Spatial-Temporal Analysis of Wild Fires in Azad Jammu Kashmir using GIS and RS Techniques

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Remote Sensing and GIS

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Of

MS Geographic Information System and Remote Sensing

Thesis Supervisor:

Dr Muhammad Azmat

Thesis Supervisor's Signature: ___________________________________

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I, **Tauqeer Ahmed**, declare that this thesis and the work presented in it are my own and have been generated by me as the result of my own original research.

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ACKNOWLEDGEMENTS

I am very grateful to all the people and the institutes that would be contributed in the making of this research possible and successful direction. Encouragement had led the completion of this research. I feel overwhelmed to show my appreciation for my supervisor, Dr. Muhammad Azmat (Assistant Professor IGIS-NUST), for supervising, guiding Also special thanks my Guidance Examination Committee (GEC) members Dr. Ejaz Hussain (IGIS-NUST), Dr. Muhammad Fahim Khokhar (IESE-NUST) and Lecturer Junaid Aziz Khan (IGIS-NUST). Their valuable advices and comments that facilitated me the improving my research and taking it into a right way.

Secondly, I would be delighted to thankful to Mr. Chaudhry Salman and Wildlife & Fisheries Department of AJK that provided the wildfires data and very helpful information about that study area.

Last but not least, I please to acknowledge my family and friends to support for show to me their love, support and wishes.

Tauqeer Ahmed

Dedicated to my family

and

Assistant professor (r) Nasrul-ul-Haq

to support for show to me their love,

support and wishes the through out of

my educational time period.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
MODIS	Moderate Resolution Imaging Spectroradiometer
HCW	Human-Caused Wildfire
FRI	Fire Risk Index
AJK	Azad Jammu & Kashmir
KM2	Kilometer Square
NDVI	Normalized Difference Vegetation Index
VI	Vegetation Index
OSM	Open Street Map
VIIRS	Visible Infrared Imaging Radiometer Suite
RH	Relative Humidity
DEM	Digital Elevation Model
FIRMS	Fire Information for Resource Management System
NASA	National Aeronautics and Space Administration
LOC	Line Of Control

ABSTRACT

Nature can’t be controlled but it is possible to map the forest fire risk index which can minimize the frequency of fire. Wildfire is one of the key of environmental hazards. The wildfire poses huge threat to human lives, health, economy, and biodiversity. In this study the MODIS active fire events data were used from 2014-2020 for temporal analysis along with computing the Fire Risk Index (FRI) and identifying the risk zone in Azad Jammu Kashmir (AJK), Pakistan. AJK is mostly mountainous area, only the southern part very low altitude. Eight factors including (Land cover, elevation, slope, aspect, temperature, relative humidity, proximity to road and settlement) were used for the FRI. After assigning the different weight to all the responsible factors make FRI map for study area. It noticed that the partially flat areas with less slope and very low relative humidity were vulnerable for fire events with raking high to very high. Moreover, high altitude areas having better RH causing risk ratings from low to very low. Second main reason is dry weather, as RH is low due to less precipitation. The southern part of AJK were highly vulnerable high risk level, while the northern part of AJK were low to very low in risk class map. The frequency of fires was higher during the years of 2016 and 2018, most of the fires (51%) occurring during the pre-monsoon season (May–June) when the weather is hotter and drier, also the ground data is analyzed the maximum fire events in these months. Furthermore, validation was carried out by overlaying the MODIS data and available ground data from Wildlife & Fisheries Department of AJK. The validation results showed 68% fire events of ground data occurred in High risk class and 13% in in moderate class, when MODIS active fire events overlaid, 56% in high and 23% in moderate risk class.

INTRODUCTION

Pakistan is a forest poor country with less than 6% of total land falls under forest category. In Pakistan there is 0.03 ha of the forest per capita as compared to global 1 ha of average. According to survey under Red Plus program, the Azad Jammu and Kashmir the highest forest cover at 36.9 per cent, followed by Khyber Pakhtunkhwa (20.3 per cent), Islamabad (22.6 per cent) and Federally Administered Tribal Areas (19.5 per cent). According to Forest, Wildlife and Fisheries Department Azad Jammu Kashmir around 42.62% of land falls under Forests. Three types of forests species are found in Azad Kashmir; named as Montane Sub Tropical Semi Evergreen Forest, Montane Temperate Forests and Sub Alpine Forests and Alpine Scrubs (AJ&K.,2013). There have been various studies for deforestation and land use/ Land cover changes for Azad Kashmir but there have been no studies regarding forest fires destruction and identified any risk zone in Azad Kashmir. Wildfires have been reported in electronic and print media frequently. Among many there is a story cover by "GNN" news in June,2020 about forest fire in Mirpur District which span in more than 10 km of area (Forest Fires in Samahni Valley in Azad Kashmir| GNN | 19 June 2020, 2020). Similarly, In June 2018 Azad Kashmir prime minister took notice of uncontrolled wild fire in Kotli district and suspended several forest officers, this story was covered by The Nation news (AJK PM Seeks Report on Jungle Fire Incident, 2018).

Azad Kashmir floral and faunal diversity is well known as a variety of mountain ecosystems. Due to various anthropogenic and natural pressures these ecosystems are vulnerable to global warming and are under greater stress. Different vegetation types distribution ranges are being changed due to this climate change. Local livelihoods and income of state of Azad Kashmir is largely dependent upon forestry and forestry products. These forests are major source of construction timber for local households and infect for whole Pakistan. Over 90% of people of Azad Kashmir depend upon these forests. Beside wood products forests provide residents with tourist attractions, medicinal plants, wildlife, grazing, job opportunities and most importantly revenue to state of

Azad Kashmir (FAO,1977). But overall situation of forest cover in Azad Kashmir is grim as the state of Azad Kashmir is losing its forest cover. Beside illegal loggings and deforestation, wildfires are one of the notable factors contributing to the deteriorating forest cover in Azad Kashmir (Rashid et al., 2015).

MODIS fire product work on absolute detection of fire strategy which means when the strength of fire is enough to be detected in MODIS sensor. This detection is relative to its background (to account for reflection by sunlight and variability of surface temperature). MODIS fire products include fire irradiative power, detection confidence, the logical criteria used for fire selection, fire location, fire occurrence (night/day) and numerous other layers describing fire pixel attributes. The detecting changes in fire distribution, changes in relative strength, changes in frequency of fires, monitoring spatial and temporal distribution of fires in different ecosystems and identifying new fire frontiers. At mid-latitudes MODIS data is acquired daily at Aqua and Tera platforms. This four times a day data acquisition fulfills demand for operational fire management need along with global fire monitoring of climate, atmosphere and ecosystems (Justice et all.,2002).

Azad Kashmir the largest percentage of forest area in all of the provinces. Local livelihoods and income of state of Azad Kashmir (over 90%) is largely dependent upon forestry and forestry products. Thus, Study of wild fires and percentage area affected by it is of much importance for policy makers as forests are essential to maintain economy, biodiversity and climate. In this study for identify the fire risk index eight factors were used in the FRI.

1.1. Background

Pakistan is a forest poor country with less than 6% of total land falls under forest category. In Pakistan there is 0.03 ha of the forest per capita as compared to global 1 ha of average. According to survey under Red Plus program, the Azad Jammu and Kashmir the highest forest cover at 36.9 per cent, followed by Khyber Pakhtunkhwa (20.3 per cent), Islamabad (22.6 per cent) and

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In recent years' forest fires have gain eye of the researchers around the world. Thousands of hectares of forests are destroyed by fire alone in the world. International communities have been busy in establishing link between forest fires and climate change. The spreading of a forest fire can impose a threat to the natural coverage of land and the safety of the population. Early detection of forest fires is essential in the reduction of fire damage. Pakistan is one the most vulnerable country to climate change in the world.

Forest fire risk zones are 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 decision on solutions can only be satisfactory when a fire risk zone mapping is available (Jaiswal et al, 2002).

The population density of 320 persons per km and a population of 4.3 million in 2013 in Azad Kashmir. Mainly people live in rural communities and their professions are livestock, agriculture, and the highest workforce work in forestry and forestry-related products. Azad Kashmir is blessed with rich and diverse forests. About 42.6% of land cover falls under forest. Due to its hilly terrain, Azad Kashmir forests exhibit altitudinal zonation of plant communities. Major forest types include Scrub, Sub-tropical, Conifer, and Temperate, Alpine, and Sub-Alpine (Mahmood et al., 2011).

In Azad Kashmir over the year's persistent droughts due to climate change have adversely affected natural regeneration and afforestation programs. Similarly, planting targets during spring and monsoon have been missed and plant mortality rate seen a considerable rise due to continuous dry spell. This paved way for different fungal diseases. Recent beatle and termite infestations in

Azad Kashmir have considerably affected pine forests attributed to climate stresses. This situation over all increased dryness and caused rapid increase in forest fires over the period in Azad Kashmir (Ajaib et al.,2014).

Large amounts of particles and trace gases are emitted by biomass fires these emissions are responsible for greenhouse gases and changes in atmosphere. Along with greenhouse gases wildfires emit large amounts of photochemical reactive compounds, coarse and fine Particulate Matter (PM) which decreases visibility, lowers biodiversity, destroys ecosystems, increase air pollution, affect health and environment, and most importantly destroys much needed forests composition (Langmann et al., 2009; Lapina et al., 2006; Simpson et al., 2006).

Forest fire risk zones are 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 decision on solutions can only be satisfactory when a fire risk zone mapping is available (Jaiswal et al, 2002).

Cause of climate change and resulting extreme weather conditions can be debated but there is a collective consensus among international community about the well-being and health impacts of climate change across population masses around the globe (Berrang-Ford et al., 2015; Kjellstrom et al., 2016; Thornton et al., 2014; Wu et al., 2016).

Wildfires influence climate change both directly and indirectly. Directly in terms of aerosols and greenhouse gases emission and indirectly by secondary effects on atmospheric chemistry e.g., cloud microphysical properties and processes, aerosol, ozone (O3) formation) and visibility reduction (Lohmann & Feichter, 2005; Naik et al., 2007).

Identified that climate change and land use/land cover (LU/LC) changes over the last few decades have strong influence on fire cycles. This contributed to increase in fire frequency, severity, total burned area and size (Liu et al., 2013; Westerling, 2016; Westerling et al., 2006).

Due to management and climate transformation, it has been observed that fire characteristics (arrangement, accumulation, moisture and size) are changing; fostering favorable conditions for both fire ignition and fire propagation (Pausas and Fernandez-Munoz, 2012 and Chuvieco et al., 2009).

Consequently, wildfires pose huge pressure on environmental, economic and human systems in surrounding and downwind regions of the burn zone. Regional air quality and subsequent human health degradation cannot be over seen (Liu et al., 2015; Reid, Jerrett et al., 2016). Smoke from wildfires contains harmful compounds which are not even found in urban settings in normal conditions (Alves et al., 2011; Kim et al., 2018; Na and Cocker, 2008).

1.2. Objectives

The objectives of the study are as below:

i. Temporal and spatial distribution of forest burned in region of Azad Jammu Kashmir (AJK).

ii. Identifying fire risk zone using parameter responsible to the forest burning (Wild fire, Manmade, Meteorological etc.) with Fire Risk Index in the study region.

1.3. Scope of the Study

Wild fires have adverse effects on economy, human health, air quality, and environment and most importantly on forests. As Azad Kashmir the largest carbon stock of all the provinces in Pakistan it is important to access damage done by wild fires through this study. This study would have applications in many fields; some of them are as follow:

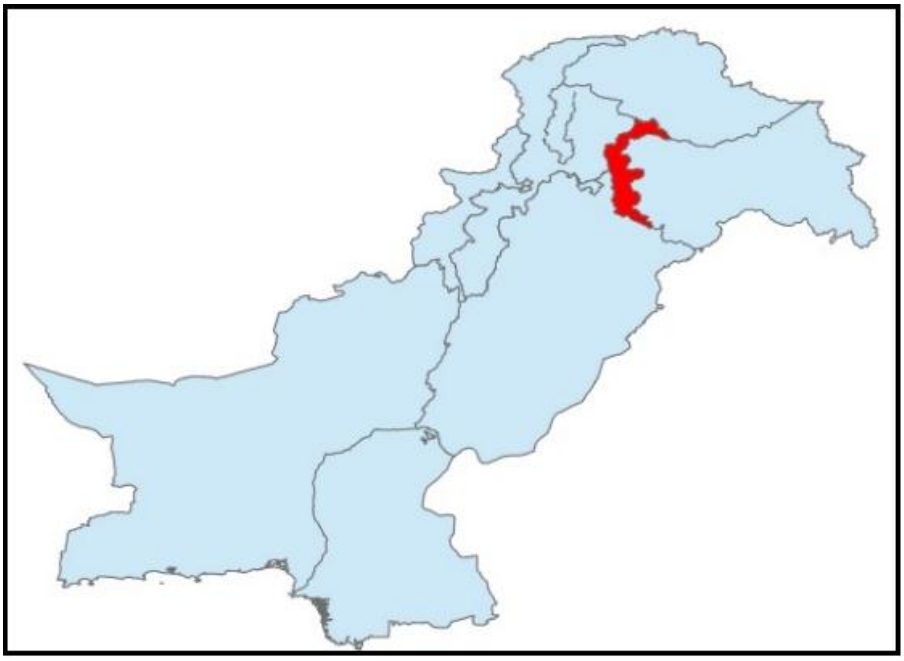
- Public health Surveillance
- Environmental protection agency
- Spatial epidemiology
- Forest Conservation
- Research Journal Publication

MATERIALS AND METHODS

2.1 Study Area

For the proposed study state of the Azad and Jammu Kashmir is selected as the study area, (Figure 1). The state of Azad Jammu & Kashmir, total area of 13297 km2. Geographically it lies between longitude 73°– 75° and latitude 33° – 36°. Altitude variation in Azad Kashmir is from 360 m to 6325 m. Azad Kashmir has rugged, deep ravines and undulating terrain and it is characterized as having mountainous topography. It falls under the Himalayan orogenic belt. Administratively Azad Kashmir could be divided into two the geographical regions, Northern mountain region Sudhnoti, Poonch, Haveli, Baagh, Hattian, Muzaffarabad, and the Neelum Districts and southern plain region Bhimber, Mirpur and Kotli Districts. (Bano et al. 2013).

Despite its relatively small size Azad Kashmir has diverse climate types. It has extreme snow deserts in the north and it is divided into climate zones of cold temperate, very cold temperate, sub-humid sub-tropical to moist-temperate. Main rivers are Poonch, Neelum and Jhelum. Azad Kashmir has high-temperature variation having maximum and minimum temperatures of 40C and 20C respectively. Its annual mean precipitation ranges from 800mm to 1600mm. its snow line is at 1200 meters in winter and this snow line rises to 3,300 meters in summer. Azad Kashmir has 4.9 cubic km of ice reserves mainly in the Neelum valley. In total there are 224 glaciers with an average thickness of 24 meters and a total area of 109 km. Moreover, there are about 76 glacial lakes in Azad Kashmir with a total area of 545 ha (Khan et al.2012). Study area of Azad Jammu Kashmir was selected. (Figure 1).



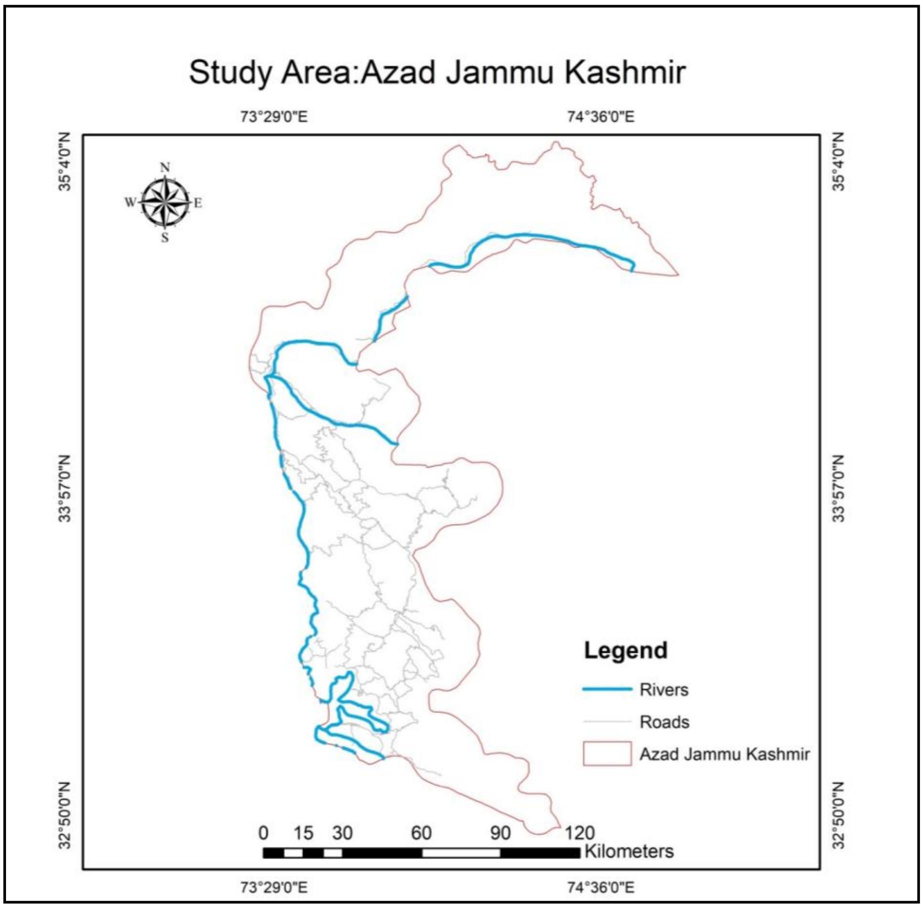


Figure 1. Study Area map – Azad Jammu & Kashmir.

2.2 Data sources, quality and limitation

Collectively for this study datasets were used which are wildfire point data, DEM, Soil Moisture, Precipitation, Relative Humidity, and Temperature. NASA has an active fire program named “The Fire Information Resource Management System” (FIRMS). Distribute near the real time data regarding wildfires within three hours of satellite observation from both Visible Infrared Imaging Radiometer Suite (VIIRS) and the Moderate Resolution Imaging Spectroradiometer (MODIS). For the present study MODIS active data fire events used.

Vegetation index for land cover, used Landsat 8. For slope and aspect, used digital elevation model. Landsat 8 and DEM were downloaded from the earth explorer USGS site. Road and settlements as vector data from Open Street Map (OSM).

Meteorological parameters of precipitation, temperature, and soil moisture are also taken into account for the present study to see whether the wildfires have any relation with them. This data in the form of net.CDF files is available from Era Interim Global Meteorological dataset. Study took period from 2014-2020 and for wild fires validation used ground data from Forestry, Wildlife & Fisheries Department of AJK period from 2018-2020 and MODIS active fire events from 2014 to 2020.

2.3 Software used

Fallowing software used for data processing and computation of results, Arc map, Advance renamel, Auto CAD, Google Earth Pro and MS office.

2.4 Analytical Frameworks

Before starting methodology were divide into three steps:

1. Fire Risk Index
2. MODIS data processing
3. Analysis of FRI with MODIS active fire data and ground data.

Using eight factor for calculating the fire risk index, assigned the different weight to all the factor with five classes for each factor from very high to very low, after assigning the weight reclassify all the factor and created a fire risk index for fire risk zone to AJK.

Rearranging the data is the most first step to get information, processing and analyzing the results. Processing from the MODIS data of features fire events point, used point data to get different charts like year-wise, month-wise and location-wise event information and also created hotspot and density maps for those areas having mostly fire events and their intensity regarding brightness values.

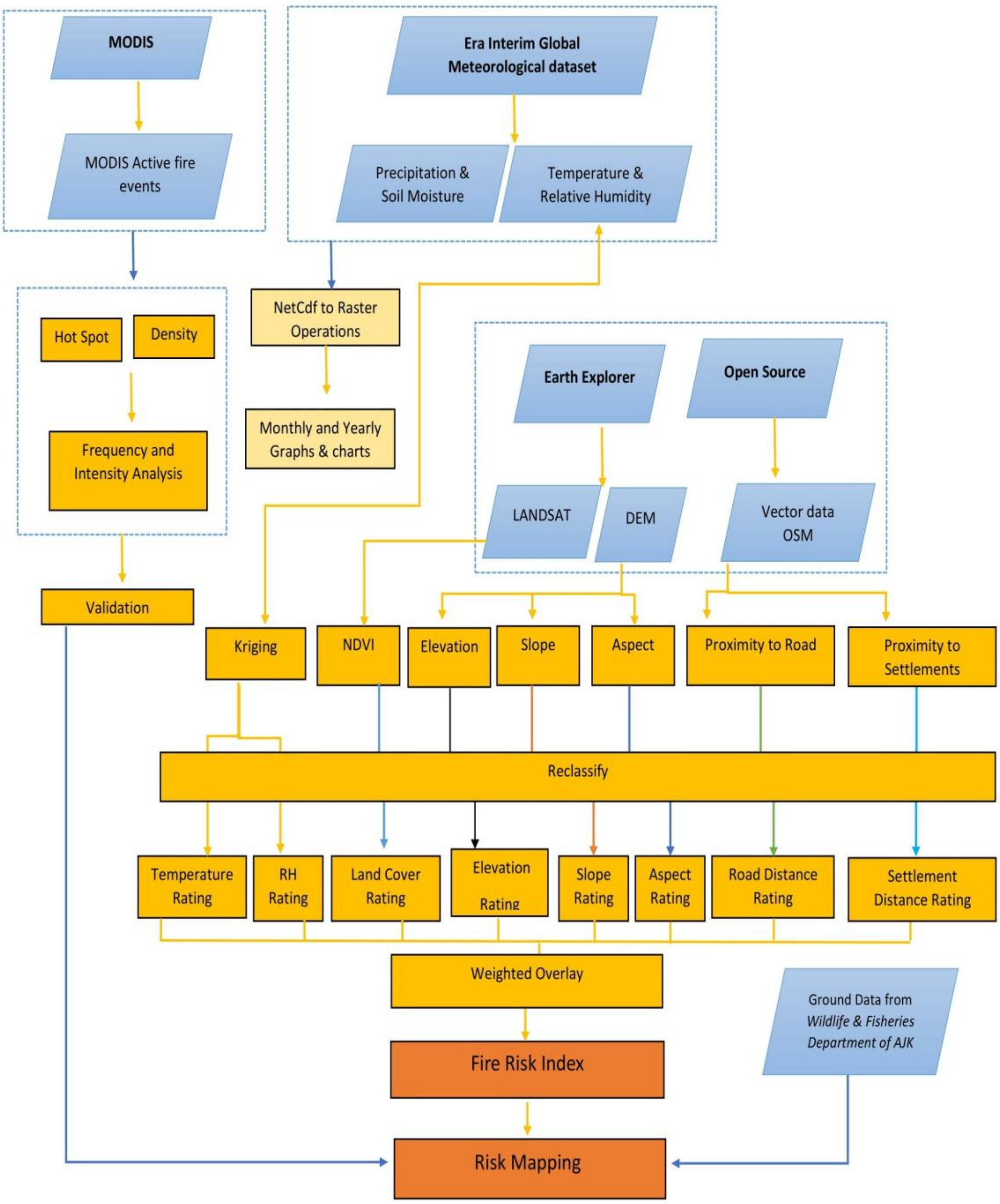


Figure 2. Methodology flow chart to determine the forest fire risk zone.

Landsat 8 data were used for vegetation layer and reclassify to different vegetation classes. Digital elevation model (DEM) is acquired from Earth Explorer platform of the USGS site. From DEM, created hill-shade for mapping, slope and aspect for topographical relation between fire events. Vector data is also used for the study. Roads and settlements were used for the proximity analysis.

Finally, in order to obtain effective and more accurate conclusions, mathematical operations in the GIS analysis were formed. The input information on forest fire influencing factors indicates the weights in the fire risk in an area. (Matin, 2017) The factors were analyzed in the following order of importance: vegetation as land cover, slope, elevation, aspect, temperature, relative humidity, proximity to settlements and roads. Each raster layer is assigned a weight for the risk analysis. Values of rasters that are reclassified to common risk scale as below.

Table 1. Common Risk Scale

Cell Value	Rating
5	Very High
4	High
3	Moderate
2	Low
1	Very Low

Prepared NDVI as a vegetation layer then reclassify it on a Common Risk Scale from Landsat 8 data. The weight of this layer used 40. Elevation is also important factor, assigned the weight 15 to elevation because it's had great variation in altitude. Temperature & relative humidity are important factors regarding recognizing dry weather conditions for fire spread and ignition. Therefore, used 5 as their weight each. also include topographical factors i.e., slope and aspect and assigned their weight as 8 and 7 respectively. Globally 90% of the fires are ignited by the humans (Arndt et al. 2013), therefore human-caused cannot be ignored, used proximity to road and settlements as human-caused wildfire factors and assigned 8 and 12 respectively.

Table 2. Common Risk scale for wildfire factors

Parameters	Weight	Classes	Factors	Fire Rating classes
Land Cover (NDVI Values)	40	-1 – 0.5	0	No Risk
		-0.5 – 0.06	1	Very Low
		0.06 – 0.15	2	Low
		0.15 – 0.21	3	Moderate
		0.21 – 0.27	4	High
		0.27 – 0.99	5	Very High
Elevation	15	>4000 m	1	Very Low
		4000 – 3000 m	2	Low
		3000 – 2000 m	3	Moderate
		2000 – 1000 m	4	High
		< 1000 m	5	Very High
Slope	8	< 5%	1	Very Low
		10-5%	2	Low
		25-10%	3	Moderate
		35-25%	4	High
		> 35%	5	Very High
Aspect	7	North	1	Very Low
		Flat	2	Low
		East	3	Moderate
		West	4	High
		South	5	Very High
Temperature c	5	<18	1	Very Low
		18.01 - 19	2	Low
		19.01 -20	3	Moderate
		19.01 - 22	4	High
		>22	5	Very High
Relative Humidity	5	> 55 %	1	Very Low
		45 – 55 %	2	Low
		35 – 45 %	3	Moderate
		25 – 35 %	4	High
		0 – 25 %	5	Very High
Proximity to Settlements	12	> 4000m	1	Low
		3000m -4000m	2	Very Low
		2000-3000m	3	Moderate
		1000-2000m	4	High
		< 1000m	5	Very High
Proximity to roads	8	> 1000m	1	Very Low
		600-1000m	2	Low
		400-600m	3	Moderate
		200-400m	4	High
		< 200m	5	Very High

RESULTS AND DISCUSSIONS

3.1 MODIS data processing

Hotspot analysis is basically the spatial analysis and identification of the clustering of mapping for spatial phenomena. The spatial occurrences are showed as points in a map and refer to locations of events or objects. Hotspot maps were generated yearly from 2014 to 2020.

The number of fire events is low in 2014, 2019, 2020 generally less than 50 events only. In 2015 and 2017 have more than 50-60 fire events were recorded. The third category is the high frequency of fire events in 2016 and 2018 that is more than 150-250. (Figure. 3).

3.2 MODIS active fire events density analysis

Kernel density is geospatial tool that calculate the magnitude per unit area from polyline features or the point using a kernel density function to fit the smoothly and efficiently tapered surface for each and every polyline or point. Calculate kernel density for the MODIS fire event data on brightness values.

Yearly density maps were made from 2014 to 2020, in the year of 2016 and 2018 more events then the other year, but year 2016 and 2017 were shoed very high density level. 2015, 2014 and 2019 were showed the moderate level. Year 2016 was more events but low in density level. (Figure. 4).

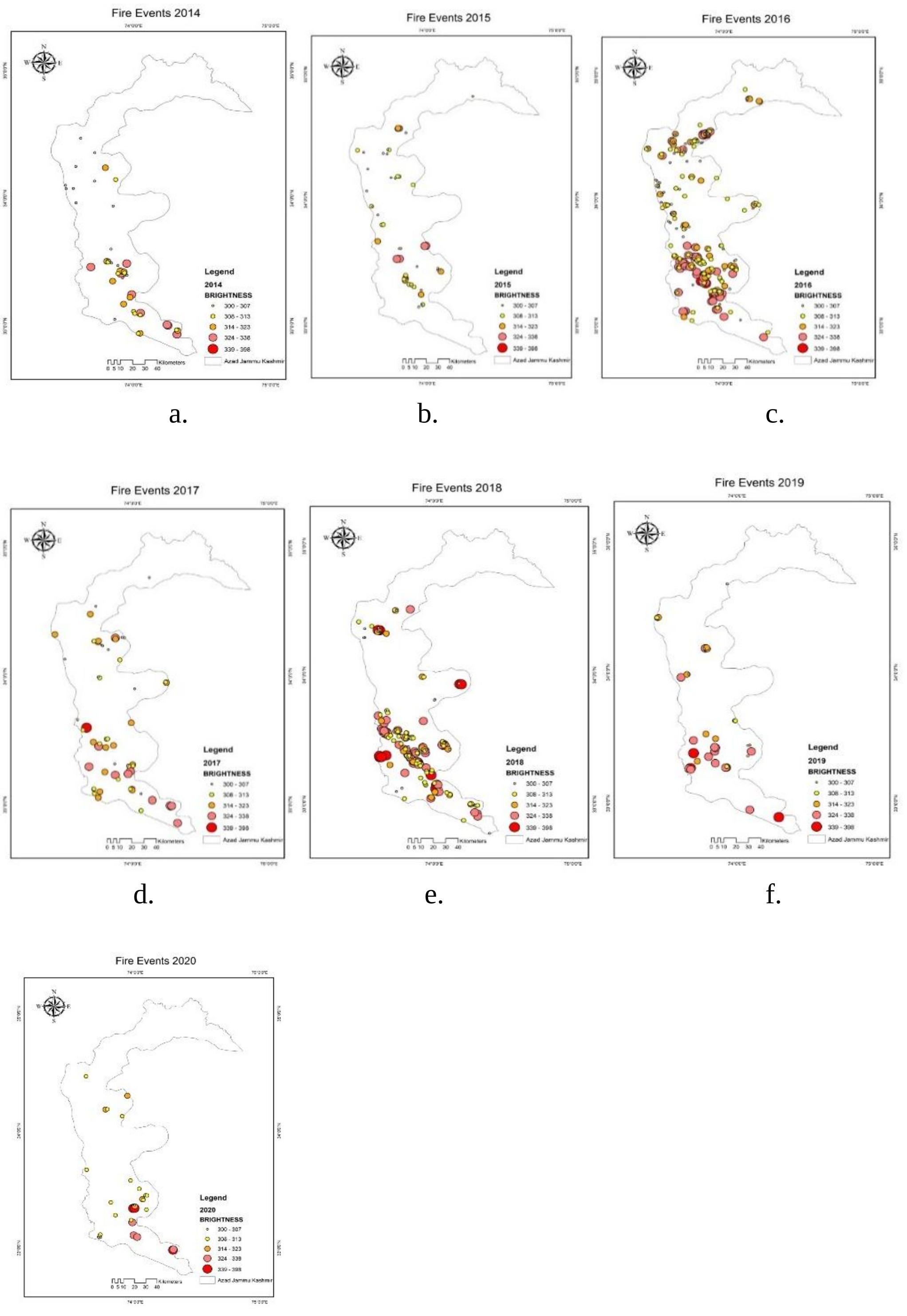
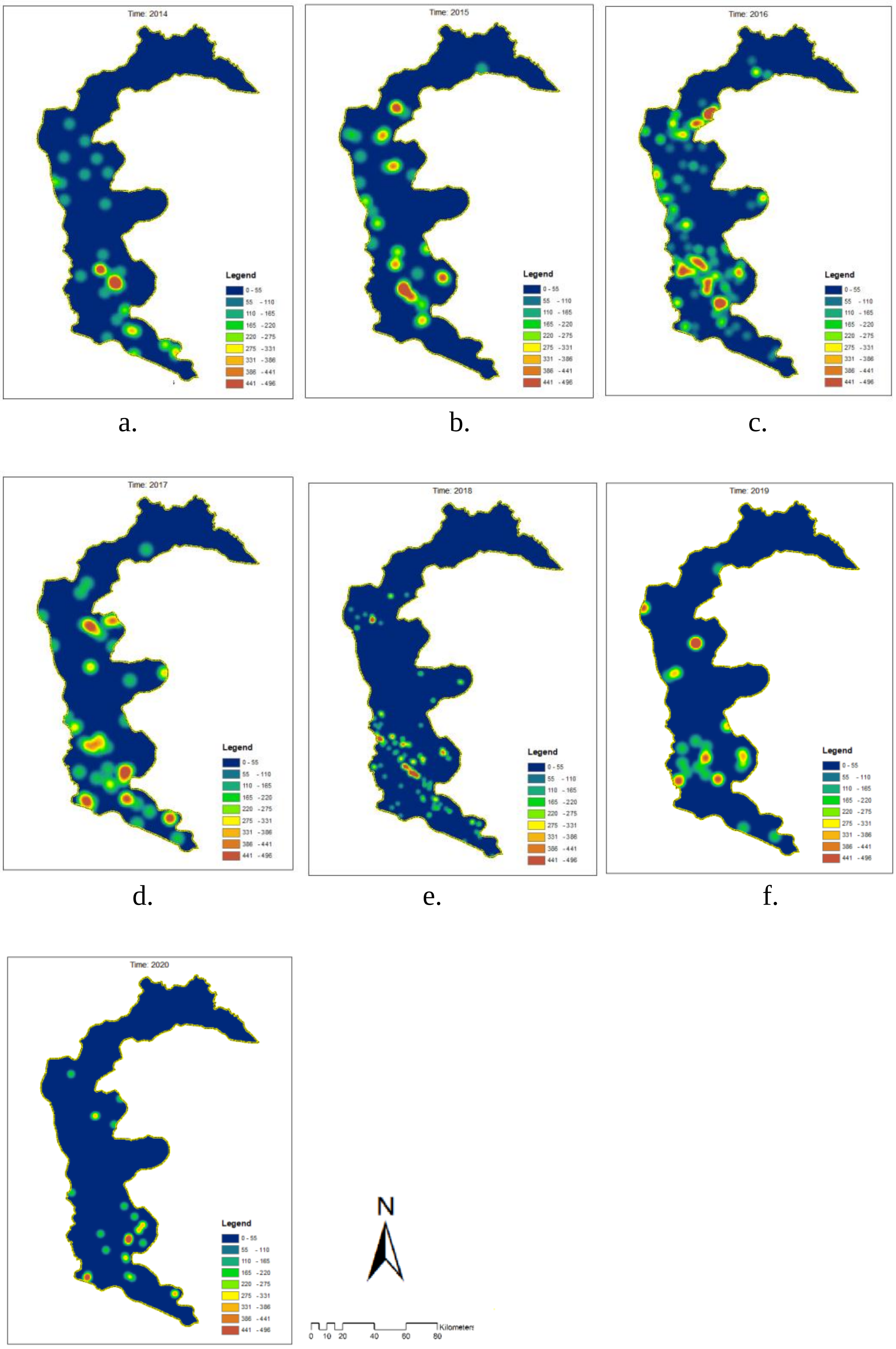


Figure 3. Yearly hotspot maps from MODIS fire evens.



a. b. c.

d. e. f.

g.

Figure 4. Density maps of MODIS fire events.

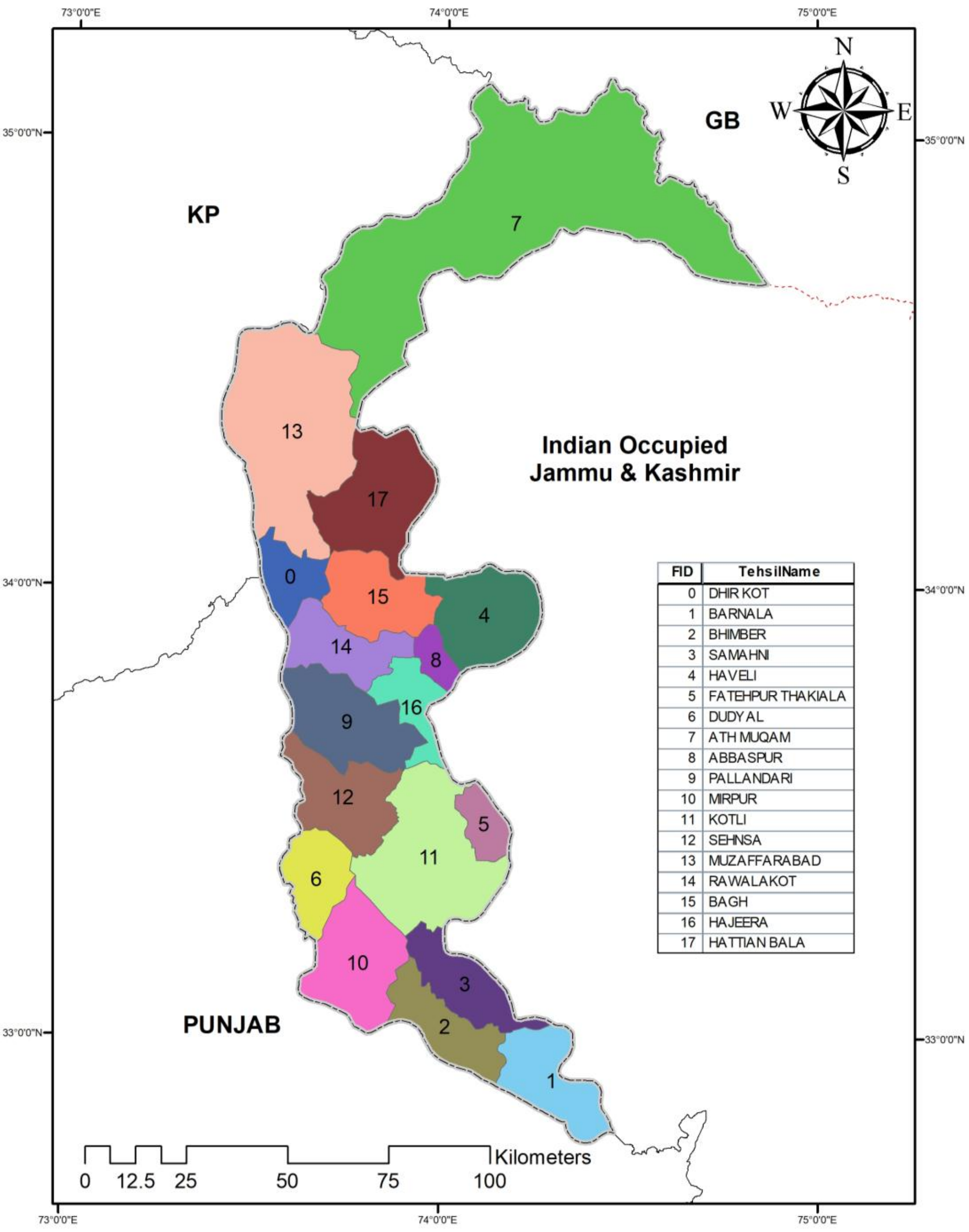


Figure 5. Tehsil map of Azad Jammu Kashmir

3.3 Level of confidence and MODIS fire events yearly analysis

From 2014 to 2020, total of 645 forest fires incident were recorded by the MODIS sensors in AJK. The frequency of fires was higher during 2016 and 2018. Fires incident start to occurred in the winter (November–February). 51% fires occurred through the pre monsoon period (May–June) when weather is the drier and hotter, (Figure 7).

3.4 Yearly relative humidity

The following chart shows minimum relative humidity. As RH in May and Jun is very low respectively other months. In Aug, the minimum value of RH is more than 30% while in Sep and Oct near 30% RH that is low correspondingly. The winter months Nov, Dec, Jan, and Feb have values from 15–20%. (Figure 11).

3.5 Tehsil wise and monthly fire events analysis

Tehsil-wise monthly fire events, when plot the wildfire event on maps, and get the Tehsil-wise number of events. The highest number of wildfires (146) were recorded in the Tehsil Kotli. Other affected Tehsils are shown below. In Kotli and Sehnsa, more than 85% events were recorded in month of May and June. (Figure 9).

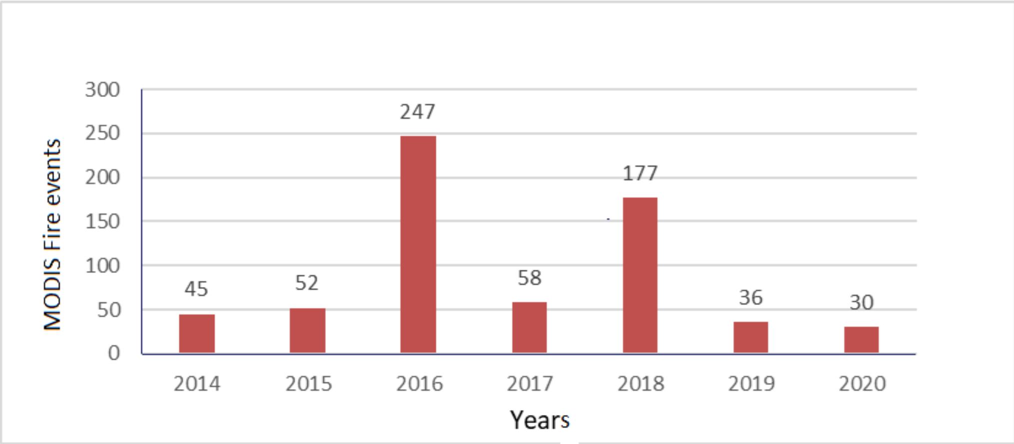


Figure 6. Year-wise MODIS fire events

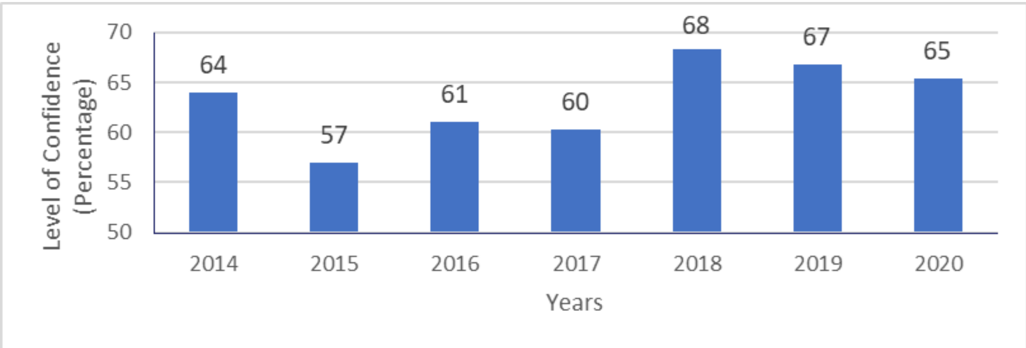


Figure 7. Confidence level of MODIS fire events

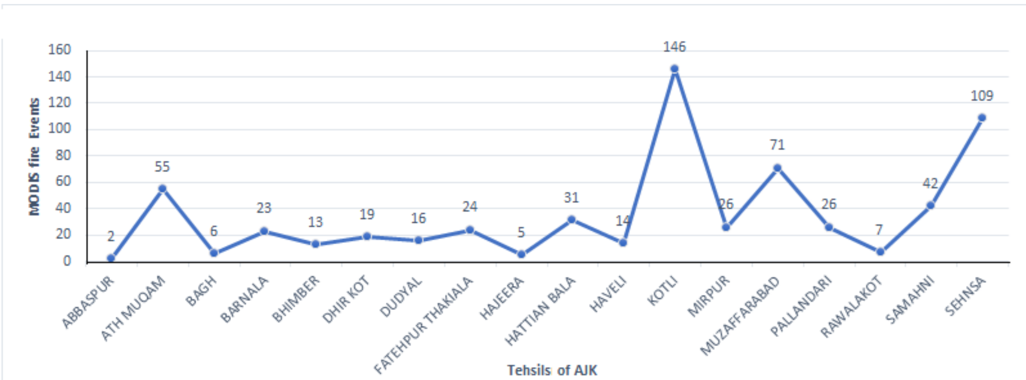


Figure 8. Tehsil-wise MODIS fire events

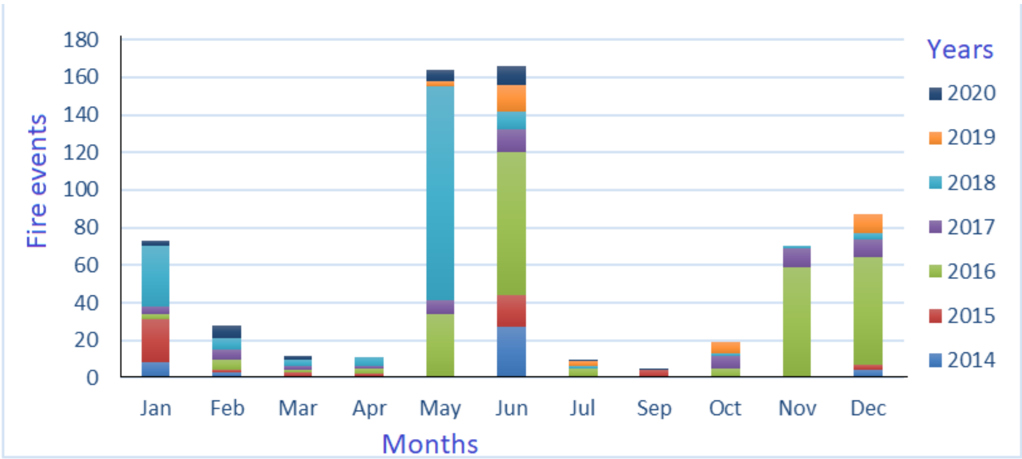


Figure 9. MODIS monthly wildfire events

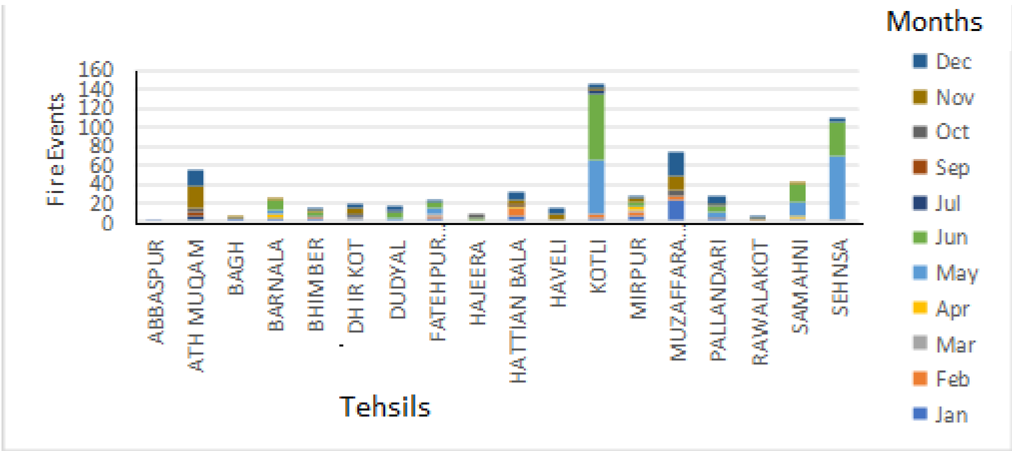


Figure 10. Fire events in tehsils month wise

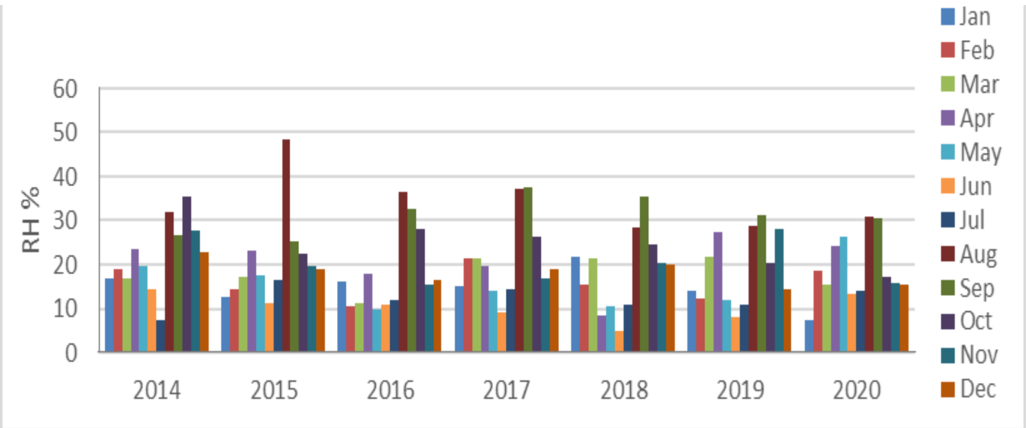


Figure 11. Minimum monthly relative humidity

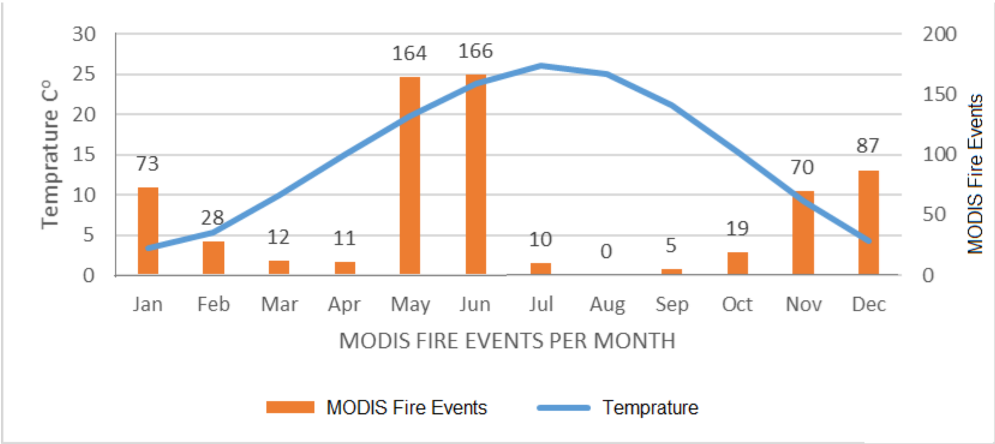


Figure 12. Temprature vs MODIS fire events

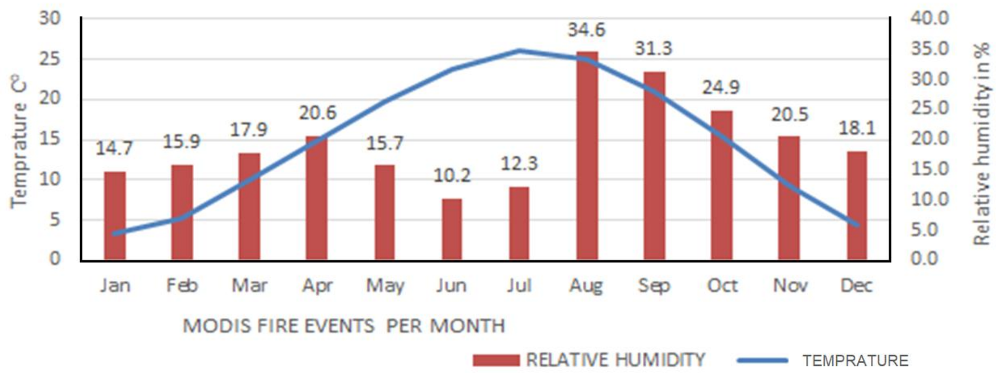


Figure 13. Temprature vs relative humidity

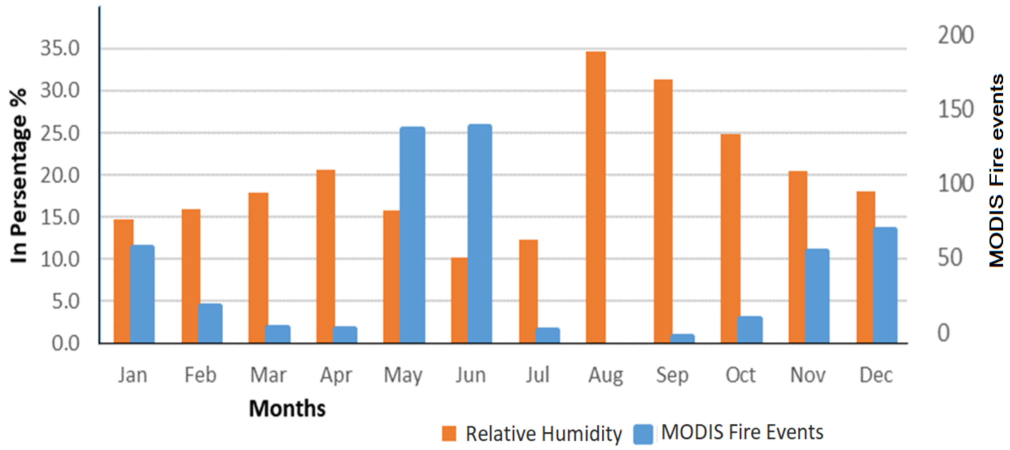


Figure 14. Relative humidity vs MODIS fire events

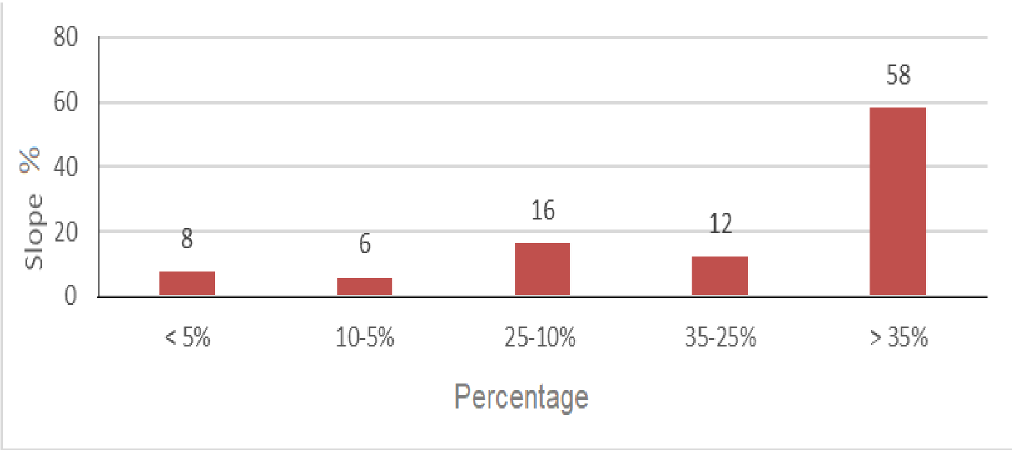


Figure 15. Percent slope of AJK

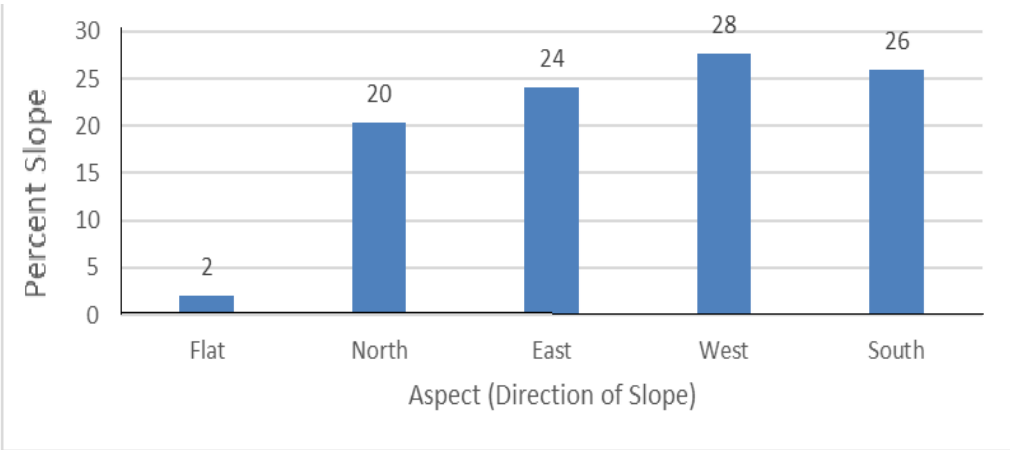


Figure 16. Aspect in percentage slope

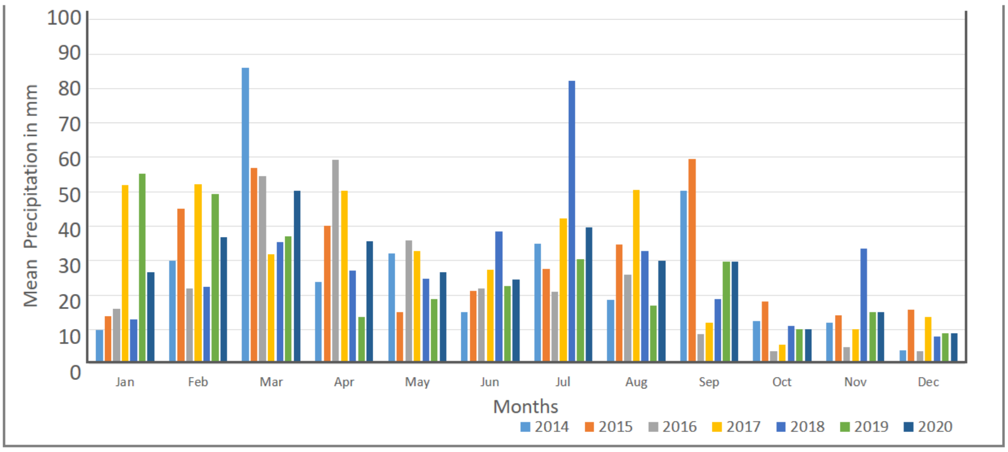


Figure 17. Mean monthly precipitation of AJK

3.6 Fire Risk Index

Using weighted overlay tool fire risk index for forest, map was generated. First, classified the raster maps that representing each parameter in the classes described in (Table 2), Classified maps were then converted into rating maps for each parameter based on the relative rating for each class, as described in (Table 2).

3.7 Land use land cover (Vegetation index)

Vegetation index for land cover, used Landsat 8 images. Classification of image is process the identifying pattern of groups in the image that constitute thematic information. Unsupervised and supervised image classification methods are the two most common approaches. In this study, supervised classification approach, most commonly used for the quantitative analysis of remote sensing image data is applied.

Table 3. NDVI values use in land cover factor.

Classes	Factors	NDVI (Values)
Others	0	-1 – -0.5
Barren Land	1	-0.5 – 0.06
Shrubs/Grass land	2	0.06 – 0.15
Forest	3	0.15 – 0.21
Dense Forest	4	0.21 – 0.27
Cultivated Land	5	0.27 – 0.99

3.8 Surface temperature

Areas have very low relative humidity in above graph. In weight assigned processed, used less than 18°C in the very low and 18°C to 19°C moderate and greater than 22°C in very high class. In April to August, the temperature rose in southern part of the AJK as well. (Table 2)

3.9 Relative humidity

In May and June, also the temperature rose in southern part of the AJK mostly fire incident of MODIS were recorded in these tehsils, similarly in the same period, these areas have very low relative humidity. (Figure 11).

3.10 Effect of elevation

Elevation is essential physiographic variable, that associated with the moisture, temperature, and wind. (Xiangwei et al. 2011). DEM (Digital Elevation Model) of the study area were extracted from the earth explorer, USGS 30m. In the high altitude area have less chance the fire activity due to low temperature, then the lower elevation area, assigned class very high, when elevation less than 1000ma and greater than 4000m very low risk (Table 2).

3.11 Distance from roads

One of basic factors is human activities, that is affect fire occurrences also proximity to road a very important factor to create FRI especially human cause is great concern in wildfire occurrence. Distance from roads, the road density are hypothetically significant parameters because of that roads are allowed to people to go into the forest and the grassland area also cause ignitions. Used the 200m distance from road in very high and 1000m in very low in fire rating class (Table 2).

3.12 Distance from settlements

Anthropogenic factors are very important variables in that influence fire occurrences as represented by the factors such as the proximity to roads and the settlements (Avila-Flores et al. 2010). Used the 1000m distance from settlement in very high and 3000m in very low in fire rating class (Table 2)

3.13 Effect of slope

AJK is the mostly mountainous area. Only the southern part were very low slope. The following chart shows the percent slope. Up to 10% of the slope only 14% of the total area. Regarding aspect, 2% area is flat and 26% of the area south facing that is more risk factor for fire ignition. Slope parameter that influence in spread rate, that fire rapidly move in the up slope and less quickly in down slope. Steeper slopes that fire may spread very fast in the closer angled to the ground surface. southern facing side slope normally provide the more favorable conditions. (Figure. 15).

3.14 Effect of aspect

Aspect is also responsible factor that solar energy that particular area receives, in aspect slop that are facing to the south much higher vulnerability then the north facing slop. This is because south facing more exposed the radiations of the sun so this side slop drier then the north facing. In AJK study area that south facing side slop is 26% on the southern face and 28% on the north facing as well. (Figure 16).

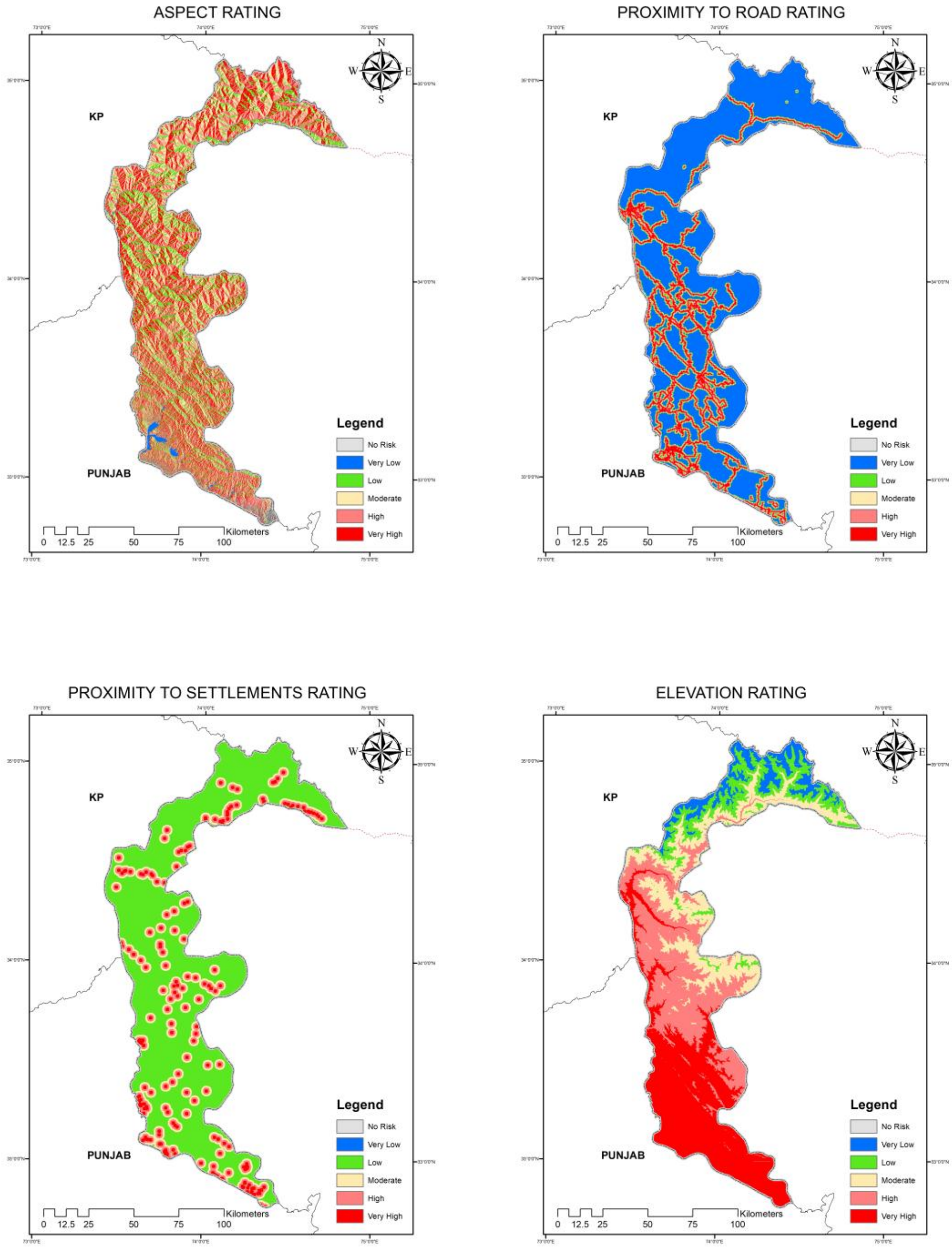


Figure 18. Risk map of factors used for FRI Index (A)

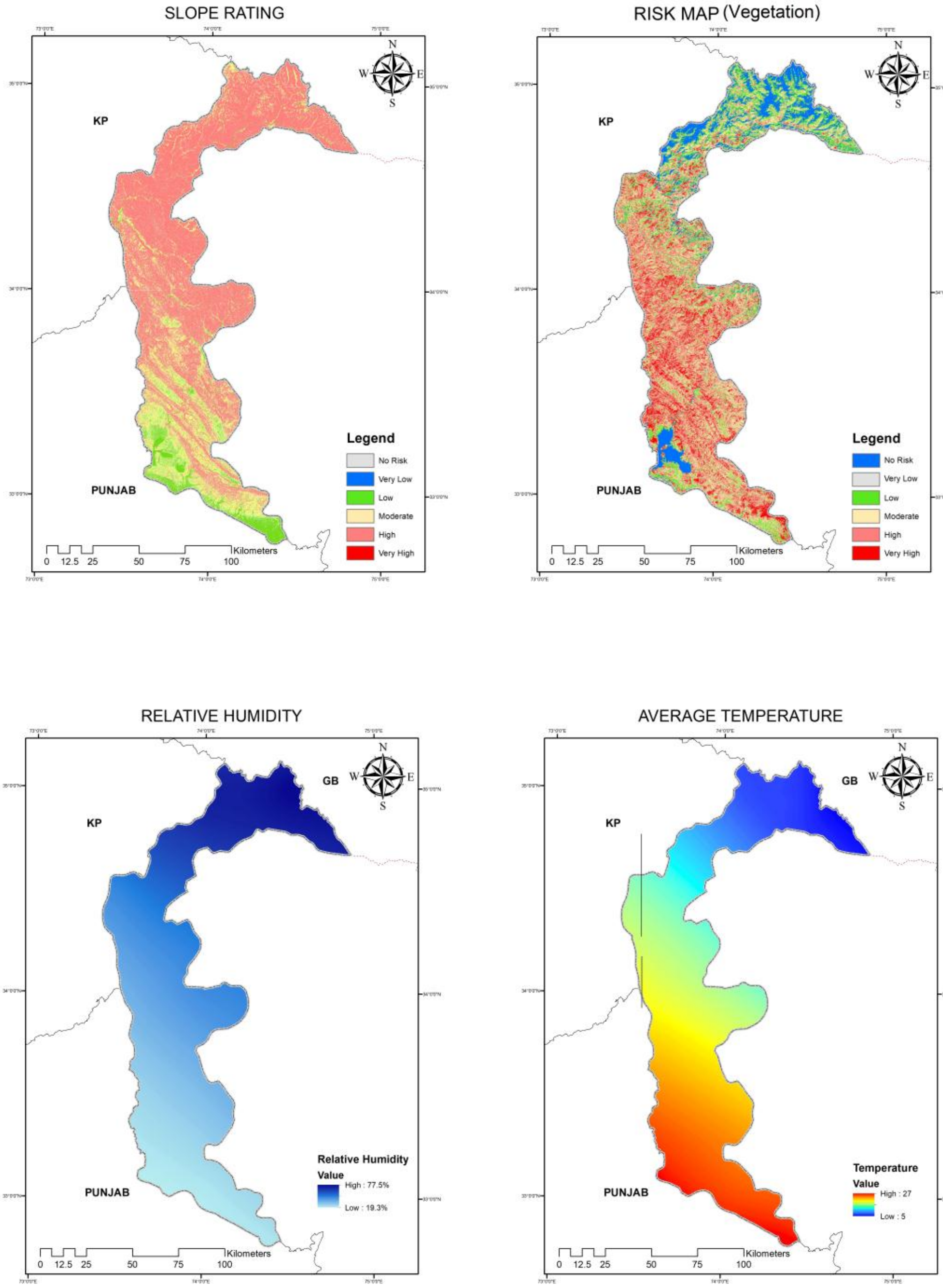


Figure 19. Risk map of factors used for FRI Index (B)

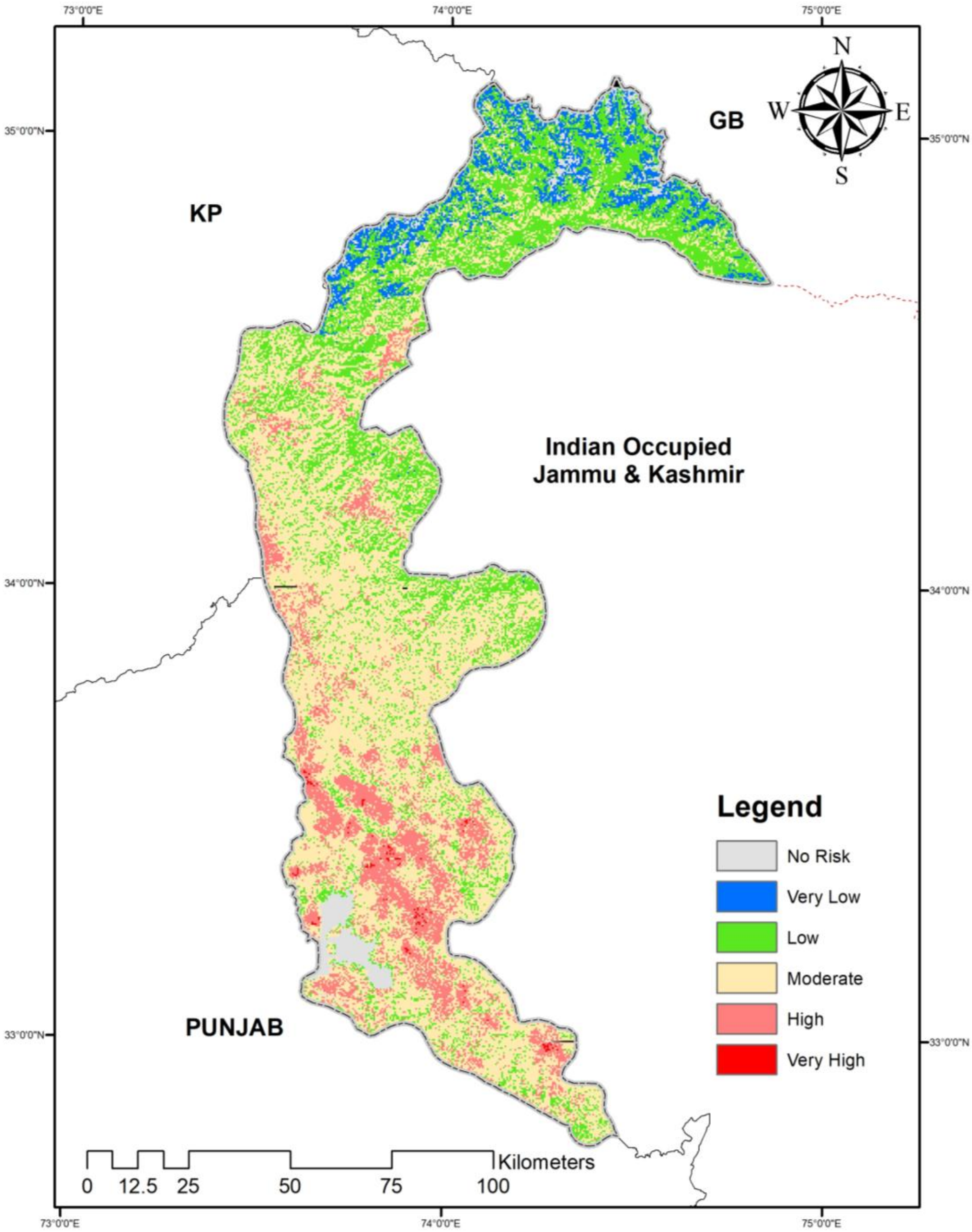


Figure 20 Fire Risk Index map

3.15 Validation of Fire Risk Index

Validate the Fire Risk Index with MODIS active fire events and used the available ground data from Forestry, Wildlife & Fisheries Department of AJK period from 2018-2020. In MODIS active fire events indicate in the month of May and June had greater number of events then other month also available the ground data of 3 years was also showed the maximum fire events in month of May and June. (Figure 21).

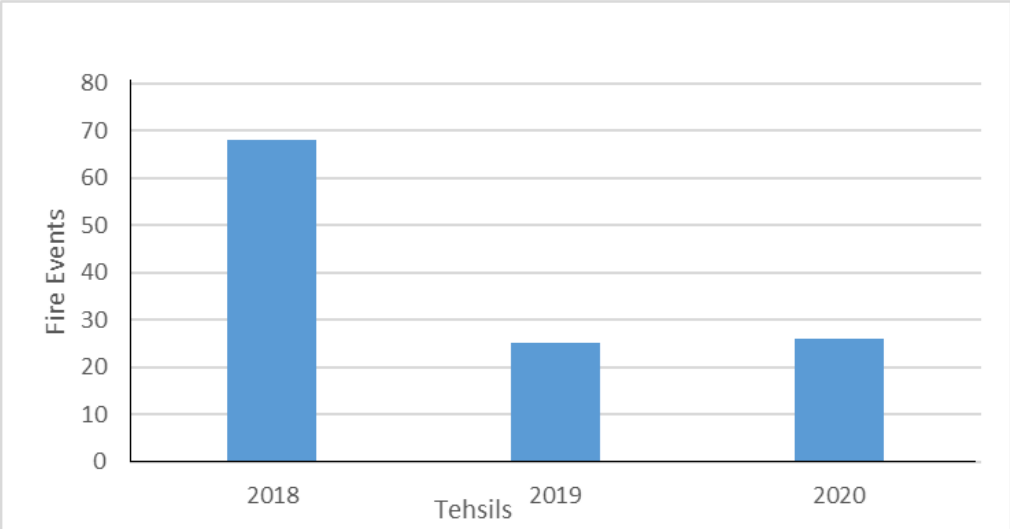


Figure 21.Yearly events of ground data

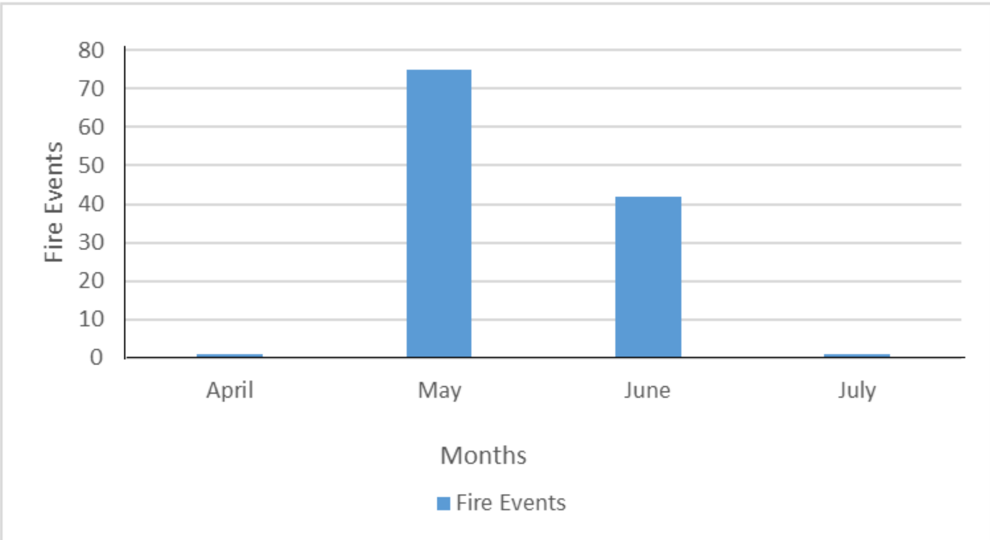


Figure 22. Monthly fire events of ground data

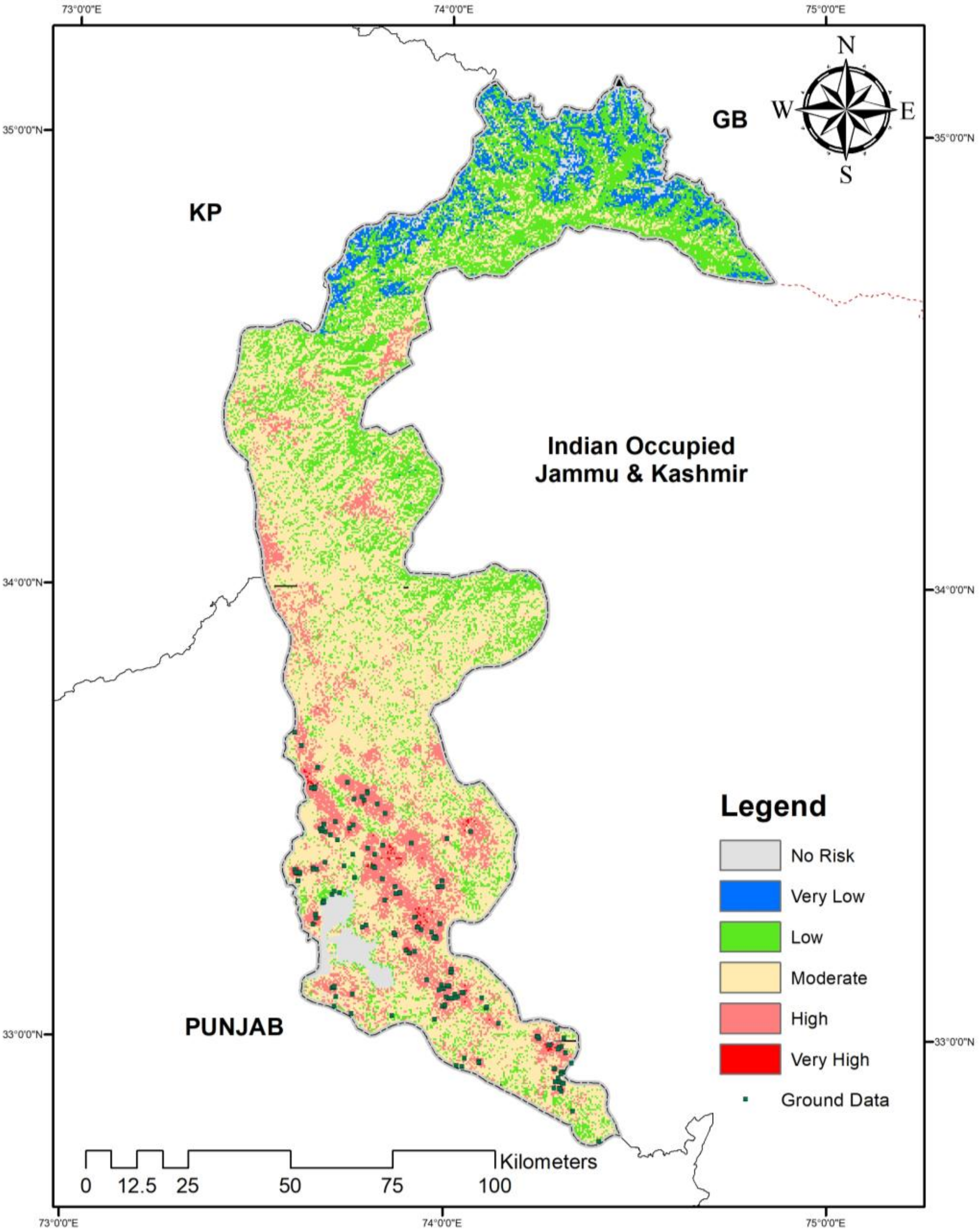


Figure 23. FRI validation with ground data

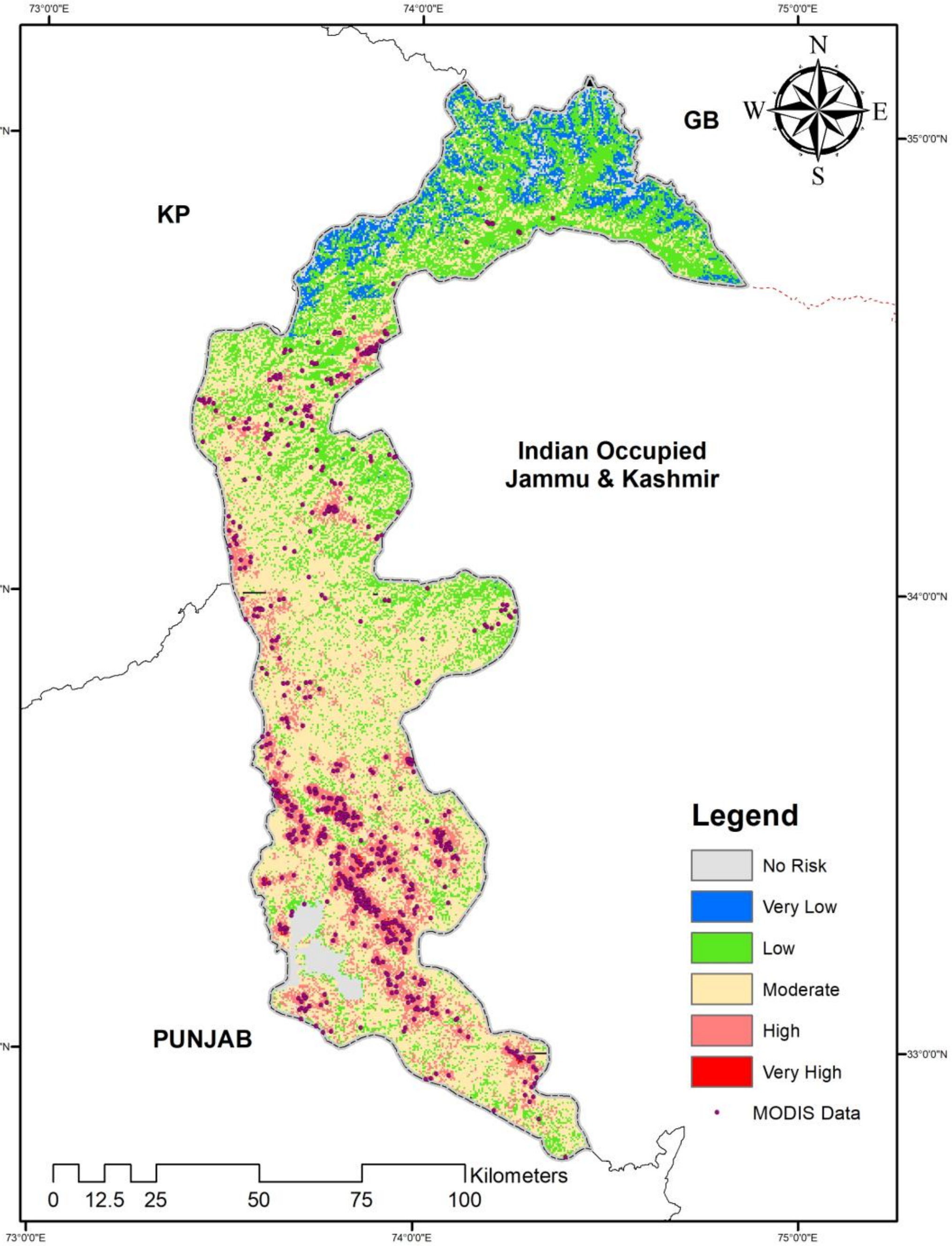


Figure 24. FRI validation with MODIS data

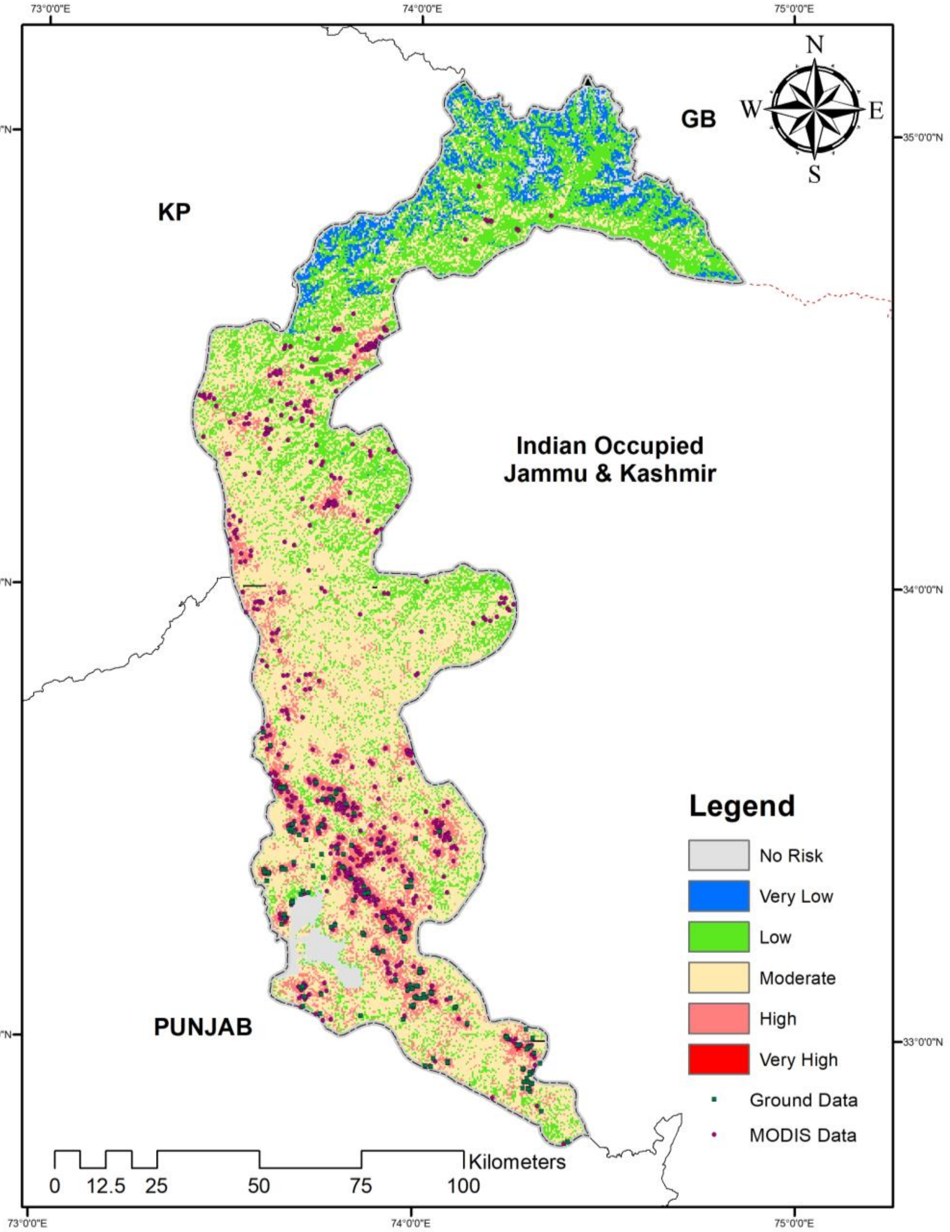


Figure 25. FRI validation with MODIS and ground data sets

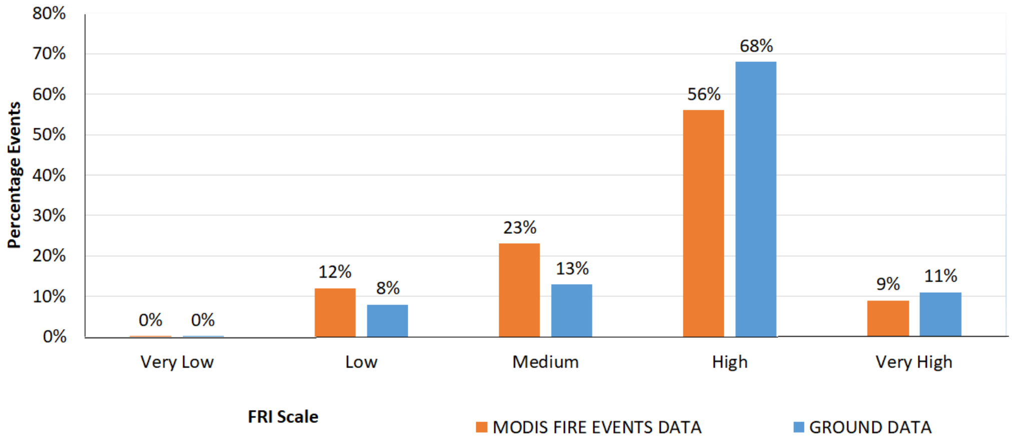


Figure 26. FRI scale with MODIS fire events & grund data

Validate of fire risk index, when overlaid the ground data of fire incidences on risk class map. The validation analysis showed 68% fire events of ground data occurred in High risk class and 11% in very high, MODIS active fire events overlaid 56% in high and 23% in low risk class in FRI (Fire Risk Index) map. One reason of highly vulnerable in the high risk class either then the very high because of that, assigned major factor (land use land cover) in dense forest at the high risk class.

During research work when visited the Wildlife and Fisheries Department Azad Jammu Kashmir. according to chief conservative officer, that major fire events occurred in the dry season and main reason of pine trees dry needle make a layer on surface when fire event occurred it spread quickly in surrounding also the liquid from pine tree in highly inflammable.

CONCLUSTION AND RECOMMENDATIONS

4.1 Conclusions

Partially flat areas with less slope and very low relative humidity were vulnerable for fire events with raking high to very high most of the forest/vegetation dry in this session. Moreover, high altitude areas having better RH causing risk ratings from low to very low. Temporal analysis showed the frequency of fires was higher during the years of 2016 and 2018, most of the fires (51%) occurring during the pre-monsoon season (May–June) when the weather is hotter and drier, also analyzed the maximum fire events in these months from ground data as well.

Southern part of Azad Jammu Kashmir is highly venerable because of that, low altitude high temperature, low humidity and human causes because, that areas close to settlement and road. The period between April to Jun is very hot and dry, with less RH and high temperature causing risk raking increasing from low to high. Temporal analysis showed in April, fire events recorded less than 2% but in May and June, these events increase more than 25%. The average temperature increases 10-20 degree Celsius in May-Jun respectively RH level decreases to 30% to 20% which cause increased risk level high to very high.

FRI maps and fire events analysis showed that, tehsil Barnala, Samahni, Kotli, Fatehpur, and Sehnsa are very vulnerable at high risk level while Tehsil Dudyal, Bhimber, Muzaffarabad, and Pallandari having risk rating moderate to low due to low RH and high temperature. As soon as starting Monsoon season, RH increases which causes wet weather therefore risk rating decreases moderately to low. Highly vulnerable area of AJK were in lower elevation in southern side. Validation results showed the 68% ground data and 56% MODIS active fire events were occurred in high risk class on FRI map. Reason of that highly vulnerable in the high risk class either then the very high because it is not possible to activate all the factors at same time and same place. Also assigned high weight for major factor (land use land cover) to dense forest in high risk class for generating FRI map.

4.2 Recommendations

- ✓ Using some more factors like wind, lightening, and soil moisture etc. that can be achieve better result for risk zone in FRI index.
- ✓ Identification the vegetation and tree species in LULC (land use land cover) data sets, that can be improve the Fire Risk Index to identify the fire risk zone.
- ✓ Fire risk zone validation can be analysis with high resolution remote sensing burn area image.
- ✓ Result can be improving by assigning the independently buffer zone to LOC (line of Control) for Pakistan and India border area.

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