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A GIS BASED STUDY TO RECOGNIZE FIRE COMPLEX ZONES IN UTTARAKHAND

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ABSTRACT

In this study, the authors address the historic fire trends in Uttarakhand by means of the Moderate Resolution Imaging Spectroradiometer (MODIS) active fire datasets. The study targets to enumerate the fire activities from 2001-2017 which accounts total 23534 number of fire points. We evaluated different fire trends that is yearly fire trend, seasonal drifts, district wise trend and on varied topographical (elevation, slope and aspect) parameters. MODIS active fire counts data from 2001–2017 discovered an average of 1384 fire numbers per year with maximum during the year 2016. The yearly trend of fire counts predicts the cyclicity of four years from 2001-2017. Starting from the year 2001-2017the study finds that month of April records maximum fire incidences 7370 followed by month of May with5597 incidences. Maximum number of fire incidences were recorded in the Garhwal district. The consequence of the hotspot analysis advocates that the critical hotspots counts 10415 majorly spread over the lower terai arc landscape. The lower attribute values of slope and elevation encounters the maximum hotspots while the upper topographic values record the cold spots.The results of the hotspots and the historic fire trends will be useful to manage the fire regimes in Uttarakhand. Nearly 49% area of the study area was predicted to be under fire sensitive zone which constitutes maximum number of hotspots.Consequence of the study suggest that dry climatic conditions, lower slopes and lower elevation regions encounters maximum number of hotspots. Thus, the key aim of the study is to use GIS ground to prepare a fire cluster map for Uttarakhand.

Keywords: Hotspot, MODIS, Topographic, Zone Mapping, Fire regimes

1. INTRODUCTION

Wild fires are spread in number of ecosystems both natural and manmade which can alter the structure of landscape and affect the function and procedures of ecology **(Dansereau et al., 1993**).These fire causes excessive loss to the entire forest ecosystem and biodiversity and as we know forests are home to more than two- thirds of all known land species **(SFR, 2015).** The quality of forest is reduced due to long term and recurring impact of forest fires **(Yuanzhao, 2012**).According to the source of ignition fires can be divided into natural and human and caused Behavior of fire is typically defined by its spread and intensity and issues that influence these two factors are available fuel, moisture and temperature, fuel composition, wind, and topography **.**The fires are categorized in terms of combustible material present and the effect of weather on the fire and can also be classified as brush fire, bush fire, desert fire, forest fire**(Yuanzhao, 2012**).

Uttarakhand is one the fire prone area where forest fires have been consistent and historic incident **(Negi, 2016).** The usual fire season in India is from the month of February to mid-June. According to the forest department of Uttarakhand, 3399 hectares forest cover has been gutted in 1451 forest fire incidents in the state this year that is 2018 (https://www.indiatoday.in). Current inclination in forest incidences in state, demands an urgent need to produce a geospatial fire events data sets to identify the significant fire prone areas.

Remote sensing and GIS based Modis datasets can contribute to a wide aspect to conserve the land from this massive natural disaster. Remote sensing has opened opportunities for qualitative as well as quantitative analysis of forests and other ecosystems at all geographical and spatial scale remote sensing has also been effectively used in the study monitoring and detection of forest fire. Understanding the influence of fires on vegetation and topographical paraments requires detailed knowledge of spatial and temporal gradients and fire occurrences chronicles **(Vadrevu et al.,2013**). For the similar, Geographical information system (GIS) and remote sensing (RS) approach with its vast exposure, multi-temporal multi spectral data abilities provides robust information. In addition, GIS applications has been used for wild fire management and planning, mapping the spatial distribution of fire events and associated hazards **(Perry et al. 1999; Hamilton et al. 1989; Roy, 2013).**

In the present study, we used Moderate resolution Imaging Spectroradiometer (MODIS) active fire data to report the following questions pertinent to fire trend over last seventeen years their spatial distribution and fire concentration in different districts of Uttarakhand. How are the fire events distributed across different regions of Uttarakhand? Are there any precise districts and ecosystems where fires group occurs? Where are the hotspots in the state? When is the peak fire season with respect to repetitive fire incidences? How are the fire hotspots distributed across different topographic inclines and geographical districts? Are the fire distributions random? If not, how are they different from random pattern? The above questions have important consequence to fire management with respect to spatial process at a given time and in each space. The study will be beneficial to understand the synoptic behaviour of the forest fire incidences over certain period of years. To understand the spatial patterns of fires will be highly beneficial to locate the critical fire zone sin Uttarakhand**.**

2. STUDY AREA

Uttarakhand state lies in the western part of the great Himalaya range which occupies total area of 53,897 km ^{2} and lies between 28°43’ N to 31°27’ N latitude and 77°34’ E to 81°02’ E longitude (Figure:1). The recorded forest area in the state is 34,651 Km^{2}, which constitute 64.79 % of its total geographical area covered by the state **(SFR, 2015).** The state is situated in the northern part of India and bonds an international boundary with China in the north and Nepal in the east. Physio graphically the state can be divided into three main zones, the Himalayas, the Shivalik’s and the Terai region. It has a temperate climate in hilly regions, and tropical climate in plains with temperature ranging from sub-zero in the higher elevation regions to 43 degrees in the plains **(SFR, 2015**). The average rainfall in the state is 1550 mm (SFR, 2015). The major forest types are Tropical Moist Deciduous, Tropical Dry Deciduous, Sub Tropical Pine, Himalayan Moist temperate, Himalayan Dry Temperate, Sub Alpine and Alpine forests (**SFR, 2015).**

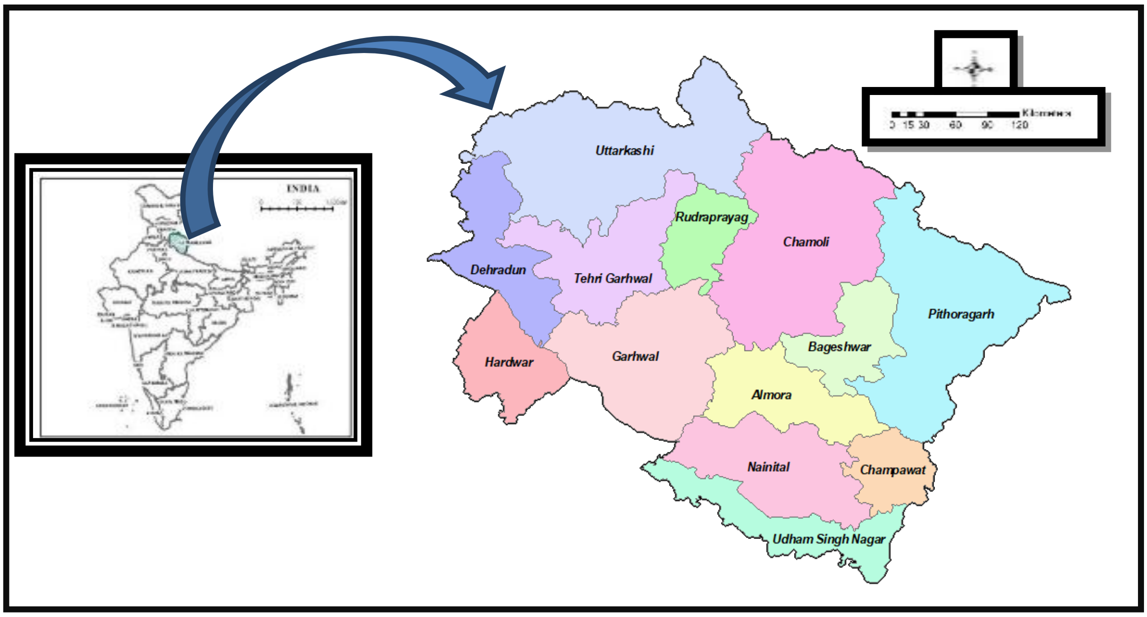

Figure 1: Study Area (Uttarakhand)

3. METHODOLOGY

The data sets for the present study comprises (i) Active fire points (2001-2017) from MODIS (Moderate Resolution Imaging Spectroradiometer) in the shapefile format from the given site (https://earthdata.nasa.gov/earthobservation-data/near-real-time/firms/active-fire-data).(ii) Simultaneously SRTM digital elevation model (DEM) have been acquired from USGS earth observation site. DEM have been used for the generation of elevation, slope and aspect map of the Uttarakhand. Finally, historical data of the fire points taken from the MOIS site overlaid on to the forest density, altitude, slope and aspect at district level to analyse relation of these factors in generation and spreading of the forest fire. Month wise data of forest incidences since 2001to 2017 have been look over to obtain the peak fire month and peak fire season. Considering fire incidence history in relation with the biophysical factors (slope, Aspect, elevation), a fire risk zone map has been modelled using the hotspot analysis in ARC domain for the study.

4. RESULTS AND DISCUSSION

4.1: Forest fire trend (2001-2017)

Spatial variation in fire counts based on MODIS active fire data from 2001-2017 for Uttarakhand and yearly variations shown in (Figure:2). An average of **1384** fires counts per year is recorded in Uttarakhand. The results indicate a notable outcome with the of trend four-year cyclicity in the forest fire occurrences. The highest frequency of fire incidences was recorded in the year 2016 (3353 incidences), 2012 (2800 incidences), 2008 (2229 incidences) and 2004 (1887 incidences). Only 343 points were recorded in the year 2001 while the 2017 show 916 points. Further, MODIS Aqua captured 77.3% of the fires relative to MODIS Terra with 23.6%, suggesting that most of the fires occur during the afternoon.

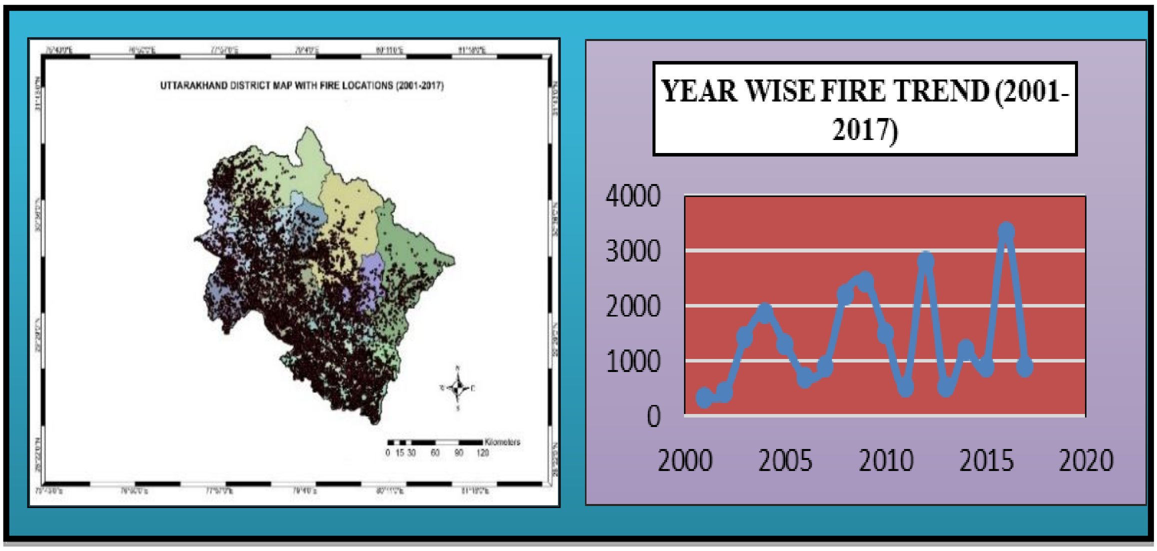

Figure 2: Yearly trend of forest fire incidences (2001-2017)

4.2 Forest fire distribution in different districts of Uttarakhand

Garhwal district shows strong number of fire incidences followed by the district Nanital and Uddhamsingh Nagar. Rudraprayag district shows the minimum number of fire incidences over last seventeen years. There is a strong occurrence of forest points in the lower districtsTerai belt in Nainital and Garhwal districts as compare to the upper districts, Uttarkashi, Chamoli and Pithoragarh areas (Table:1). The Garhwal district covers 18.65 % of incidences with only 5.72% of total geographical landmass. 15.45 % of fire incidences recorded for Nanitaldistrict which covers an area of 10.02 % in Uttarakhand. District Champawat covers only 3.30% of area and records 3.05% of fire points. While Uttarkashi with being the largest district covers 1757 points comprising only 7.47 % of the total fire records (Figure:3)

Table 1: Fire incidences according to different districts

District	Number of fire incidences	District area (km 2)	% of District area	%of Fire incidences
Almora	1746	3,083	5.72	7.42
Bageshwar	666	2,302	4.27	2.83
Chamoli	1667	8,030	14.90	7.08
Champawat	718	1,781	3.30	3.05
Dehradun	1158	3,088	5.73	4.92
Garhwal	4390	2,360	4.38	18.65
Haridwar	1140	3,860	7.16	4.84
Nanital	3635	5,399	10.02	15.45
Pittoragarh	979	7,100	13.17	4.16
Rudraprayag	565	1,890	3.51	2.40
TehriGarhwal	1791	4,080	7.57	7.61
Uddhamsingh Nagar	3322	2,908	5.40	14.12
Uttarkashi	1757	8,016	14.87	7.47
TOTAL	**23534**	**53,897**	**100**	**100**

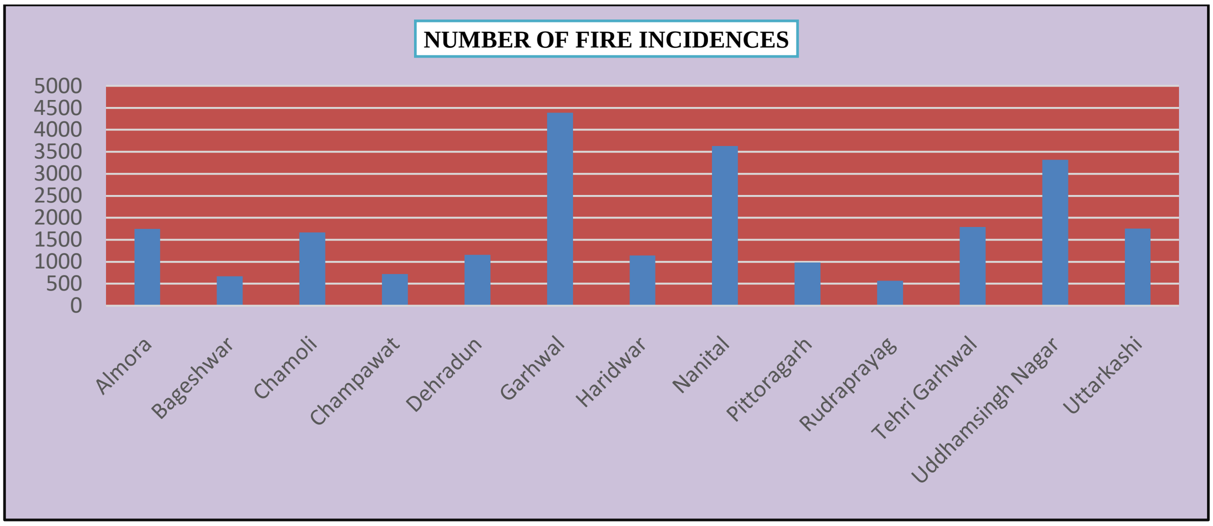

Figure 3: Trend of forest fire incidences according to the districts (2001-2017)

4.3 Seasonal forest fire trend

Fire season in India extends from October to June during which more than 70% of total fires are recorded with the peak during March .The maximum number of fires occurs in the month of April that amounts 7370 followed by month of May which holds 5597 incidences whereas month of June sums 2720.The minimum incidences occurred during the month of July august and September with only 37, 39 and 40 amount of incidences. While the month of December and January demonstrations only 1158 and1240 fire points. There is high litter content in the moist deciduous forest due to which regions of high density forests are extra prone to fire. Examination of relation between historical forest fire during different months shows that the month of April (peak fire month) is prone to forest fire followed by month of May and June. During summers dry condition and less humidity makes the preferable conditions for more fires. Less number of fire occurrences recorded during month of July, August and September as the area receives highest rainfall during these months. From October to February the study area experiences the winter season with low temperature hindering the forest fire incidences. Litter content again start increasing during the month of February due leaf shedding process in Shorearobusta.

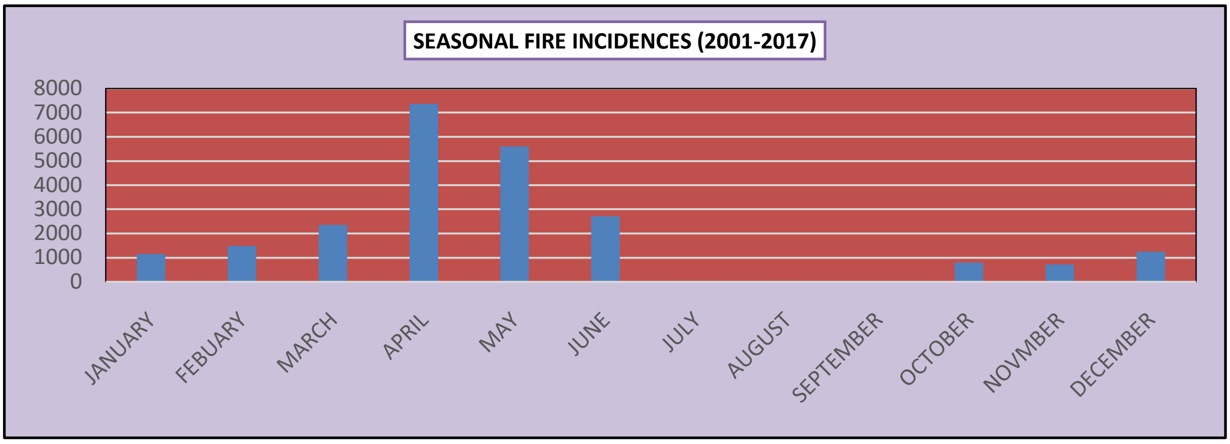

Figure 4: Seasonal trend of forest fire incidences (2001-2017)

4.4: Forest fire trend over slope, aspect and elevation

Along the various districts of the Uttarakhand state fire trend was observed for elevation, slope and aspect parameters. It has been observed that the fire incidence has no significant relation with the elevation in the present study. However, the indirect effect could be seen. We categorized the elevation model in to five classes from 185-7000 (m). The first-class ranges from 185-965 (m) with 11311 (48%) number of active fire points followed by class two 965-1942 (m) which comprises 902 points (3%), 1742-3154 (m) with 11092 (47%) number of points, 3154-4544 (m) with 221 (0.9%) number of points and last class counts only 8 (0.03% points that is from 2544-7000 (m) of elevation (Figure 5). The slope of the Uttarakhand (Figure 7) valley derived from DEM came out to be from 0-84 which was further categoric in to five classes (Degree slope). The class one intervals between 0-7 degree which constitutes 7498 which amounts 31% of the total incidences. The second interval class 7-18 occupies 4326 (18%) of points. The third class 18-27 amounts 5554 (23%) number of incidences. The fourth class 27-38 accounts 4880 (20%) of fire points. The last class 27-38 includes 1276 (5%) of numbers. The trend of fire over aspect expresses that the southern aspect comprises maximum number of incidences with 4006 (17%) points followed by the Southern west part with 3851 (16%) and south east covers 3407 (14%) points. North side includes 2187 (9%), North east 2416 (10%) of the points (Figure 6). It is observed that South and south west aspect is extremely disposed to fire incidence as these two sides aspects obtain more sunshine and consequently have lower humidity ‘s and higher fuel temperatures which creates favourable state for the forest fire. The study area is situated in the northern hemisphere which receives more sunlight during the month of April and May. Slope meaningfully effects the forward rate of spread of surface fires. The result shows that lower slope regions are more prone to fires due to two main factors (i) high litter content (ii) drier conditions (ii)high temperature.

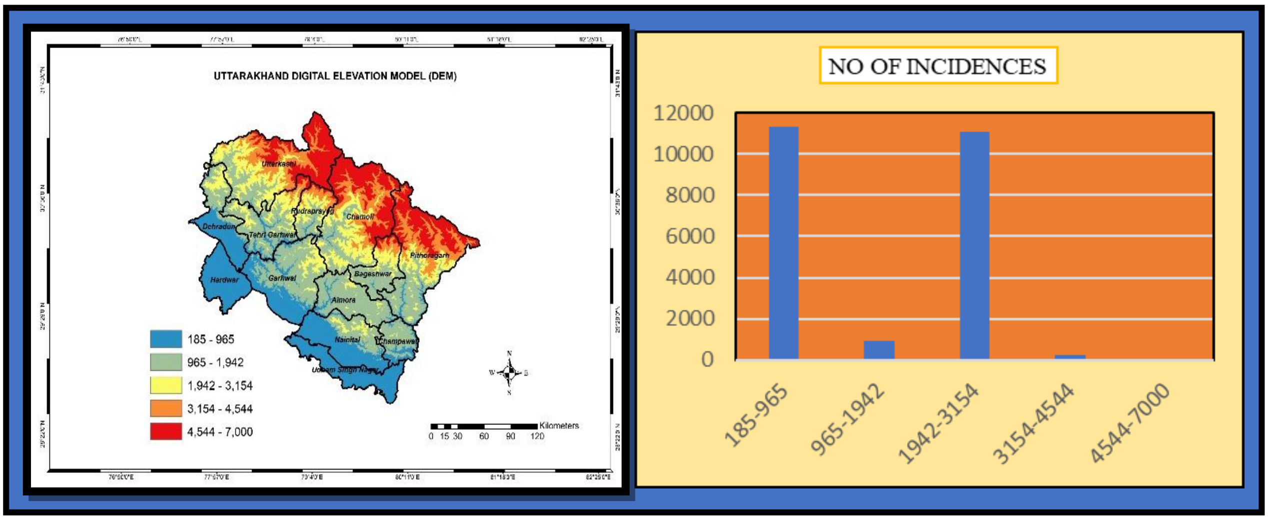

Figure 5: Trend of forest fire incidences with respect to the elevation (2001-2017)

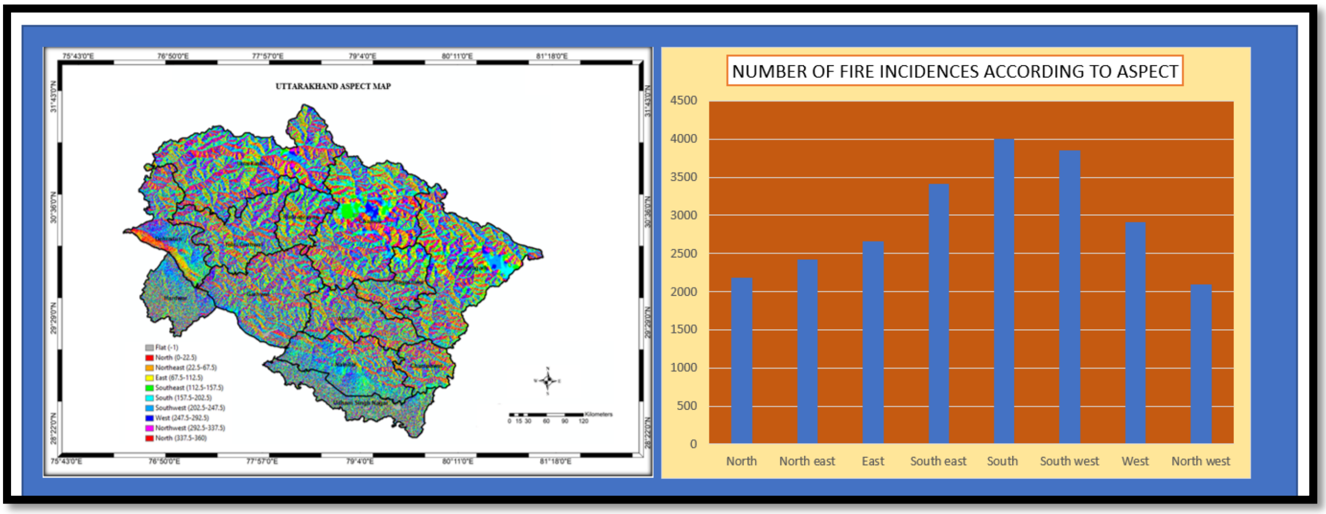

Figure 6: Trend of forest fire incidences with respect to the aspect (2001-2017)

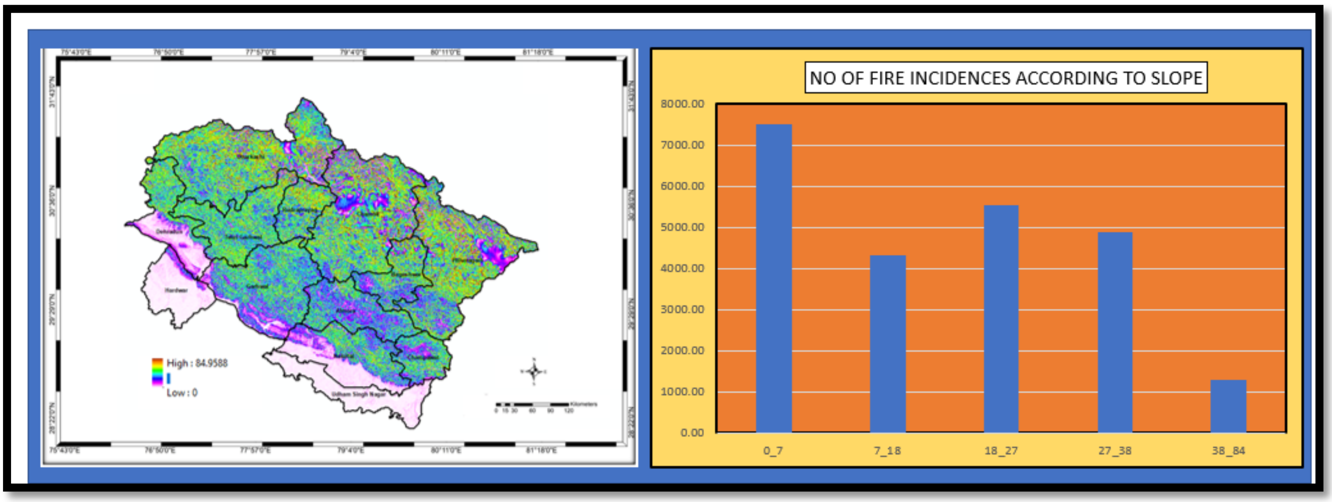

Figure 7: Trend of forest fire incidences with respect to the slope (2001-2017)

4.5: Hotspot Analysis

The tool when applied to historic fire dataset products six statically significant spatial clusters for 23534 number of fire points. Total 7091 cold spots which covers 30 % of the total fire data set. The analysis guesses total 4330 non-significant points which amounts only 18% of the total fire incidences as (Gi_Bin 0). The statically important hotspot occupies total 51 % of fire counts which amounts 12113 number of incidences. Out of which points 90 percent confidence level (Gi_bin 1) covers 489 (2.0%), 95 percent confidence level (Gi_bin 2) 1209 (5.1%) total 10415 points with 99 percent confidence level (Gi_bin 3) occupies 44.2 % of points (Table 2).Maximum statistically critical points cover 51 % of the entire dataset which is located over the lower terai belt. It occupies seven major districts that is Dehradun, Haridwar, Nanital, TehriGarhwal, Almora, Champawat, Uddahamsinghnagar and Gharwal with 49% of total geographical area of state (Figure 8). Of the diverse districts, extreme number of fires hotspots was recorded in Garhwal (32.3%) followed by Nanital (19.9%), Champawat (15.7%), TehriGarhwal (10.6%), (Table 3).

The result suggests that Garhwal district with only 4.4% of total geographic area records the maximum number of fire incidences. Nanital covers 10% of total geographical landmass but counts only 19/9% number of fire incidences. Analysis of fire counts based on elevation and slope range. These results recommend that maximum number of fires occurred in very low and low elevation types and in areas having very low to low-slope (Figure:7). Also, results clearly suggests that hierarchical nearest neighboring technique can be effectively used to detect 'hotspots' of fire clusters. These results obtained on fire characteristics will help resource managers and environmental scientists in identifying potential hotspot areas where fire management efforts can be focused.

The analysis suggests that most of the hotspots were recorded in lower regions with drier most conditions and high temperature as comparison to higher altitude districts. The lower terai belt is mostly covered by the shorearobusta which start shedding its leaves during February which in result accumulates more litter content and make areas more prone to fires.

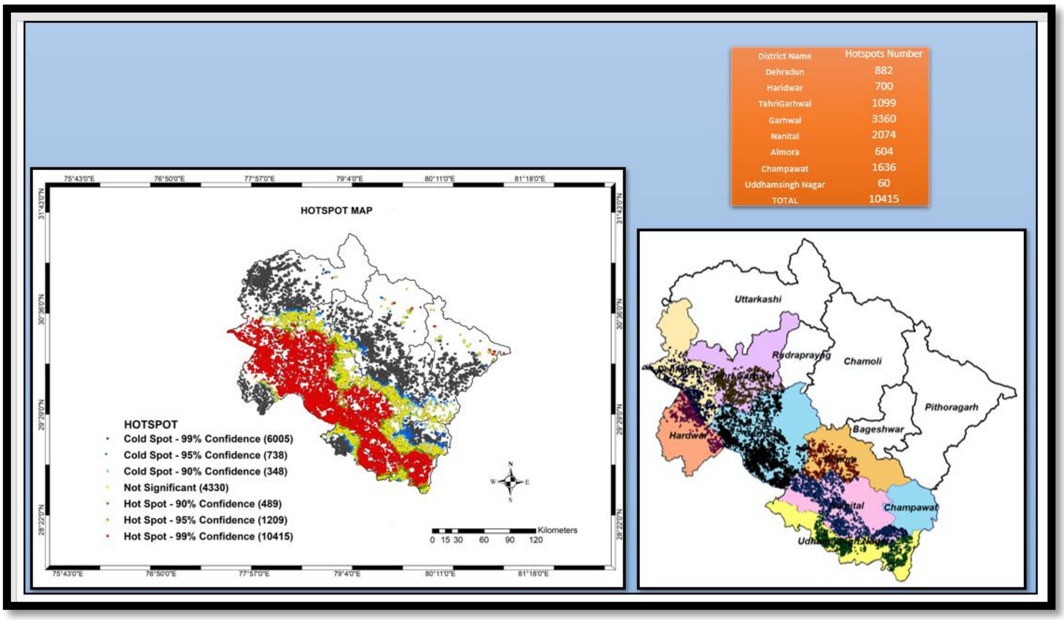

Figure 8: Hotspot map and the critical zones of fire occurrence

Table 2: Hotspot statistically significant values

Hotspot (Gi_Bin)	Statistical significance	Number of Incidences	% of Incidences
-1	90 percent confidence level	348	1.4
-2	95 percent confidence level	738	3.1
-3	99 percent confidence level	6005	25.5
0	Not significant	4330	18.3
1	90 percent confidence level	489	2.0
2	95 percent confidence level	1209	5.137248237
3	99 percent confidence level	10415	44.25512025
	TOTAL	23534	100

Table 3: Districts which occupies the critical hotspot

District Name	Hotspots Number	% of hotspot
Dehradun	882	8.47
Haridwar	700	6.72
TehriGarhwal	1099	10.55
Garhwal	3360	32.26
Nanital	2074	19.91

Almora	604	5.80
Champawat	1636	15.71
Uddhamsingh Nagar	60	0.58
TOTAL	10415	100

5. CONCLUSION

Our analysis suggests that clustering of fire points is an effective method for identifying fire hotspots from satellite contributions. The total geographical area of state is 53,897 km^2 out of which 49% of its area is most delicate to the fire risk zone. The cyclicity of four year indicates how the spatial distributions and temporal fire points are related with each other. The results obtained from this study on the spatial features of fire events have several ecological and management inferences with respect to topographical inputs. The southern aspect receives the maximum hotspots. Particularly in the month of April and May Northern hemisphere receives more sun light and the study suggest maximum number of fire incidences during these two months April May and Mid-June months are constituting summer season (the season of leaf senescence of the tropical and sub-tropical vegetation) with hot and dry weather condition. Clustering analysis fire zone mapping combined with the topographical factors influence the susceptibility of fire incidences. We infer that use of hotspot analysis and its spatial statistics is only the first step in exploring patterns of historic fire distributions in Uttarakhand. Since the study is an attempt to predict the basic fire patterns in different districts. This data base can be now successfully used to build fire probability models and hypothesis to understand the contributing issues of fire actions. The results are comparable with (Negi, et al., 2016) which indicates the threats of forest fires in Uttarakhand (Figure:4).The frequency of the forest fire incidences is higher in the areas having high forest fuel, low slope, high temperature and drier conditions. As the study has been done at district level, Garhwal and Nanital were subject to highest fire frequency. The results suggest that fire management in few districts of the state should be given importance which includes Garhwal and the Nanital. Extensive forest fire incidences during summer of 2016 dew wide attention of the forest managers and. This study attempts to provide estimates about forest fire damaged areas using satellite data and identification of fire risk zones. The result suggest that more fire lines and technical methods are needed to control fires in Garhwal and Nanitaldistricts. More scientific studies are required to control the spreading of fires. The GIS and remote sensing based techniques to establish historic datasets which cane helpful in management and conservation practices.

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