Forest fire modeling to evaluate potential hazard to tourism sites using geospatial approach

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Abstract: Aim of the current work is to prepare a model which articulate the forest fire risk to tourist spots so that the concerned authorities can minimize the fire danger. The models were generated using fire risk models using MCDA (Multi-Criteria Decision Analysis), AHP (Analytic Hierarchy Process) & Fuzzy techniques and tourism model. The gradients of tourist potential sites were created in GIS environment with binary weighted overlay methods. The potential tourism sites were generated and both overlaid to produce final tourism suitability potential map. Fire risk maps were created in GIS using statistical modeling- knowledge based weightage, AHP and Fuzzy. For each fire risk map, 5 classes were assigned and out of these high and very high risk zones were overlaid to generate final fire risk map using raster calculator in GIS. Final hazard map was prepared using overlay operations of forest fire risk model and suitable tourist sites with GIS.

Keywords: Geospatial techniques, Fire Hazards to Tourism, Forest fire models, MCDA and Fuzzy techniques

1. Introduction

Forests form an integral part of the forest environment which plays an important role in shaping the flora and fauna. The flora, fauna and its environment attract people due to its scenic beauty and adventurous outlook. Thus, it nourishes and flourishes tourism spots in its lap with growing economic support for local inhabitants. Tourism and forest resources form the economic centre of its surrounding regions. Tourism business and forest resources continue to play major role in economic development of region. The tourism depends on the people upon their leisure time, desire and their interest in wild life, and forests. Eagles (1995) proposed that nature-based tourism has at least four sub-markets differentiated according to the travel motives of the tourists. They are wilderness, eco-tourism, adventure and scenic beauty. Natural tourism concept is totally based on the use of natural resources in relatively undeveloped state, including scenery, topography, water features, vegetation and wildlife as introduced by Healy (1988).

Forest fire risk zones are the locations where a fire is likely to start and from where it can easily spread to other areas (Kanga et al., 2011, a). Different factors accelerate fire- climate, vegetation type, physiographic factors, proximity to road (Butler et al., 1991) and settlements etc. Climatic regime determines the vegetation in a region and hence plays a dominant role in ascertaining the fire-prone sites. Drier the climate, more prone would be the site (Flannigan and Harrington, 1988; Robinson, 1991). Altitude, aspect and slope influence and play an important role in fire spread. South and south-western slope is exposed to direct rays of sun and therefore prone to catch fire easily as compared to northern and north-eastern slope aspects. In the case of slope, fire travels most rapidly up-slopes and least rapidly down slopes (Rothermel and Richard, 1972).

Forest fire play major role in shaping the forest ecosystems. But frequent fire may be either beneficial or detrimental to resources, individuals, and species. The effect of a single fire is not as environmentally significant as a change to fire regime (Smith, 1995). Forest fire causes loss to physical, biological, ecological and environmental areas (Jaiswal et al., 2002). Fires cause extinction of species, alter species compositions and successional stages as well as bring significant functional changes in ecosystem. Humans have altered the natural fire regimes by changing the frequency and intensity of fires in all types of forest landscapes. People have excluded or suppressed fires and changed the nature of the landscape so that a naturally occurring fire will not behave in the same way it would have in the absence of human impact. Countless number of studies and report shows that there exists a complex inter- relationship between humans, forest landscape and fire (Jackson and Moore, 1988).

Forest fire risks were mapped using remote sensing and GIS techniques incorporating factors like slope, aspect, forest type & density, land use, proximity to settlements based on weightage (Jaiswal et al., 2002, Chuvieco and Congalton,1998, Chuvieco and Salas, 1996). The forecast of forest fire risks can be achieved with the use of fire risk zone maps. A common practice was that forest fire risk zones were delineated by assigning subjective weights to classes of all the layers according to their sensitivity to fire or their fireinducing capability. Different techniques like AHP (Analytic Hierarchy Process) has been used for the conservation of wildlife habitat in Corbett National Park, India (Sharma, 1995) and Motichur range of Rajaji National Park (Porwal et al., 1997) with different parameters. These techniques can be combined together for finding tourism potential sites, creating fire risk zones and then combining them together with geospatial tools to map final fire risk to tourism sites. The risk to forest tourism is greatly enhanced and causes damage to tourism business and threat to tourist life trapped there in. Without reliable information about the extent of fires, fire management is totally difficult to handle (Chuvieco, 1996). Thus, geospatial approach integrated with field verification help in finding the reliable and accurate information and mapping of forest fire risks. Internet-based forest fire management system is used for the forest fire monitoring and prevention (Burke et al., 1997). Thus, geospatial techniques have been used to develop fire information system based on graphic user interface.

Every year thousands of tourists come to enjoy the scenic and adventure tourism, as Shimla has many places of cultural, adventurous and scenic beauty. Tourism in Shimla is nowadays given top most priority for increasing the inflow of tourists. Thus, it needs to be managed scientifically using GIS technology as it helps develop tourist sites gradient maps according to adventurous and scenic beauty (Kanga et Al., 2011, b). This give the potential tourism spots where a person can find place of interest according to leisure, scenic, adventure etc. Tourism sites sometimes fall under threat categories in hilly forested area due to forest fires. It is possible to forecast forest fire risks and thus reduce fire frequency and damages (Johnson Gutsell, 2008). Fire disaster proves to be fatal for the life of tourists and ultimately loss to tourism business. To fight with this problem, study was conducted to prepare fire risk to the specified tourist sites, integrating potential tourism sites and forest fire risk mapping.

Figure 1: Location map of the study area

2. Study area

Taradevi forest range is a part of Shimla district (Himachal Pradesh, India) having spatial extent between 76º59'12.66"E to 77º11'16.96" E and 31º01'15.59" N to 31º 10'45.42" N covering an approximate area of 1564.90 (ha) as shown in Figure 1. The area has hilly terrain with the elevation ranging between 900-2200 m. The area is covered with thick forest cover which constitutes mainly chir Pine (Pinus roxburghii), blue pine (Pinus wallichiana), Ban Oak (Quercus leucotrichophora) and Deodar (Cerdus deodara) with variety of broad leave trees along with shrubs and grasses. The average annual precipitation is 1520 mm and temperature falls between 15 °C-22 °C.

3. Data and methodology used in study

Satellite imagery IRS-P6 LISS-III of year 2009, SRTM (Shuttle RADAR Topographic Mission) 90m and SOI Toposheets on 1:50000 scales were used in the study for evaluating forest fire risks to tourism sites. The overall methodology used in the study follows three steps as shown in Figure 2.

3.1 Potential tourism site identification

In the first step, potential tourism site maps were created for both scenic and adventurous importance as shown in Figure 3 (A and B). The topography, soil, vegetation, drainage pattern, climate have played important role in shaping of the region for its tourism sites. Satellite remote sensing data have been used to prepare different thematic layers- road, settlements, forests, water bodies etc. Forest type and density, historic tourist places, wildlife areas and transportation map are also taken in to consideration. SRTM data was used for the generation of slope, aspect and elevation maps which are also used for delineating adventurous and scenic beauty tourism. Slope, elevations and wildlife were some factors of adventurous tourism. Slope and elevation determine the sightseeing places like sun-rise or sun-set points for people. The slope map has been used to identify ecotourism potential areas and for the creation of slope index map for fire risk assessment too. Recreational zones, as high slopes are sources of adventures sports like rock climbing, trekking and hiking, middle slopes gives the site seeing, green parks, botanical gardens and other nature parks and flat to gentle slope for residential and service centers. The analysis has been done using weighted overlay approach to identify the areas having ecotourism potential. Classes with high moderate and low (potential) were created. Then, the scenic and adventurous maps were extracted to prepare maps of classes having high and very high potential sites as shown in Figures 3 (C and D). There after Scenic and adventurous potential sites were extracted and used for generating final potential tourism sites in the study area as shown in Figure 3 E.

3.2 Forest fire risk zone identification

Second step was to prepare forest fire risk model using Multi-Criteria Decision Analysis (MCDA) in GIS, AHP and fuzzy AHP Spatial modeling techniques to get combined effect of various index types- fuel type, elevation, slope, aspect, road

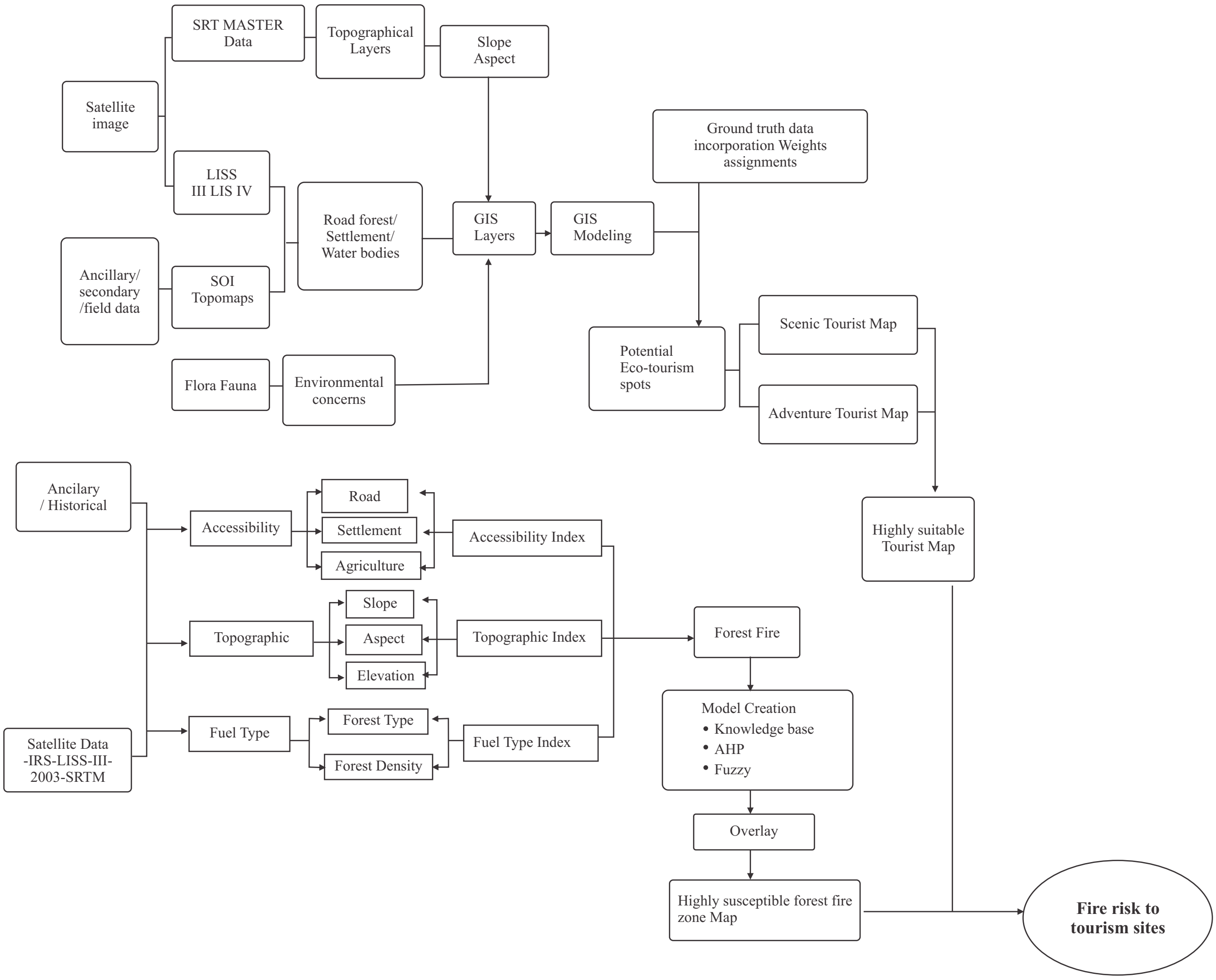

Figure 2: Methodology adopted in the study

and settlement with weightage assigned on the basis of relative importance of individual variables. Three forest fire risk zone identification maps were prepared using MCDA, AHP and fuzzy as shown in Figures 4 (A, B and C). Then, the three maps were extracted to prepare maps of classes having high and very high risk zones only as shown in Figures 4 (D, E and F). All three were again combined and overlaid to generate final risk zone map as shown in Figure 4 G illustrating only risk zones of high and very high values.

3.3 Final fire disaster to potential tourism spots

In final step, overall potential tourism sites and final forest fire zones were used to generate fire disaster to potential tourism sites (Figure 5). Finally Forest Fire Potential Risks to Tourism map has been generated which help in management of sites properly.

4. Results and discussion

4.1 Potential tourism site evaluation

Total area taken for the study is 15.8 km^2. The maps generated for adventurous and scenic beauty tourism are shown in figures 3 and 4. In the area for adventure tourism be most suitable potential site is calculated as 0.58 km^2 (3.17 %), moderately suitable area is calculated as 2.6 km^2 (16.46%), area found to be less suitable is 6.6 km^2 (41.77%) and 6.1 km^2 (38.6 %) area was found not suitable. Whereas most suitable area is calculated as 9.81 km^2 (62.10%), moderately suitable area is calculated as 5.98 km^2 (37.85%) and only 0.01 km^2 (0.19%) area was found to be not suitable for scenic tourism potential site as shown in Table 1. Thereafter, these were extracted for calculating values common to scenic and adventurous sites for high and very highly suitable for tourists. Extracted scenic and adventurous sites were merged together to generate final potential tourism sites. Table-1 shows the area falling under this category for extracted scenic, adventurous and final potential tourism sites common to both. Most potential site were calculated as 0.11 km^2 (high potential) and 2.08 km^2 (very high potential) for the final tourism site model.

4.2 Forest fire risk evaluation

In evaluation of the forest fire risk for the region, knowledge

Table 1: Tourism potential site area evaluation

Sl. no.	**Values**	**Scenic potential sites**		**Adventurous potential sites**		**Scenic potential site (Extracted area)**	**Adventure sites (Extracted area)**	**Potential tourist sites model (Common zone both)**
		Area (km^2)	% age	Area (km^2)	%age	Area	Area	Area
1	Not Suitable	0.01	0.064	6.1	38.60	-	-	-
2	Less suitable	-	-	6.6	41.77	-	-	-
3	Moderately suitable	**5.98**	37.848	**2.6**	16.46	5.98	**2.6**	**2.08**
4	Most Suitable	**9.81**	62.088	**0.5**	3.17	9.81	**0.5**	**0.11**
	Total	15.8	100	15.8	100	15.79	**3.1**	**2.19**

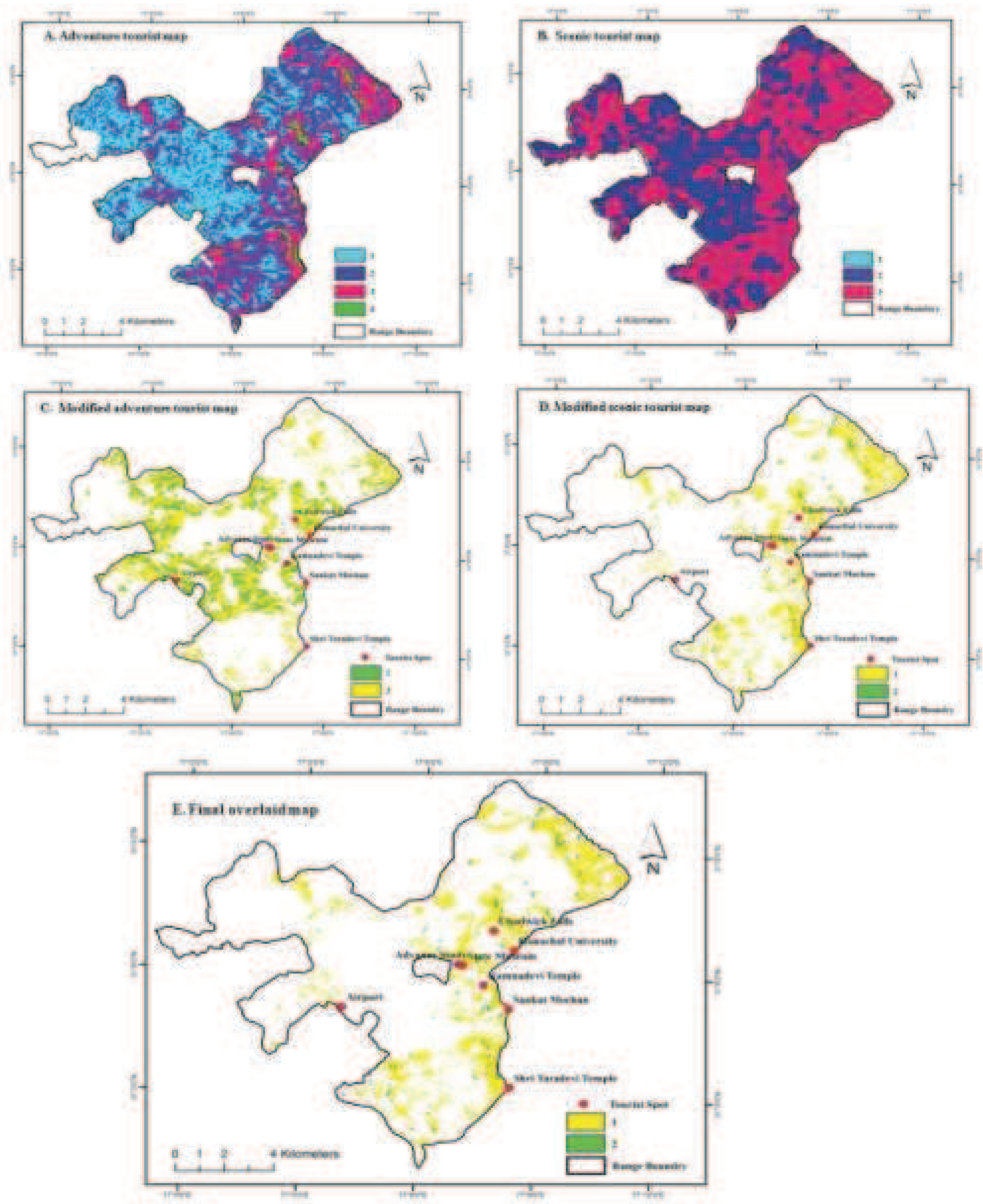

Figure 3: Tourism potential site assessment maps

Table 2: Forest fire risk zone assessment using various models

Sl. no	Risk categories	Knowledge based		AHP		Fuzzy		Fire risk zone model (Common zone in all three)
		Area (km^2)	percentage	Area (km^2)	percentage	Area (km^2)	percentage	
1	Very low risk	0.071	0.45%	0.27	1.71%	0.287	1.82%	
2	Low risk	3.324	21.04%	5.672	35.90 %	5.685	35.98%	
3	Moderate risk	6.779	42.91%	4.893	30.97%	4.878	30.87%,	
4	High risk	4.536	28.71%	3.583	22.68%	3.572	22.61%,	2.63
5	Very high risk	1.089	6.89%	1.381	8.74%	1.378	8.72%	1.07
	Total	15.8		15.8		15.8		3.7

Table 3: Assessment of potential tourism site, forest fire risk zone and fire hazards to potential tourist sites

Sl. No	Potential tourist sites model	Fire risk zone model	Fire risk hazard to tourist site
Total (km^2)	2.19	3.7	**0.79**

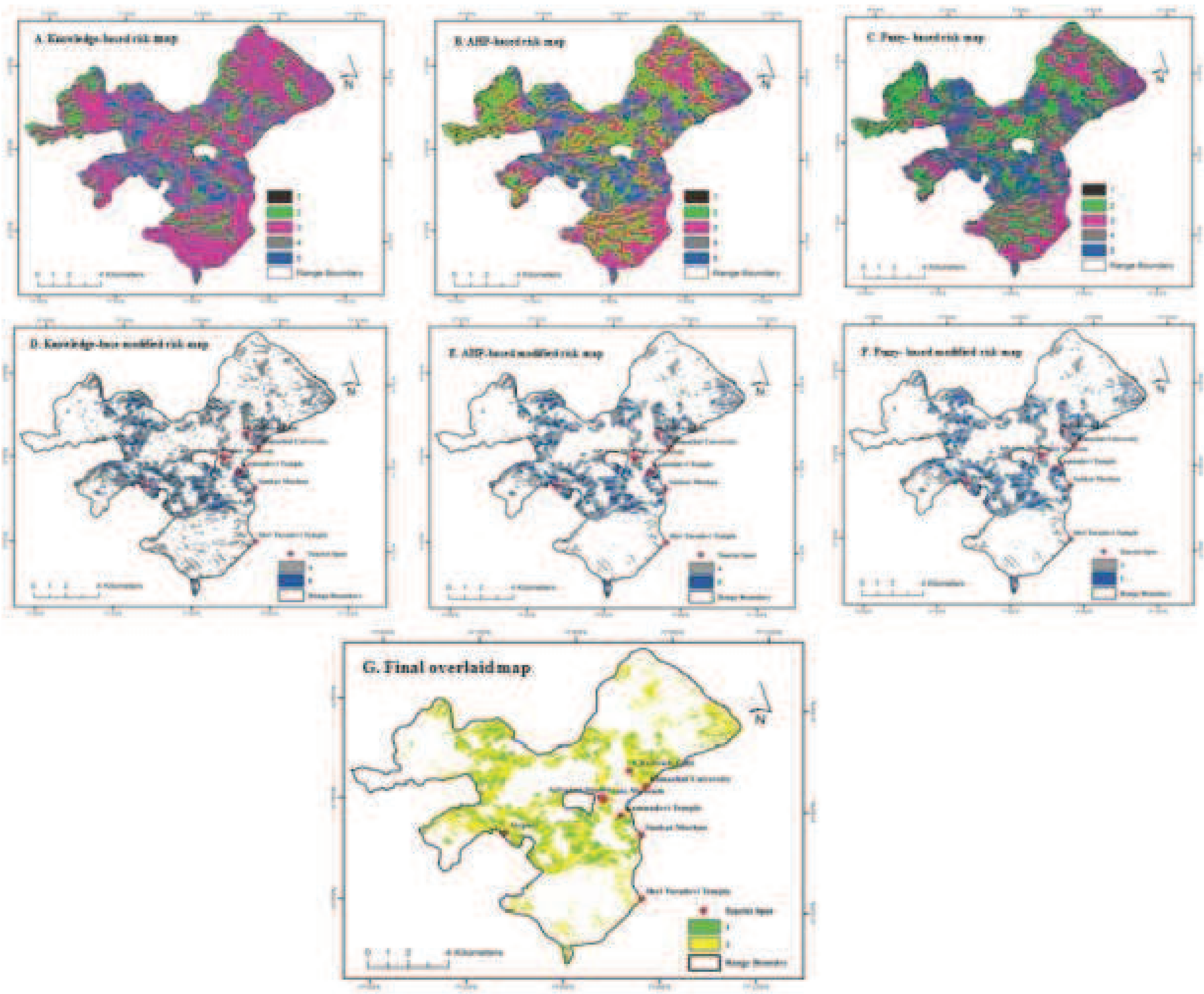

Figure 4: Forest fire risk zone assessment maps

based, AHP and fuzzy models show different fire risk as shown in Table 2. Risk zone classified for knowledge, AHP and fuzzy were in order of severity, 1.089 km^2 (6.89%), 1.381 km^2 (8.74%) and 1.378 km^2 (8.72%) spread over five classes. Difference in the form of area covered under each risk zone is obtained for the three models applied here. Thereafter, three models were intersected for the high and very high risk zone mapping to generate Fire risk zone model (common zone in all three model). The values came to be 2.63 km^2 (high risk), 1.07 km^2 (very high risk) and total 3.7 km^2 which is further used with potential tourism site to generate fire risk hazards to tourist sites.

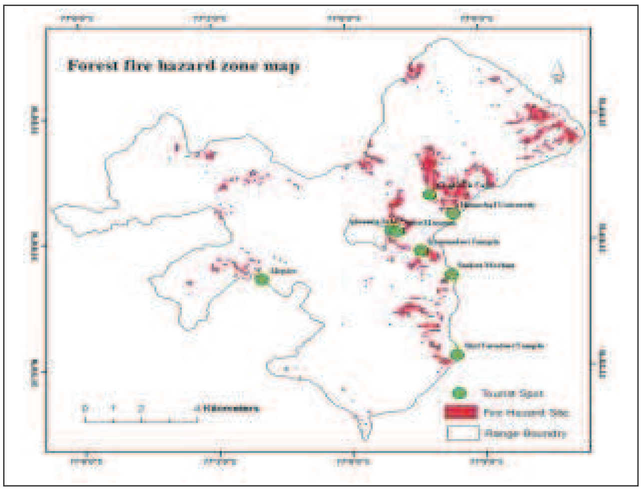

Figure 5: Fire hazards to potential tourist site map

4.3 Forest fire risk hazards to potential tourism sites

Figure 5 shows high potential tourism site which is prone to very high risk to forest fire due to various factors which include natural and human induced reasons. These potential sites fall in the categories of very high risk zone of forest fires (Table 3). The area corresponds to about 0.79 km^2 which need better management for prevention and control of fire. The outcome has area common to potential tourism spots and susceptible and prone to forest fire risk hazards. Assessment of potential tourism site, forest fire risk zone and fire hazards risk to potential tourist sites were evaluated by applying models, knowledge based approach and field data incorporation in GIS themes.

5. Conclusions

The present study relates the forest fire risk hazards to tourism sites with risk mapping and potential tourism site evaluation. These include incorporation of slope, aspect, different themes (road, settlements, forest type & density) etc for preparation and generation of models. These results will help tourism to flourish in the study area. The knowledge of hazards site will have prior precautionary and control management strategies in advance.

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