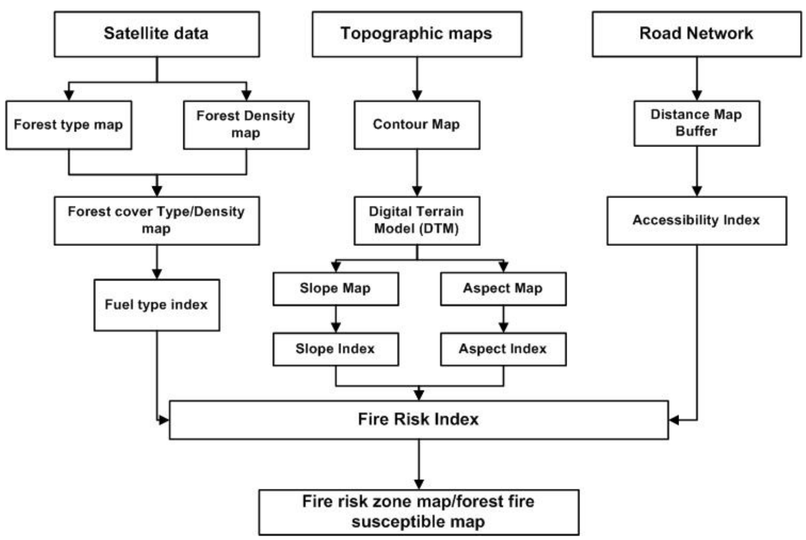


Figure2: General approach adopted for the proposed study

Vegetation Classification

In this study, vegetation mapping employed the use of LISS III (Linear Image Self Scanning) data of Indian remote sensing satellite IR-IC, wherein mapping of vegetation types was done through computer aided digital image classification.

The objective of the digital image classification was to produce a detail map of vegetation types and characteristics of the study area. The image selected for the processing presented free from cloud cover and also depicts the convenient phenological conditions for discrimination different vegetation types. Training sets were selected in satellite image and spectral separability of different classes was used to distinguish their apparent uniqueness and individual spectral signature. The vegetation cover / land cover map prepared depicts seven different categories based on the spectral signatures of ground realities (Fig.3). These include northern dry mixed deciduous, Himalayan subtropical dry scrub, Himalayan sub-tropical chirpine dominated, grassland, barren / fallow land, agriculture and water body. The area estimate of various vegetation cover classes is shown in (Table-1). The derived classes were compared with the classification of Champion and Seth (1968). Classification accuracy was estimated to be 93% which is perfectly acceptable for many applications including the extrapolation of observations (Fuller et al., 1998). Majority of the area in the district is dominated by subtropical dry deciduous vegetation covering 27% of the total, followed by barren / fallow land i.e. 26.2%. Agriculture holds 20.6% of area, whereas grassland and subtropical dry scrub occupy an area of 11.7% and 10.1%, respectively. Subtropical chirpine dominated forest contributes a meager percentage of 3.4 only. Cloud and hill shadow account for negligible area. The details of vegetation classification and brief description about the land cover classes have been given below.

Table-1: Aerial extents of vegetation types in Jammu district.

Vegetation type	Area (sq km)	Percentage	Tone	Texture
Northern Dry Mixed Deciduous Forest	804.46	27.3	Bright red	Smooth
Himalayan Subtropical Scrub	296.80	10.1	Dull red	Coarse
Himalayan Subtropical Pine Forest	99.85	3.4	Dark maroon	Coarse
Grassland	345.45	11.7	Bluish green	Medium
Agriculture	606.80	20.6	Light pink / Dull blue	Smooth / Medium
Barren / Fallow land	769.46	26.2	Bluish green	Medium
Water body	17.85	0.6	Light blue / Deep blue	–

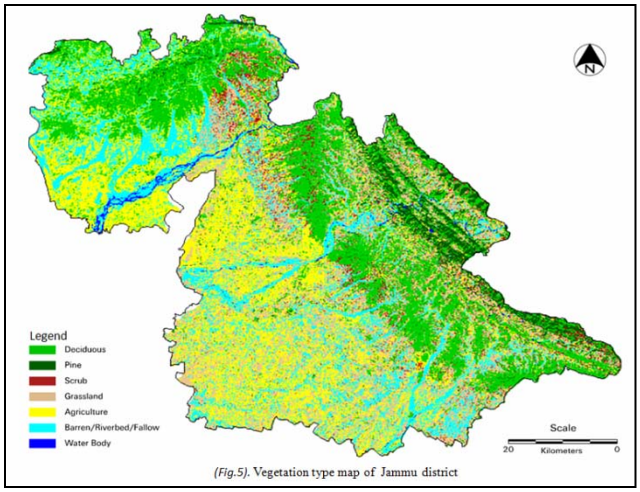


Fig.3: The vegetation cover / land cover map of Jammu district

Generation of DEM (Digital Elevation Model), Slope and Aspect Map:

By digitizing contour lines on 1:50000 scaled topographic map in 20M interval and using interpolation (TIN) procedure the digital elevation model (DEM) is created (Fig.4). which efficiently make the representation of continuous variation of relief over space within the study area. The false color composite of IRS-1D LISS III image is draped with DEM for better visualization and accessing the reliability of data source. Frequency of the point selected on the land and the mathematical method used in conversion are important for quality and accuracy of Digital Elevation Model. In addition Digital Elevation model (DEM) is used to create slope (Fig.5) (as well as aspect map (Fig.6). For reason being to use as layer in GIS. The slope and aspect were graduated into eight classes.

Proximity Analysis: Roads, tracks, railways, and habitation area are also important factor that must be considered in fire risk mapping reported by Chuvieco and Congalton(1988), that in spite of the apparent importance of these features, they are not widely used in fire risk mapping because of the difficulty in dealing with the linear features in any raster data structure. However in present study proximity to the road and railway were considered. The proximity to the road data was obtained through the vector layer created from scanning and digitization SOI toposheets 10 buffers at an interval of 200m were created within the study area Using Arc View 3.2a which approximately covers the entire area.

Generation of Forest Type and Forest Density Maps: The forest cover map (Fig.7) and forest density map (Fig.8) was prepared by on screen image interpretation of Georeferenced IRS-1C LISS 111 image coupled with ground verifications. Later both were combined by crossing and overlaying to generate the fuel map, weights are given on the basis of forest type and density. Grasslands which have maximum inflammable material were given weight of 10. Degraded forests and Shrubs containing undecomposed leaf litter were given weight of 9, where as the dry mixed, mixed forests and sal forest containing more leaf litter and fire prone species are assigned with weights of 5, 7 and 8 respectively.

Fire Risk Zonation Modeling - Integrating In GIS:

Although in most studies conducted on the fire risk modeling was not given much importance but the ability of GIS to spatially interrelate multiple types of information, spreading from a range of sources in a useful and organized way is most important and stunning benefits.

Further, it was revealed that fuel classes derived from satellite imagery and topographic data to be an input in a standard fire rating system while other projects did not attempt to integrate vegetation, topography, insolation, and fire history altogether in a single fire risk index. The map layers generated after analyzing the thematic layers using GIS i.e. fuel type map, slope map, aspect map, distance map and digital elevation model (DEM) has been re-classified using classifying Tables 2, 3 and 4; and the index map like accessibility index map have been generated. Dry mixed (medium, low and degraded), mixed (degraded) and the degraded sal forest area are given higher index values because they contain maximum dry inflammable material. Spatial modeling of Jammu district forest division was done to obtain the combine effect of fuel type index, slope index, aspect index map and the distance accessibility Index (Fig.9). Weights given are based on the importance of variables participating in fire environment. Cumulative fire risk index value map was obtained using the map calculation function.

CFRISK = FUI + ASI + SLI + ACI

In the present case the highest weight of 4 has been given to fuel type index because of maximum extend due to high inflammability factor, the second highest weights has been given to aspect because sun facing aspects receives the direct sunrays, the south, southwestern and southeastern aspect has been given maximum weightage of 8,7 and 6 *Table - 2;* respectively and the third heights weights has been given to slope contributing to convectional heating, easy ignition and its spread on a wider area, the slope from >60 degree and above has been given maximum weight of 8 *Table - 2;*

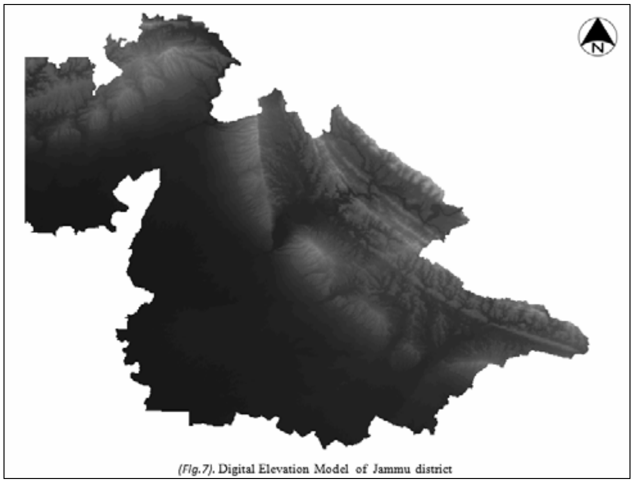
The model output i.e. cumulative fire risk was obtained using map calculation function in *Arc View 3.2a* software and the model is:

CFRISK = FUI*4+ASI*3+SLI*2+ACI

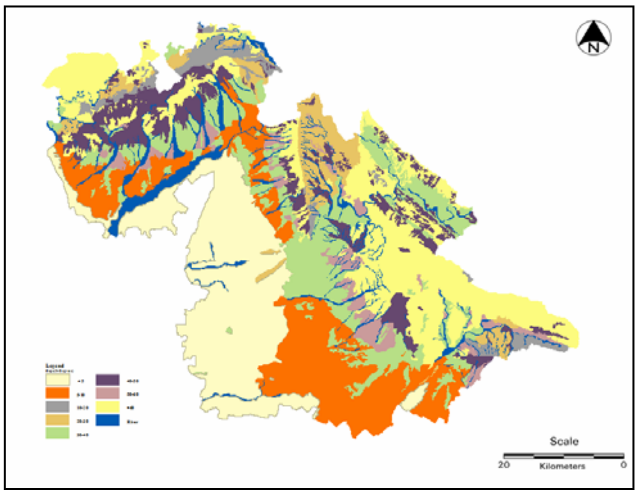
Where,

CFRISK	=	*Cumulative Fire Risk Index Value*
FUI	=	*Fuel Type Index*
ASI	=	*Aspect Index*
SLI	=	*Slope Index*
ACI	=	*Accessibility Index*

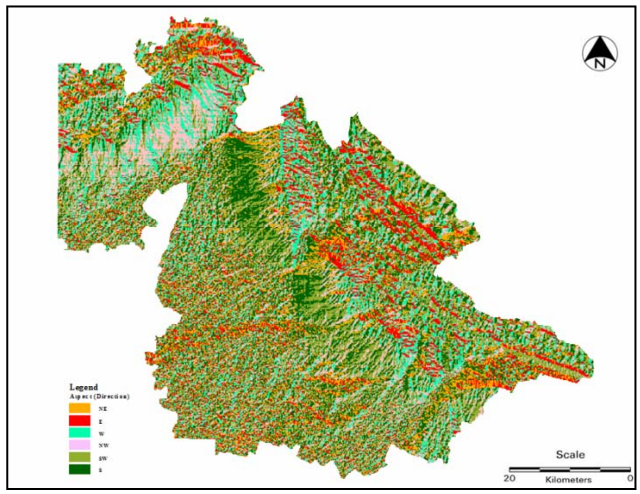
Based on the various statistics of different weights assigned, the map was reclassified into five classes as Low, Moderate, High and Very high to generate fire risk area map *(fig.9).*



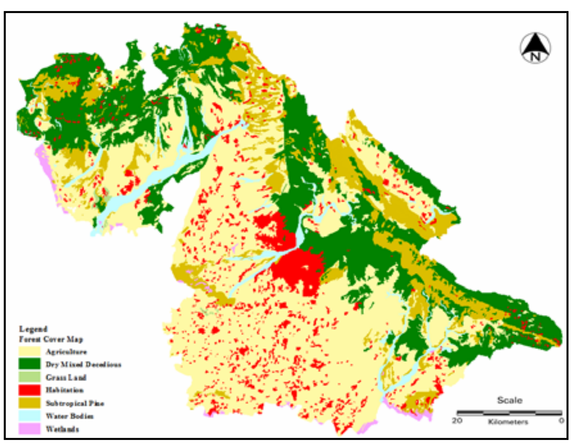
(Fig.4). Digital terrain model of Jammu district



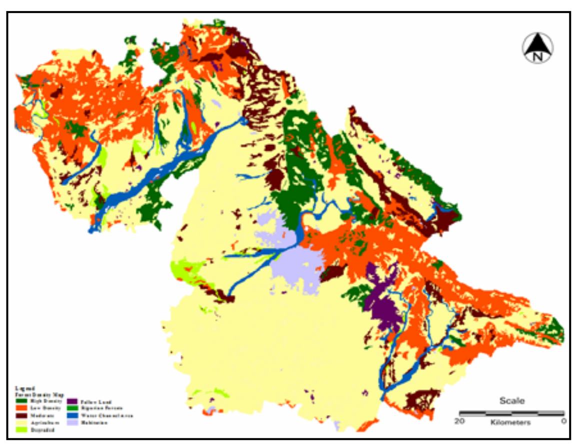
(Fig.5). Slope Index map of Jammu district



(Fig.6). Aspect Index map of Jammu district



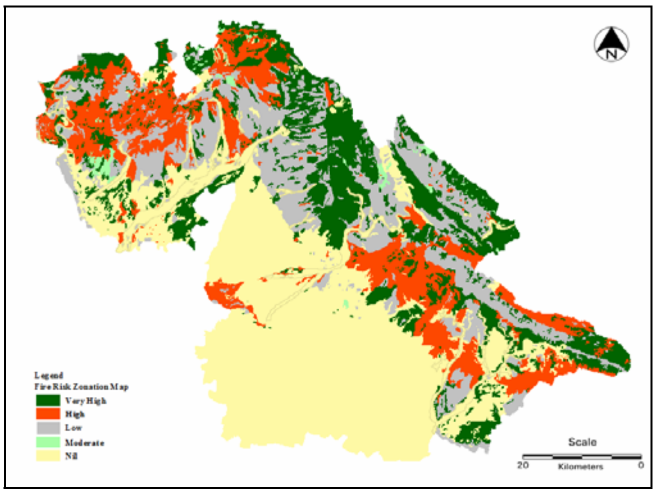
(Fig.7) The forest cover map of Jammu district



(Fig.8) The forest density map of Jammu district.

RESULTS AND DISCUSSIONS:

Final fire risk map has been categorized into four classes i.e., low, moderate, high and very high, with habitation, agriculture and water assigned the least, and the chirpine and chirpine mixed the maximum weight age. The fire risk zone map (Fig.9). obtain by the integration of different layers indicate that 20.34% of total area under very high risk zone, whereas 18.43 % area falls in high fire risk zone, followed by .65% and 20.53% in moderate and low risk zones, where as 40.05% is non forest area and have negligible chances of fire risk. These areas need special attention for formulating fire management plan and fire inventorisation.



(Fig.9). Fire Risk Zonation map of Jammu district

Efficient fire fighting measures shall be the sole criterion, especially during dry months. Chirpine mixed, mixed and sal mixed is prone to very high fire risk followed by sal mixed and sal falling in high-risk areas. Riverine and scrub are least vulnerable to the fire risk. Study indicates that 20.34% of the area is a computed as very high risk zone, which calls for high priority in fire management strategies for district Jammu forest division.

Table 2 and 3.Classification tables used for generating index maps and Accessibility Index Map.

Slope Index Map (SI)

Classes	Weights
0 - 5°	1
5 – 10	2
10 – 20	3
20 – 30	4
30 – 40	5
40 – 50	6
50 – 60	7
>60	8

Aspect Index Map (AI)

Classes	Weights
FLAT .N	1
NE	2
E	3
W	4
NW	5
SE	6
SW	7
S	8

Accessibility Index Map (Table3)

Distance Class (M)	Index value
200 – 400	10
400 – 600	9
600 – 800	8
800 – 1000	7
1000 – 1200	6
1200 – 1400	5
1400 – 1600	4
1600 – 1800	3
1800 – 2000	2
>2000	1

Table 4.Various Fuel Types with Weights for the generation of fuel type index

Fuel Type	Density	Weight
Dry Mixed	High	7
	Medium	6
	Low	5
Chirpine	High	8
	Medium	7
	Low	6
Chirpine Mixed	High	8
	Medium	8
	Low	7
Moist Mixed	High	4
	Medium	3
	Low	2
	Degraded Forest	2
Sal	High	6
	Medium	5
	Low	4
Sal Mixed	High	7
	Medium	6
	Low	5

Fuel Type	Weight
Plantation	7
Habitation	1
Agriculture	1
Degraded Forests	9
Blank	1
Grass	10
Riverine	1
Scrub	5
Shrub	7

CONCLUSION:

The major causative factors were identified by the help of classification, digitization and overlay of the burnt areas with respective causative factors map inconsequence with index maps. The overlay of fire burnt areas with various causative factors provides the predominance of the particular causative factor in the specific area. The results of the present study carried out that the blend (integration) of Remote Sensing and GIS coupled with Digital Image Processing will be beneficial for further research purpose, identifying the high risk area, implementation of forest fire management plans and fire mitigation.

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