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Climate induced variation in forest fire using Remote Sensing and GIS in Bilaspur District of Himachal Pradesh

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Abstract- *Himachal Pradesh forests have frequent incidents of forest fires especially in the months of March to June which causes loss of forest wealth, biodiversity, ecology and environment. Due to the scarcity of a broad and efficient work to be acquainted with its fire-sensitive forest regions. Hence, the current study was carried out in Bilaspur district of Indian Western Himalaya to identify forest fire by overlaying geographical coordinates of weighted thematic layers such as elevation, slope, aspect, mean annual temperature, humidity, wind speed, accessibility to habitation & settlement and fuel map of the region. In the present study Climate induced variation in forest fire in Bilaspur District of Himachal Pradesh were estimated. The LISS 3 and ASTER DEM has been used for forest fire risk map, Forest density map, land use /land cover ,extraction of DEM features and other spatial object in which the topography of the area represents the forest type and various land forms of the study area. The fire-sensitive regions were further prioritized into very high, high, medium, low, and very low forest fire-prone areas. The Pinus roxburghii forest type, low elevation, high temperature, high slope, south-west facing aspect, May month and anthropogenic disturbances were identified as major factors responsible for forest fire in the region. The half of the forest cover was identified as fire sensitive.*

Keywords: *Forest Fire, Climate change, Remote sensing, climate parameters, risk, GIS*

Introduction

Forests around the world are expected to face significant pressure from climate change over the coming century. The impact of climate change are decrease in rainfall, increased dry spells and the resultant soil moisture stress which evident few cases of forest fires [1]. Forest fires have been causing very high economic loss, destruction of biodiversity and transboundary pollution mainly in the South and South East Asian region [2]. The fire incidence problem for South East Asia put the cost of damages stemming from the Southeast Asian fires (all causes) at more than $4 billion. Health impacts are often serious. As per one estimate 20 million people are in danger of respiratory problems from fire in Southeast Asia [3]. Economic costs are hard to quantify, but a conservative estimate by the Economy and Environment Program for Southeast Asia [4] put the cost of damages stemming from the Southeast Asian fires (all causes) at more than $4 billion. Forest fire season varies according to the location. In India most of the fires occur during the month of February to June. The impact of the fire is diverse on the forest ecosystem. Besides directly damaging the forest trees, the fire also adversely affects forest regeneration, microclimate, soil erosion, and wild life etc. In most of the cases, the forest fire causes retrogression of forest vegetation. As per the information compiled in GFRA- 2010, on an average one percent of all forests were reported to be significantly affected by forest fire each year. However, the areas affected by fires are severely underreported, with information missing from many countries. Forest fires in India are generally ground fires and about 95 percent of the forest fires are caused by human beings, especially to promote new flush of grasses, collection of minor forest produce or to prepare land for shifting cultivation. About 35 million hectares of forest area is affected by fires annually. Statistical data on fire loss states that the forest areas prone to forest fire annually ranges from 33% to over 90% in different states. The forest fire data of the year 1995 and 1999 in the two States- Uttar Pradesh and Himachal Pradesh where forest worth crores of rupees was turned to ashes during the period. The severity of the problem may be judged from the forest fire cases which witnessed a near 55% increase in forest fires in 2016, compared to the previous year, where total of 24,817 forest fire. The area of forests in Bilaspur district of Himachal Pradesh consists of pines and broad leaved forests. Here Chirpine is hard fire resistant, but still needs protection in the seedling stage. Forest fire management can be performed with the information derived from conjunctive use of

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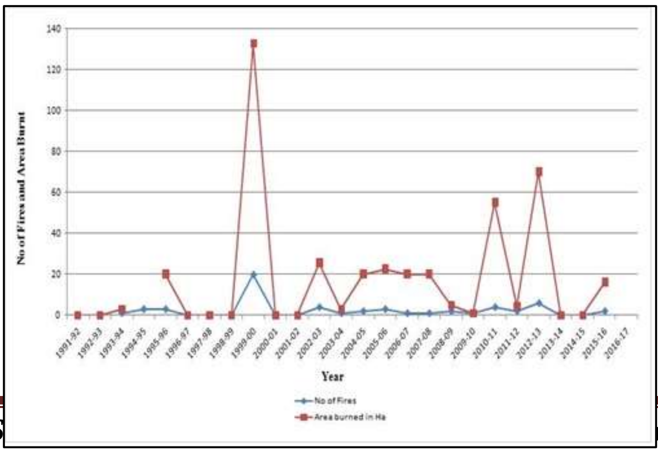
satellite remote sensing and GIS software packages. Scientists can efficiently manipulate, spatially analyze and display landscape variables which can support the management of forest fire [5-7]. Satellite remote sensing has become a primary data source for fire danger rating prediction, fuel and fire mapping, fire monitoring, and fire ecology research. Fuel-type maps from remote-sensing data can now be produced at spatial and temporal scales quite adequate for operational fire management applications. US National Oceanic and Atmospheric Administration (NOAA) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellites are being used for fire detection worldwide due to their high temporal resolution and ability to detect fires in remote regions. Results can be quickly presented on many Websites providing a valuable service readily available to fire agency. Furthermore, remote sensing provide regular observations allowing for regular updates of the fire situation [8-13]. Additionally, remote sensing has the advantage of presenting different spectral reflectance characteristics between the fire scars and healthy vegetation [14-18]. Current research aims at the role of climatic factors along with other parameters i.e. topographical and anthropogenic factors to develop a forest risk model using geospatial techniques. Finally prepare a forest fire management plan to reduce socio economic loss based on the fire risk map.

1. Study Area

Bilaspur District in the state of Himachal Pradesh is located at latitude 30˚15'16"N - 30˚35'16"N and longitude 76˚20'15"E - 76˚55'51"E. It has an average elevation of 673 metres (2208 feet). It lies at foot of Bandla Hills. The average annual rainfall of Bilaspur district is 1373mm. It lies near the reservoir of Govind Sagar on the Sutluj River. It is first major town after entering Himachal on way to Manali. It is hot in summer as it is situated in valley at lower altitude while surrounding mountains top experience pleasant weather and cold in winters. Monsoon brings plenty of rain from July to September. Best time to visit is October to November, during this time Lake is completely full and weather is also pleasant. Hottest months are May and June when temperature usually hover around 37-38^{0}C and sometimes for few days jumping to above 40^{0}C. Two types of soils are observed in the district i.e. alluvial soil and non-calcic brown soil. The rock formations occupying the district range in age from pre-Cambrian to Quaternary period. Rainfall is the major source of recharge to groundwater apart from the influent seepage from the rivers, irrigated fields and inflow from upland areas. The district has hilly terrain having very high slopes (Figure 1 and 2).



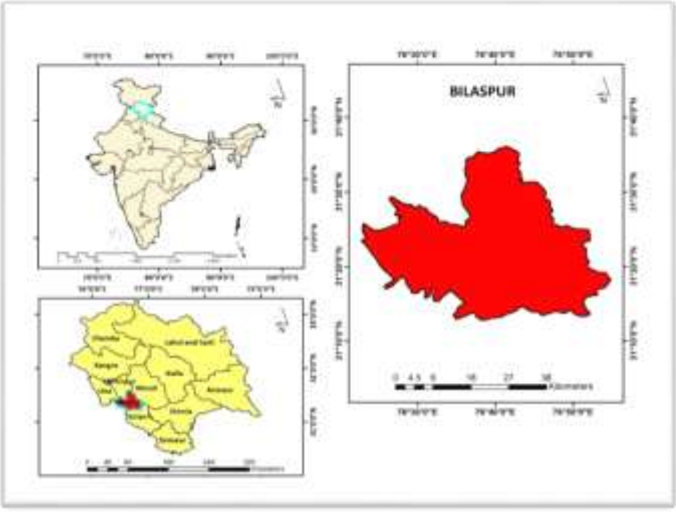


Figure1: Study area map

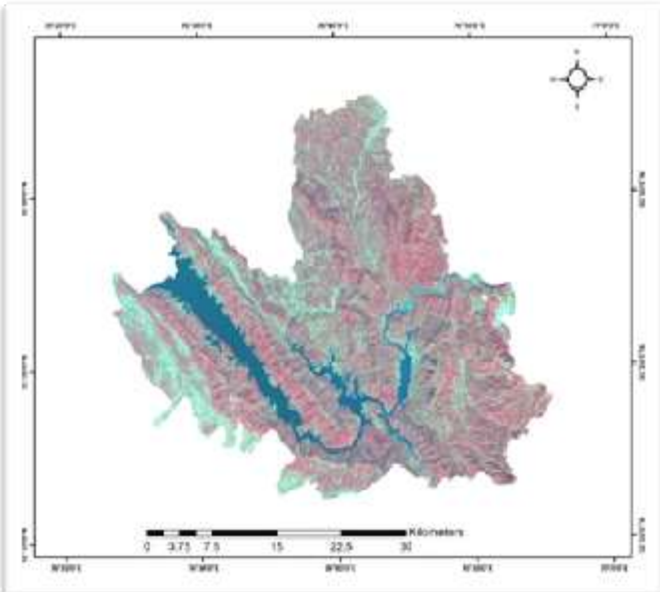
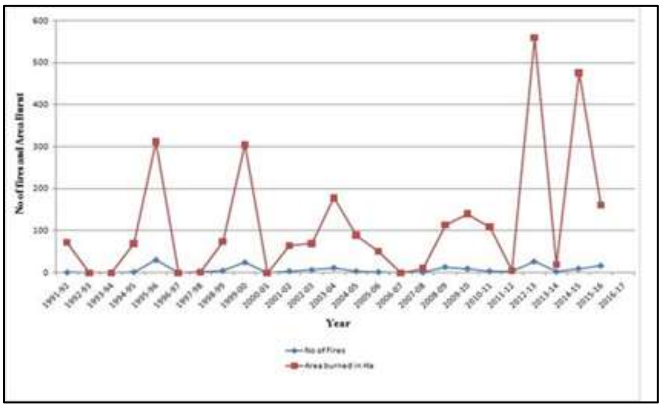


Figure 2: Satellite Map of Study Area IRS LISS-III 20 Oct 2010

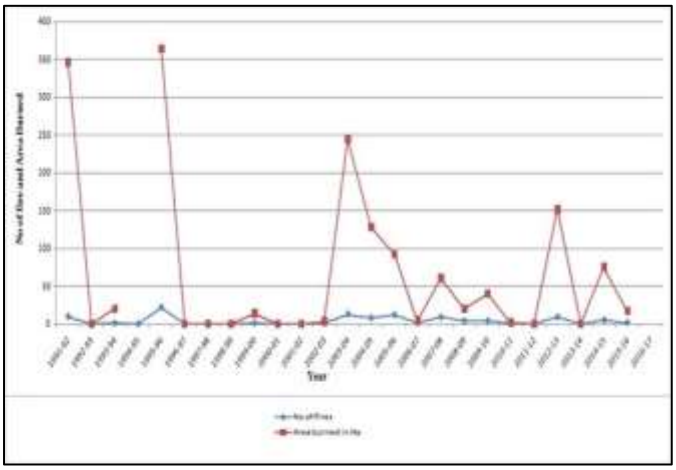
2. Data Used and Methodology

Study was done systematically to estimate the Forest type, Forest Density Map, Slope Map, Aspect Map, Elevation Map, Habitation Map, land use/land cover Map, Road map and all other important Value Map related to forest fire. Among all this climatic parameter shows an important role to show the relationship between the Climate variations in forest fire. The methodology applied for the research work in the study area can be categorized into three parts: Pre-field work, Fieldwork, and Post-field work. The entire methodology has been shown in the Fig.3. ERDAS Imagine 9.3, Arc GIS 10 software is used for image processing and to create the map layouts of the image. Instrument used GPS, Field notebook, Hypsometer, Measuring type etc. Field work is one of the main components in research for the ground truth and accuracy assessment of the maps. GPS device was used to collect the data such as elevation, Forest type and density and locating the forest fire villages. Apart from all this the various climatic data have been collected from Indian meteorological department (Figure 3 and 4, Table 1). Visual interpretation is done based on the spectral signature with the knowledge of the ground provides the keys to interpret a particular feature on satellite image or topographic maps in meaningful manner. The features such as forest type and density, LU/LC, various topographical aspects (slope aspect and elevation) road, settlement etc. based on interpretation keys.

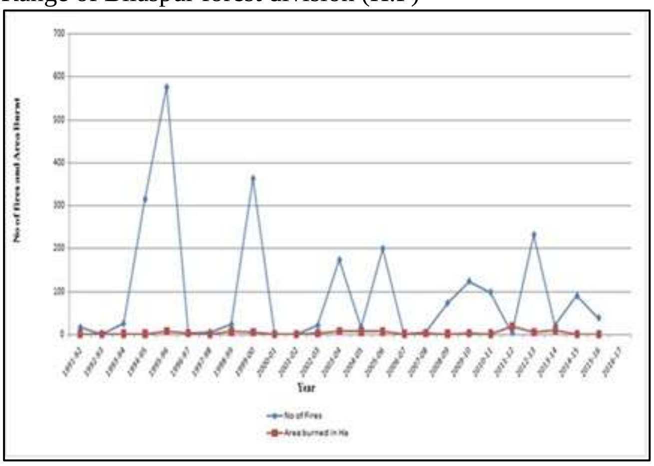
4a. No. of forest fire and area burned of Ghumarwin Forest Range of Bilaspur forest division (H.P)



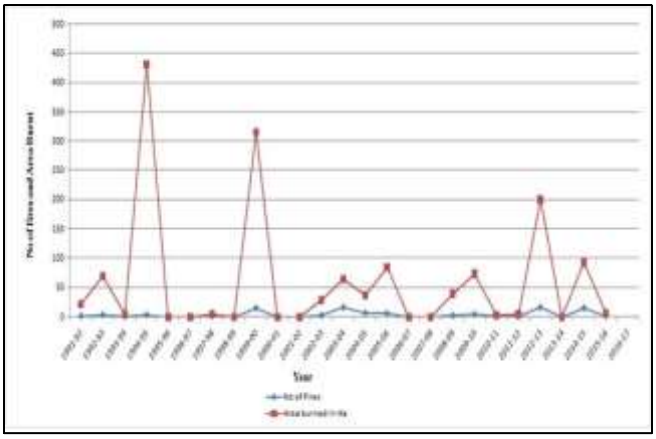
4b. No. of forest fire and area burned of Sadar Forest Range of Bilaspur forest division (H.P)



4c. No. of forest fire and area burned of Bharari Forest Range of Bilaspur forest division (H.P)

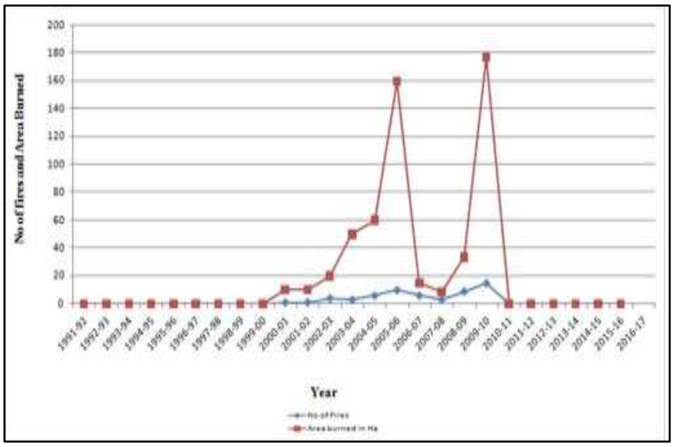


4d. No. of forest fire and area burned of Jhandutta Forest Range of Bilaspur forest division (H.P)



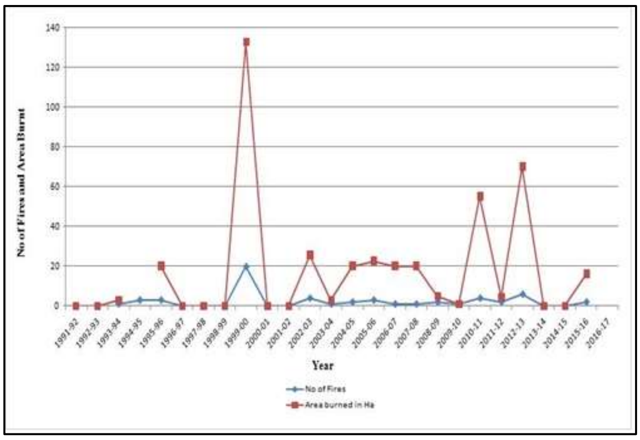
4e. No. of forest fire and area burned of Kalol Forest Range of Bilaspur forest division (H.P)

4f. No. of forest fire and area burned of Swarghat Forest Range of Bilaspur forest division (H.P)



4g. No. of forest fire and area burned of Naina Devi Forest Range of Bilaspur forest division (H.P)

Figure 4: Graphical Representation of the forest fire cases in various ranges of Bilaspur District



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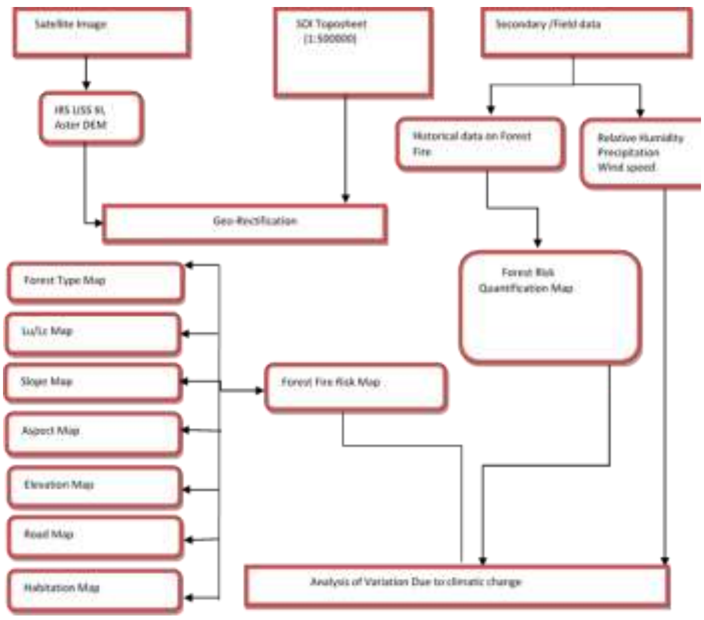

Figure 3: Methodology adopted

Table 1: Data sets used during the study

Satellite Data						
S. N	Spectral Resolution	Spatial Resolution	Temporal Resolution	Radiometric Resolution	Sensor Name	Maps
1.	0.52-0.59 (Green) 0.62-0.68 (Red) 0.77-0.86 (NIR)	23.5 m	24 days	10 bit	LISS III	LU/LC Forest type Road map
2.	0.52-0.59 (Green) 0.62-0.68 (Red) 0.77-0.86 (NIR) 1.55-1.70 (MIR)	56m	5 days	12 bits	Awifs	Slope Aspect Elevation
Secondary Data					Source	Maps
4.	Toposheet				SOI	Road Map Forest density
5.	Seconadary Data				Bilaspur forest division	Forest Type map Historical data

		Indian Meteorological Center(Shimla), NASA Power	Relative Humidity Precipitation Wind Speed

3. Result and Discussion

Forest fires represent one of the most critical issues in global change. The climatic parameter shows an important role in forest fire. They are responsible of several damages like loss of biodiversity, decrease in forests, increment in landscapes, soil degradation in the form of production capacity, increase in greenhouse effect, etc. In India 90% of the fire cases are caused by human beings. Only 10% cases are caused by natural processes. But also there are so many natural factors, above all summer drought, that strongly influence fire ignition and spread. The spatio-temporal statistical analysis of forest fires provided useful information for understanding lightning-causes of forest fire, improving fire occurrence prediction and fire management planning, for supporting investigation relating the role of forest fire in landscape processes, land-cover changes and degradation. Several studies were performed on this topic in order to specify the main features of fire dynamic and to model fire risk zones. The main objective of the study was to generate the forest risk zone map on the basis of all risk index layers (Aspect, Slope, Elevation, Road, Settlement, Forest Type) that are important input to evaluate forest fire risk map.

4.1 Generation of Thematic Layers

These layers are input layers to generate model that are, forest type, slope, aspect, elevation, LU/LC, road and habitation were generated and used in the process of multi criteria fire risk zonation map. Here some following figures are given that shows area distribution for each layer (Figure 5-10).

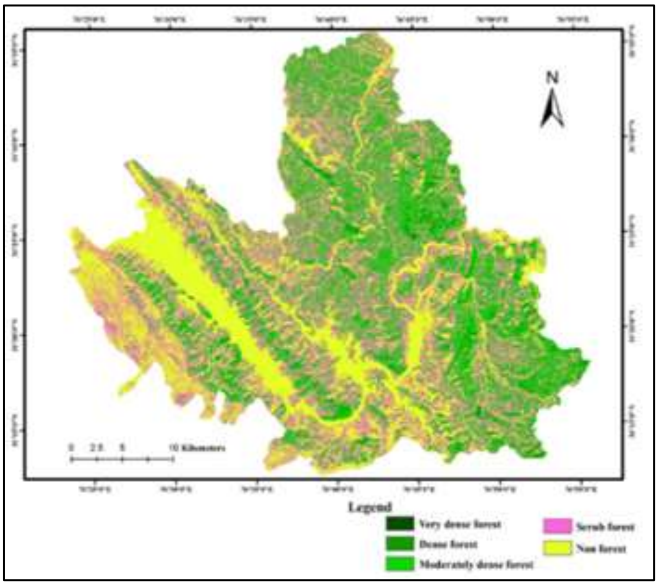

Figure 5: Forest Density Map

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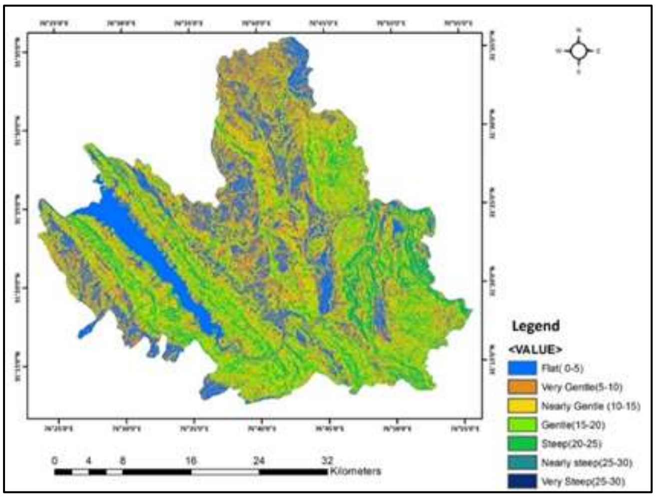

Figure 6 Slope Map

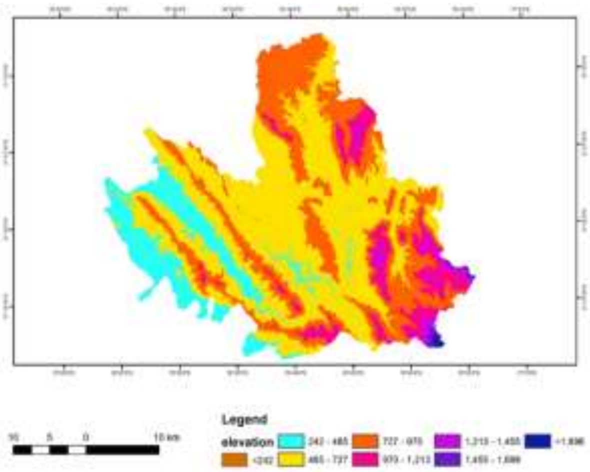

Figure 7 Elevation Map

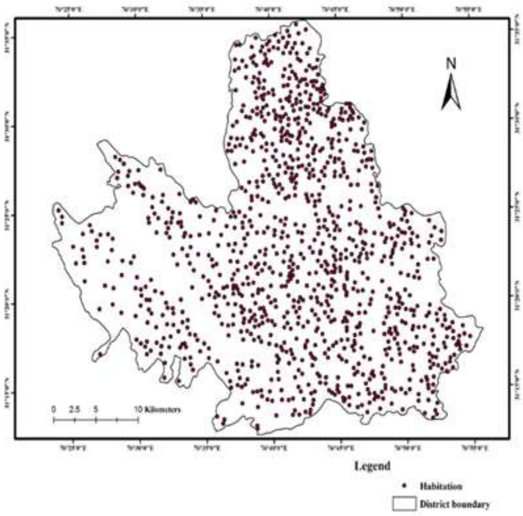

Figure 8 Habitation Map

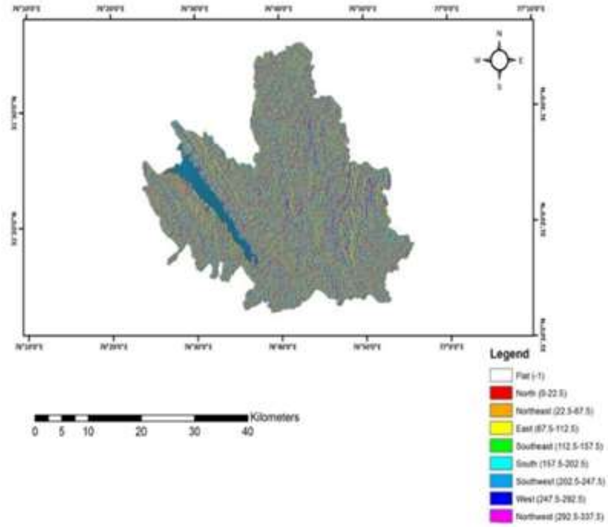

Figure 9 Aspect Map

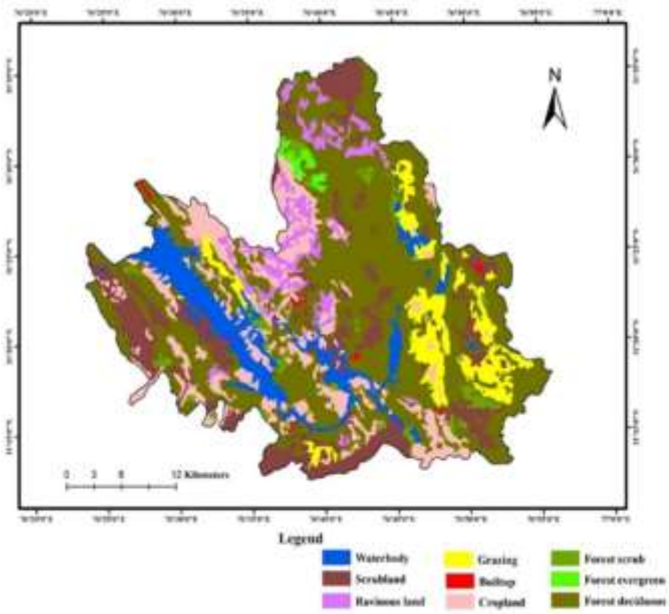

Figure 10 Land use/ Land cover Map

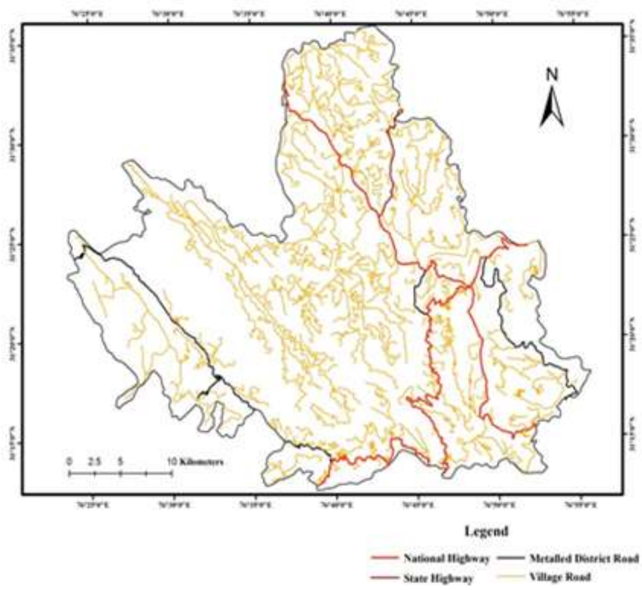

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Figure 16: Road Map

4.2 Climatic data

With the help of various sources and NASA power website we have collected various climatic parameter such as Relative Humidity, Precipitation, and Wind speed. After collection of all the dataset we have do some of the analysis part over it. The dataset which was downloaded from the website from the year 1991-2015 and the value of Relative humidity, Precipitation and Wind speed was obtained and then the average value was evaluated.

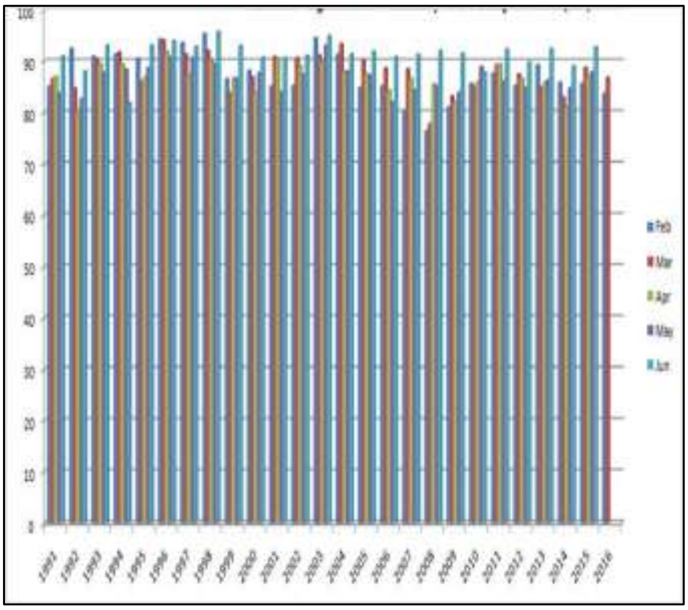

Figure 11: Chart showing the Relative Humidity of Bilaspur District (H.P)

Relative humidity was find out afterwards we average the whole value of the month from February-June of Various point map have been done (Figure 11). Now the average value of the data has been observed and various Graphical data have been plotted over it. The study area is having very low Wind speed from the month February-June. Generally it has been seen that the value is below 10m/s which means there is dry weather which is favorable for the forest fire cases in that particular region. The wind speed graph is shown in figure 13. The average value of various point maps have been consider and the average value of the month have taken. On the basis of climatic parameter which plays an important role in forest fire cases. The graph of the Precipitation is shown in the figure 12.

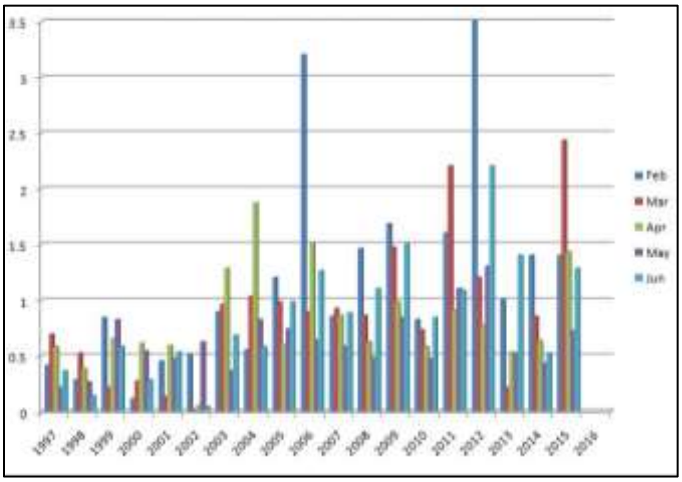

Figure 12: Chart showing Precipitation (mm) of Bilaspur District.

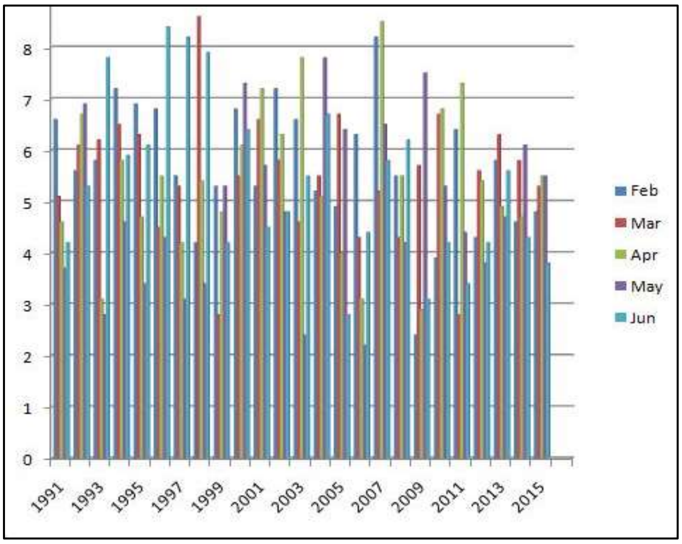

Figure 13 Chart showing the Wind Speed (m/s) of Bilaspur district.

4.3 Forest Fire Risk Map

In the study are the forest-fire case are generally been seen in the areas where there are high terrain and the forest density in that particular location is seems to be very dense. Besides all these parameter the climatic parameter plays an important role. We have concluded the Relative humidity; Precipitation and Wind Speed data from which we correlate it with forest fire cases and finally get the quantification of Map and then it has been seen that when there is less amount of Relative humidity and the Precipitation is low in the study area then there are chance of occurrence of forest fire. From the map it is seems to be that major areas of the Bilaspur Forest division is Moderate risk. As main objective was focuses on finding the relationship between the climates induced variation in forest fire. For that we have to find the forest fire risk zone map and forest quantification map. And at last prepare the management plan for forest fire using geospatial techniques. For achieving results, a step wise work was carried out; image processing and visual interpretation techniques. Important base layers are forest type map, forest density map, slope, aspect, elevation, road, habitation, land use/ land cover. With the use of remote sensing and GIS we can easily delineate the area which are more prominent to high risk Forest fire prone areas. But

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overlaying all the base layers we can easily delineate that whether the climatic parameter plays an important role in the forest fire risk zone map.

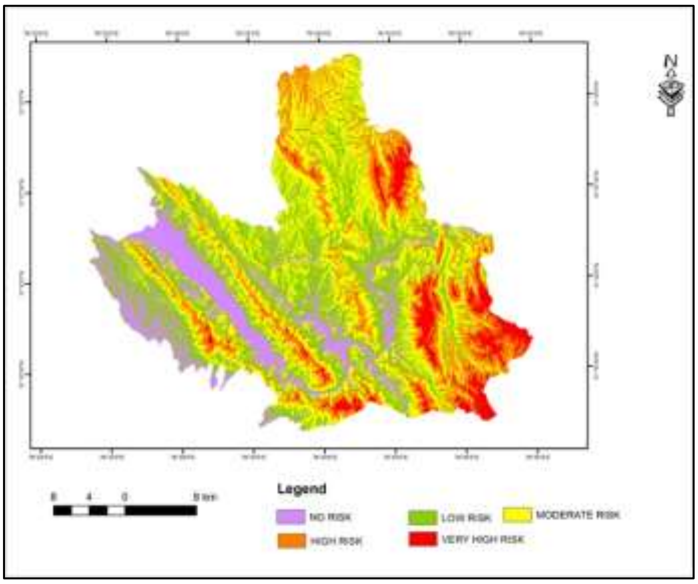

Figure 14 Forest Fire Risk Map of Bilaspur forest Division.

Forest Fire Risk Zone	**Area(km^2)**	**Area in %**
No Risk	179.8	14.92
Low Risk	354.0	29.38
Moderate Risk	382.6	31.75
High Risk	213.4	17.71
Very High Risk	75.1	6.23

Table 2 Forest fire Risk zone

The Map shows that the area covered by high terrain shows that it is more prominent towards the forest fire cases and climatic parameter such as the Relative Humidity, Wind Speed, and precipitation is an influencing factors among all these. At the output of the Forest Fire Risk Map there are 75 km^2 area which are categorized under Very High Risk prone areas (Figure 14, Table 2). On the behalf of the results of this study the suggestions and recommendation can be given to the forest department for the fire management in the future, and can be suggested for the enhancement of existing conventional fire control system. Model provides a clue for estimating the loss of forest resources, if wild fires occurred unexpectedly.

4. Conclusions

Forest is the major concern for the degradation of natural resources in huge amount and human beings are directly or indirectly dependent on the natural resources. So from last few years forest fire received the public attention globally due to their significant short and long-term threat to forest ecosystem and to public safety and property. Major reasons for the occurrence of forest fire are basically human interference but somewhere climatic parameter play an important role between them. In the study we have concluded the Forest density map in which the topography of the area represents the forest type and various land forms of the study area. According to the topography there is gradual change in the vegetation type pattern above 1000 m elevation. Pinus roxburgii (chirpine) are the main species. These type of species are having high amount of resin which is highly inflammable and causes forest fire in the Himalayan region. Further southern and more or less western aspect has more dry forest type that these aspects receive more sunlight. Moist forests are present in northern aspect and very close to settlements that is also a severe region for the occurrence of Forest fire. In the study southern and western aspect is having more dry and mixed type forest that are having minimum chances for the occurrence for forest fire. More fire breaks in the south western direction as the sun rays directly falls on the slopes facing south and south-west and the forest type in higher slopes along this direction were dry in nature, which is more vulnerable to forest type. The slope map was generated from the digital elevation model using ASTER data. During fire season (May-June) the area receives heavy wind and high slopes plays very important role in the spread of fire. The study area is having elevation in between 242 m to 1698 m. There are so many anthropogenic factors as well as many inflammable materials that are leading to the forest fire. In the study area it has been seen that most of the habitation are on along the road. Buffer intervals are 100 m that takes during the generation of buffer along the roads. First 0-100 m buffer is assigned maximum weight age for the forest fire, as it goes far from the road vulnerability is going to decrease as per the distance. Habitation is also an important cause of forest fire due to which the some climatic parameter plays a side role in it. In the land use/land cover map of study area major portion of the land are covered by the forest area. The forests are of the types of the deciduous, evergreen and scrub but the major areas are covered with the deciduous. The naina devi forest Range is having the reserved as well as unreserved forest area which is concluding Govindsagar lake. There were cropland areas between the forest areas of Bilaspur forest division. Besides all these parameter the climatic parameter such as Relative Humidity, Precipitation, Wind speed have been considered. And it have been seen that these parameters plays an important role in the forest fire cases. Relative Humidity has been observed highest for the following years i.e. 1996, 1998 and 2006 while in 2008 it was lowest. It has been seen the value of Relative Humidity lies between 80-100. In case of Precipitation data it has been seen that the study area the highest rainfall is 3.5mm in the year 2012.While the lowest is 0.1mm in the year 2002. Inspite of all this the rainfall seems to be influent throughout the year. It receives very less amount of rainfall so the weather seems to be dry which is supporting factor of forest fire. As wind speed play an important role the graphical data shows that the wind speed is below 10m/s which is showing that the wind speed is very low in the areas where there is high forest density. In the year 1999, 2007, 2009 it has been seen that there is low wind speed. Lastly we overlaid all the climatic data with the various base maps and it has been seen that the Bilaspur forest division have the majority of the portion of the forest area comes under the Moderate Risk zone and the area of moderate risk zone is 382.6km^2 and 179.8 km^2 areas are having the high no risk zones while 75.1km^2 areas comes under the high risk zone. As a general remark, it should be noted that policy maker and citizens should not just react where severe fire events occur.

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