A Project report

on

Forest Fire Susceptibility Mapping of

Pauri Garhwal District,

Uttarakhand

using

AHP and GIS

Submitted in the partial fulfillment

for the award of certificate in

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To

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ABSTRACT

Forest fires are one of the major environmental hazards affecting the Himalayan region, particularly in Uttarakhand. Pauri Garhwal district experiences frequent forest fire incidents due to favorable climatic, topographic, and vegetation conditions. This study aims to identify forest fire susceptibility zones in Pauri Garhwal using Geographic Information System and the Analytical Hierarchy Process (AHP). Various factors such as land use/land cover , NDVI, slope, aspect, elevation, land surface temperature, rainfall and wind speed were considered. Each factor was reclassified and weighted according to its influence on forest fire occurrence. A weighted overlay analysis was performed in ArcGIS Pro to generate the forest fire risk map. The final output was classified into six risk zones: very low, low, moderate, high, very high, and extreme. The results indicate that moderate to high fire risk zones dominate the study area, mainly in forest and grassland regions. The generated susceptibility map can support effective forest fire management and mitigation planning in the district.

1.Introduction

Forest fires are a recurring environmental problem in many parts of India, particularly in the Himalayan state of Uttarakhand. Every year, large areas of forest in Pauri Garhwal district are affected by fires during the dry season, leading to loss of vegetation, wildlife habitat, and deterioration of air quality. The occurrence and spread of forest fires are influenced by a combination of natural factors such as terrain, vegetation condition, temperature, rainfall, and wind, along with human activities.

With the advancement of geospatial technologies, Geographic Information System (GIS) and remote sensing have become effective tools for analyzing and mapping forest fire risk. These technologies allow the integration of multiple spatial factors to understand areas that are more vulnerable to fire occurrence. The Analytical Hierarchy Process (AHP) is a widely used multi-criteria decision-making method that helps in assigning relative importance to different influencing factors in a systematic manner.

This study focuses on identifying forest fire risk zones in Pauri Garhwal district using GIS and AHP techniques. By integrating various environmental and climatic parameters, the study aims to produce a forest fire susceptibility map that can assist forest authorities and planners in fire prevention, monitoring, and management efforts.

2. Study Area

The present study is conducted in Pauri Garhwal district, which is located in the Garhwal region of Uttarakhand state, India. Geographically, the district lies in the central Himalayan belt. Pauri Garhwal covers an area of about 5,230 km² and is characterized by rugged mountainous terrain.

The district exhibits highly variable topography, with elevation ranging from about 300 m to over 3,000 m above mean sea level. The terrain consists of steep slopes, deep valleys, ridges, and river systems such as the Alaknanda, Ramganga, and their tributaries. These physiographic conditions strongly influence climate, vegetation distribution, and forest fire behavior in the region.

Pauri Garhwal has extensive forest cover dominated by chir pine , oak (Quercus spp.), mixed broad-leaved forests, and temperate coniferous forests at higher elevations. Pine forests are particularly fire-prone due to the accumulation of dry pine needles and prolonged dry conditions during summer months. Grasslands and scrub vegetation also contribute to increased fire risk.

Ecologically, the district is highly significant as it forms part of the Western Himalayan biodiversity hotspot. The forests support rich biodiversity, help in soil and water conservation, regulate local climate, and provide livelihoods to local communities. Frequent forest fire incidents threaten forest ecosystems, wildlife habitats, and nearby human settlements.

Pauri Garhwal was selected as the study area due to its recurring forest fire incidents, complex terrain, diverse vegetation types, and ecological importance. The increasing frequency of fires caused by climatic variability and human activities makes the district suitable for forest fire susceptibility analysis using GIS and AHP techniques

3. Materials and methods

3.1 Data Sources

- Sentinel-2 based land cover products
- USGS Earth Explorer Landsat 8 Level 2
- Open Topography Digital Elevation Modal
- CHRS Data Portal
- NASA Power data access viewer
- Survey of India Digital products

3.2 Tools Used

- GIS Software: ArcGIS Pro
- Analytical Techniques: AHP, NDVI, Weighted overlay, Reclassification, Raster Calculator, Field calculator, Raater projection, Layout view

3.3 Workflow

- **Data Collection**

  Relevant spatial and climatic datasets including LULC, Sentinel-2 imagery, Open Topography DEM, Landsat-8 Level 2 satellite data,CHRS rainfall data, wind speed, and administrative boundaries from Survey of India were collected.

- **Data Pre-processing**

  All datasets were projected to a common coordinate reference system. Raster datasets were resampled to a uniform spatial resolution and clipped to the Pauri Garhwal district boundary.
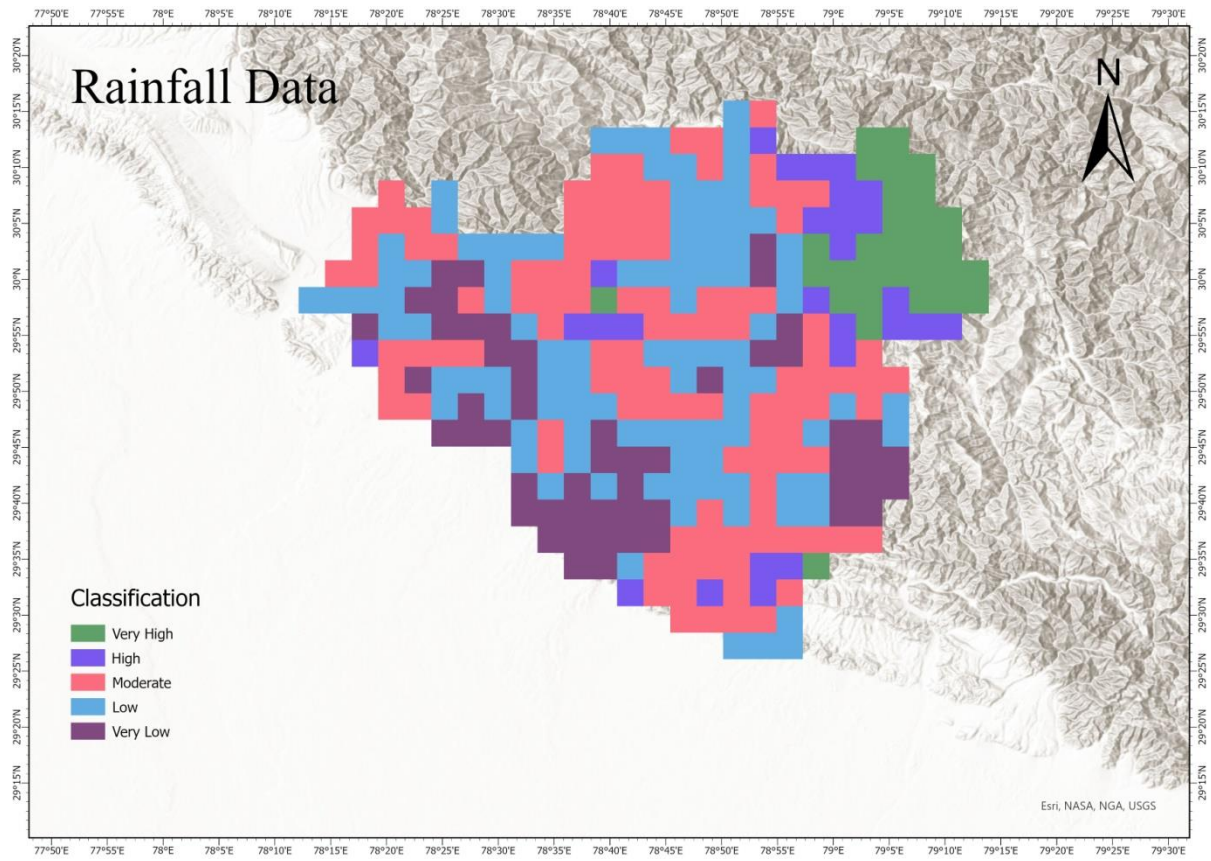
- **Derivation of Thematic Layers**

  DEM data were used to generate slope, aspect, and elevation layers using spatial analyst tools. NDVI was calculated from Landsat 8 imagery using red and near-infrared bands. Land Surface Temperature was derived from Landsat-8 Band 10.
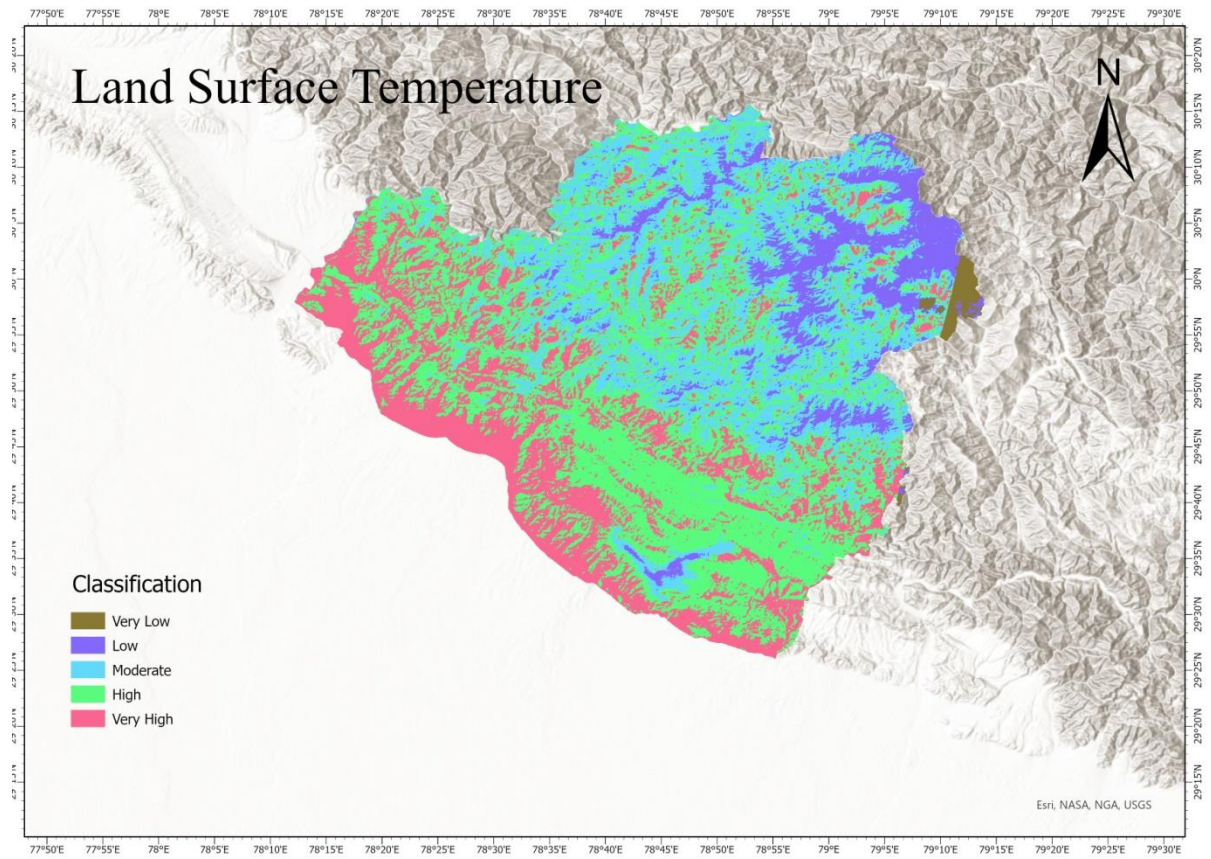
- **Reclassification of Factors**

  Each thematic layer was reclassified into suitability classes based on their influence on forest fire occurrence using the Saaty scale. Higher ranks were assigned to conditions favoring fire occurrence.
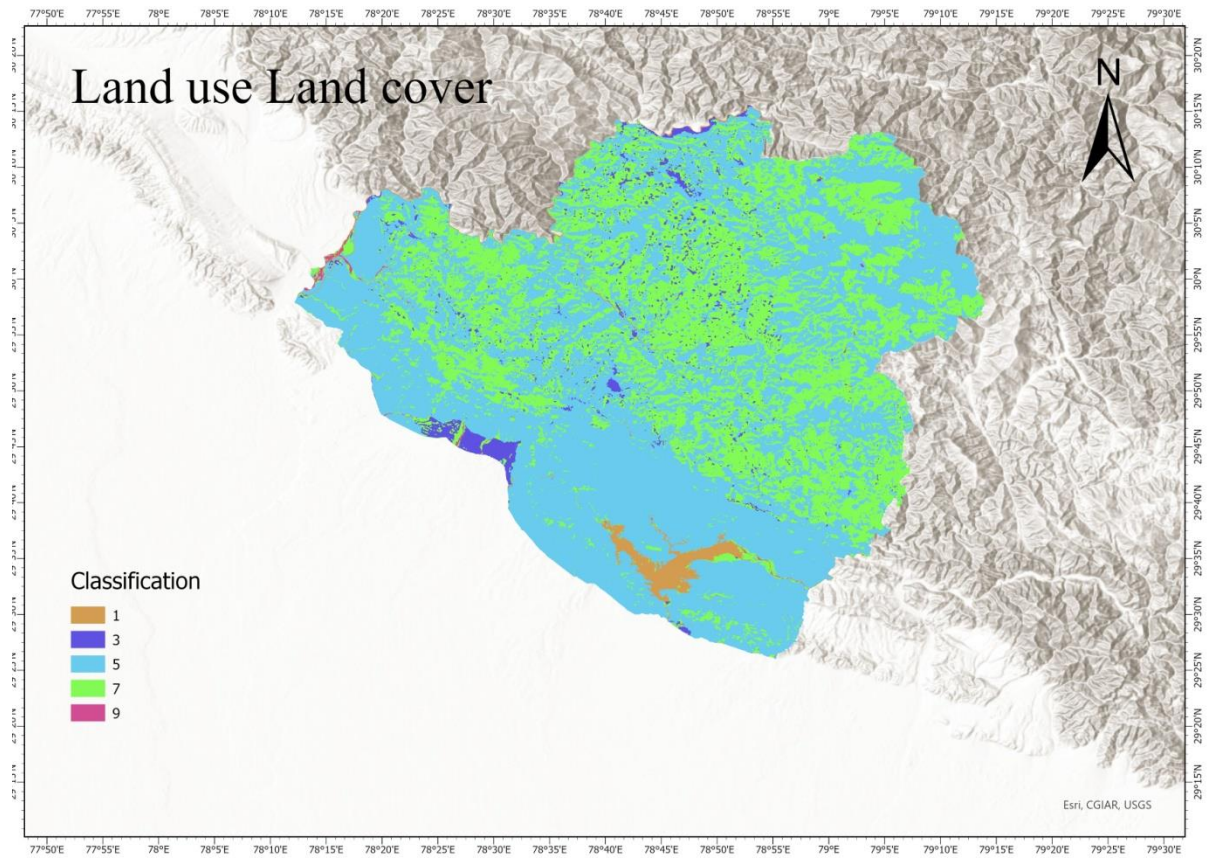
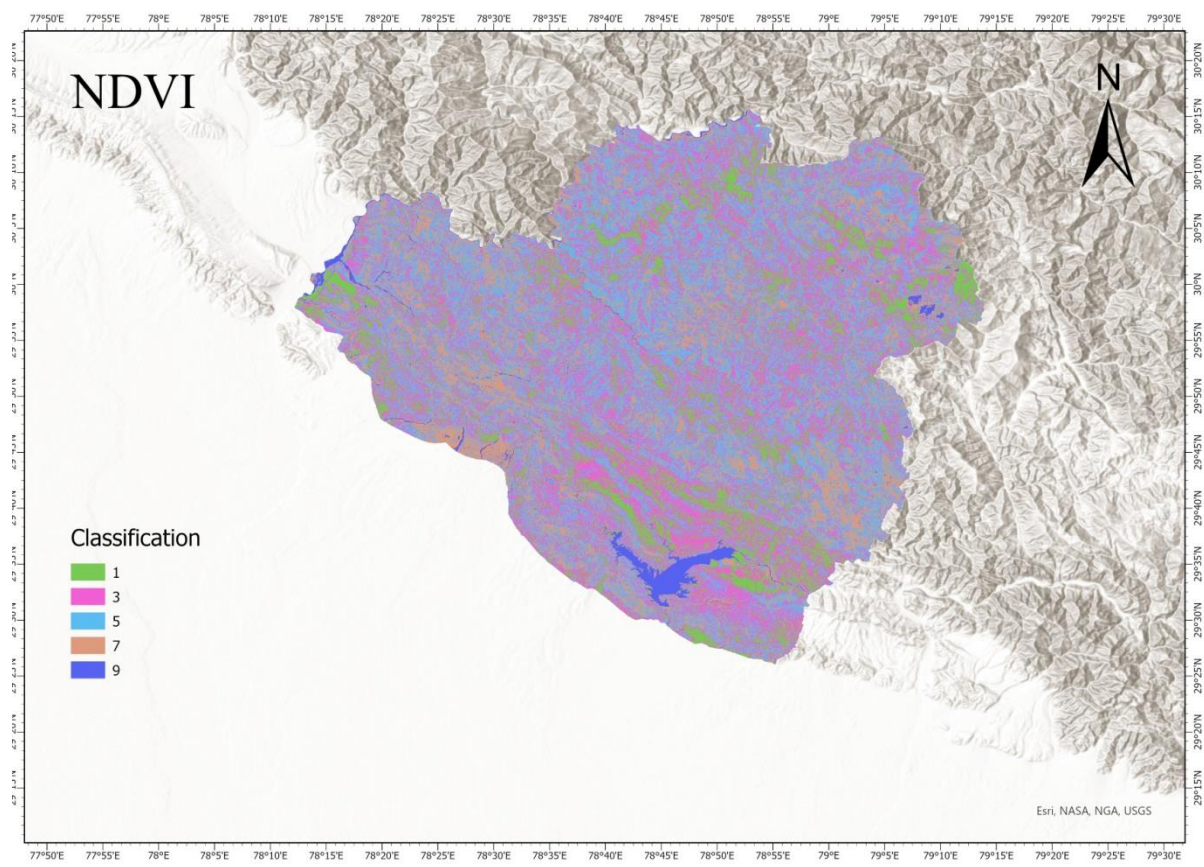# A.Reclassified rainfall data of Pauri Garhwal

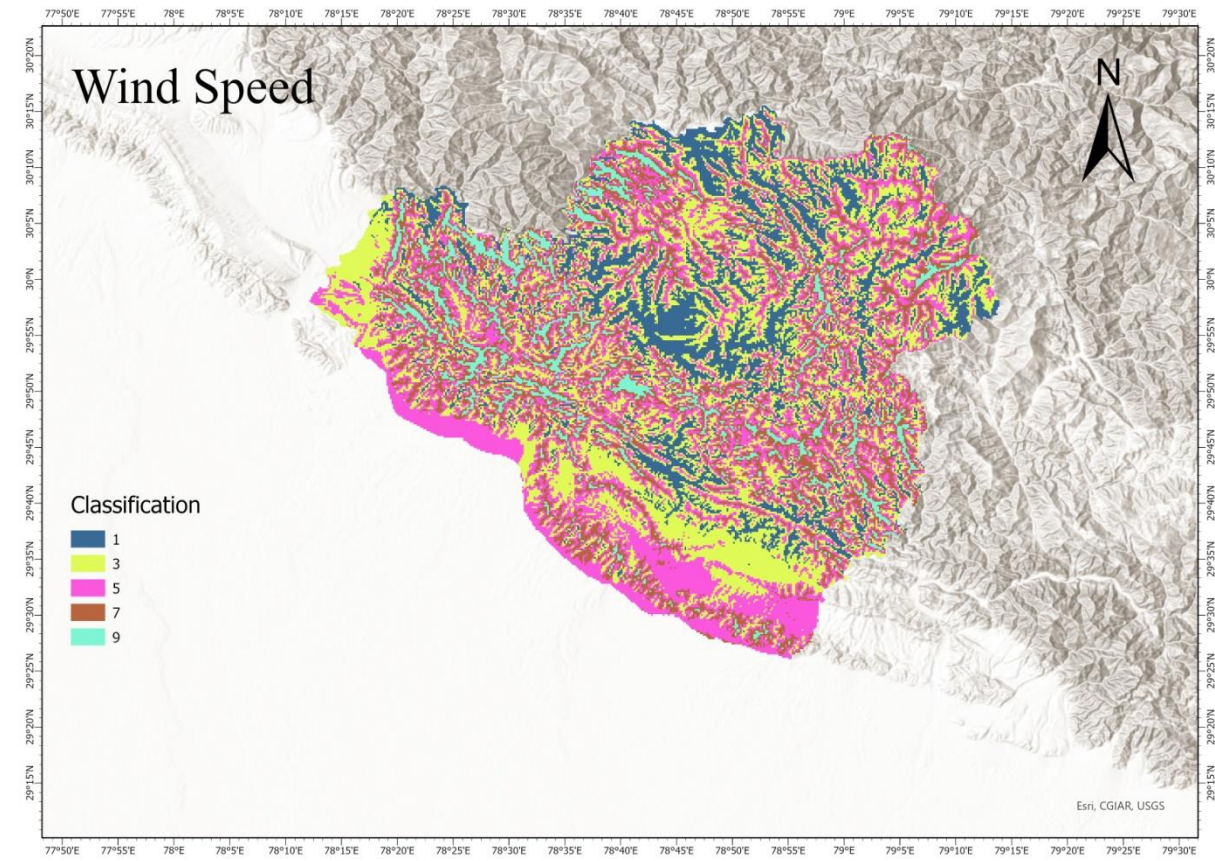# B.Reclassified LST Data of Pauri Garhwal

C.Reclassified LULC data of Pauri Garhwal

Land use Land cover

Classification
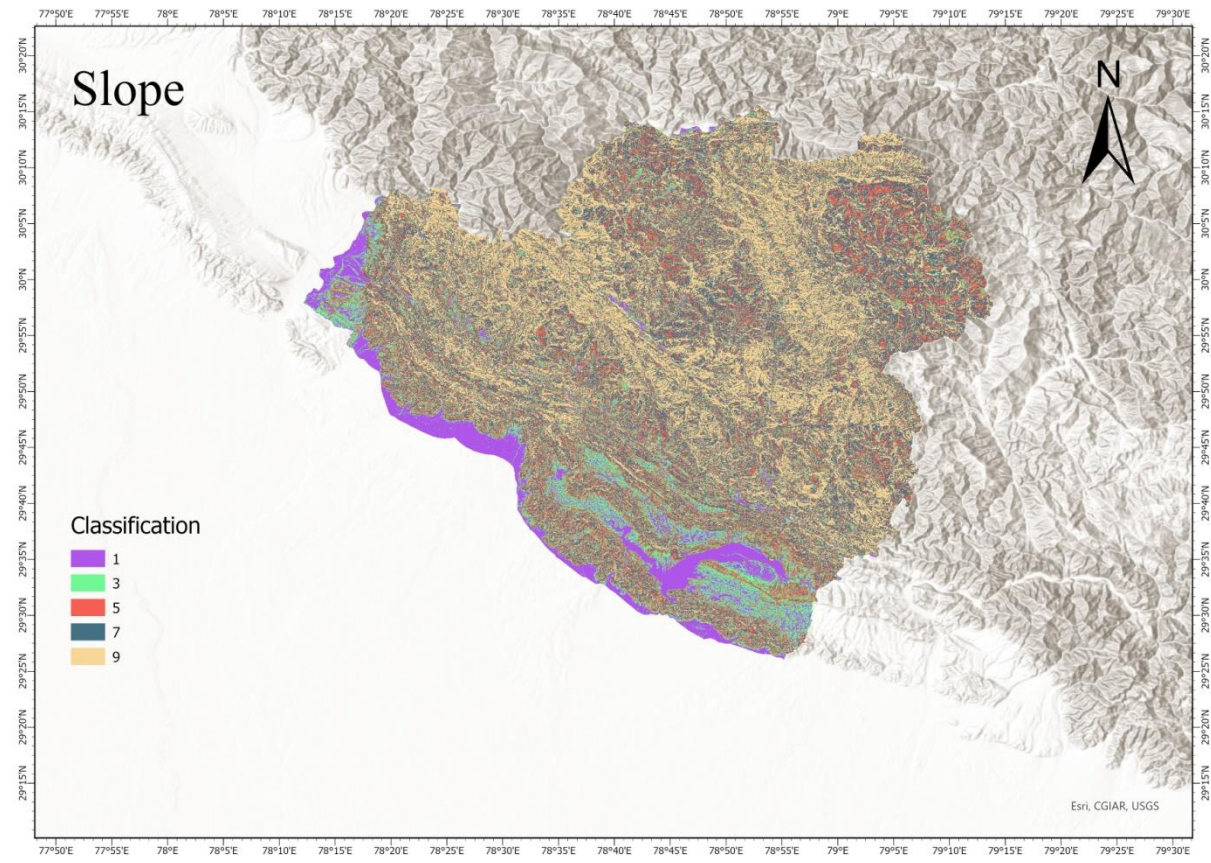- 1
- 3
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Esri, CGIAR, USGS

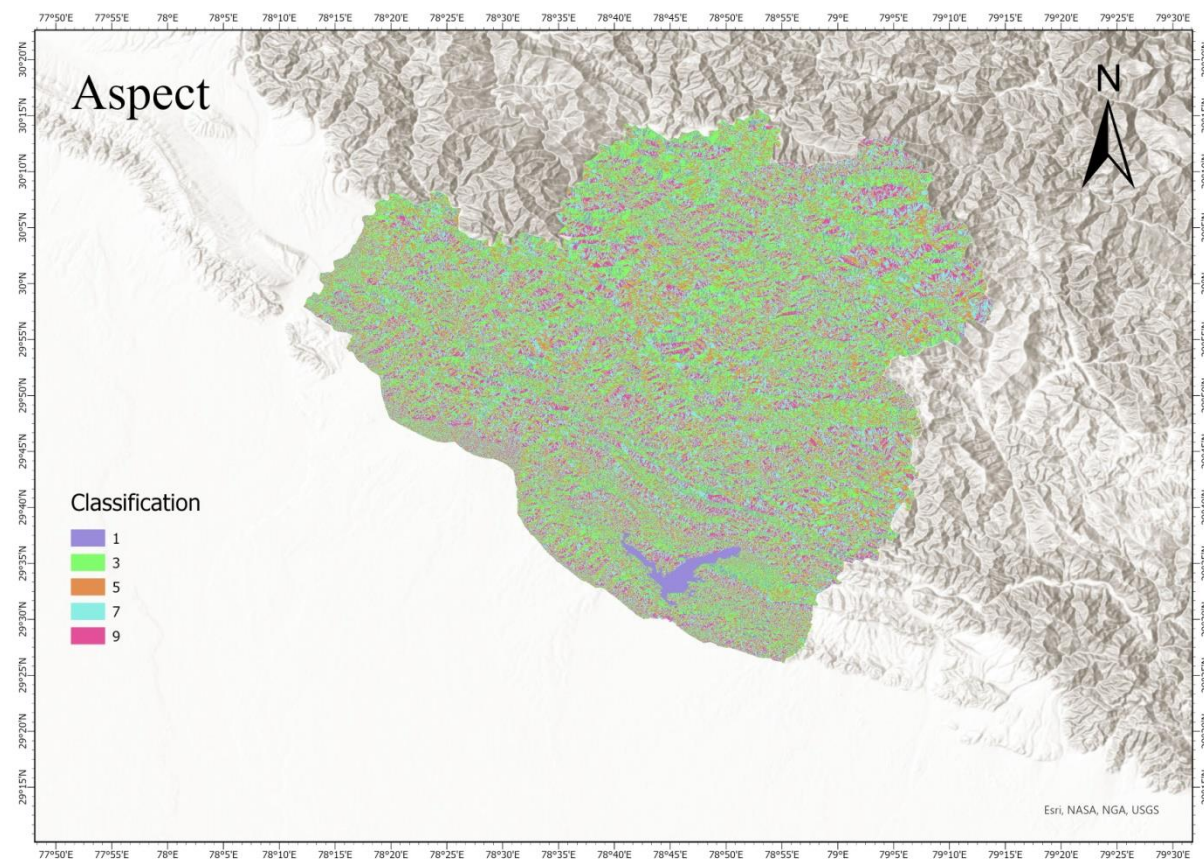# D.Reclassified NDVI data of Pauri Garhwal

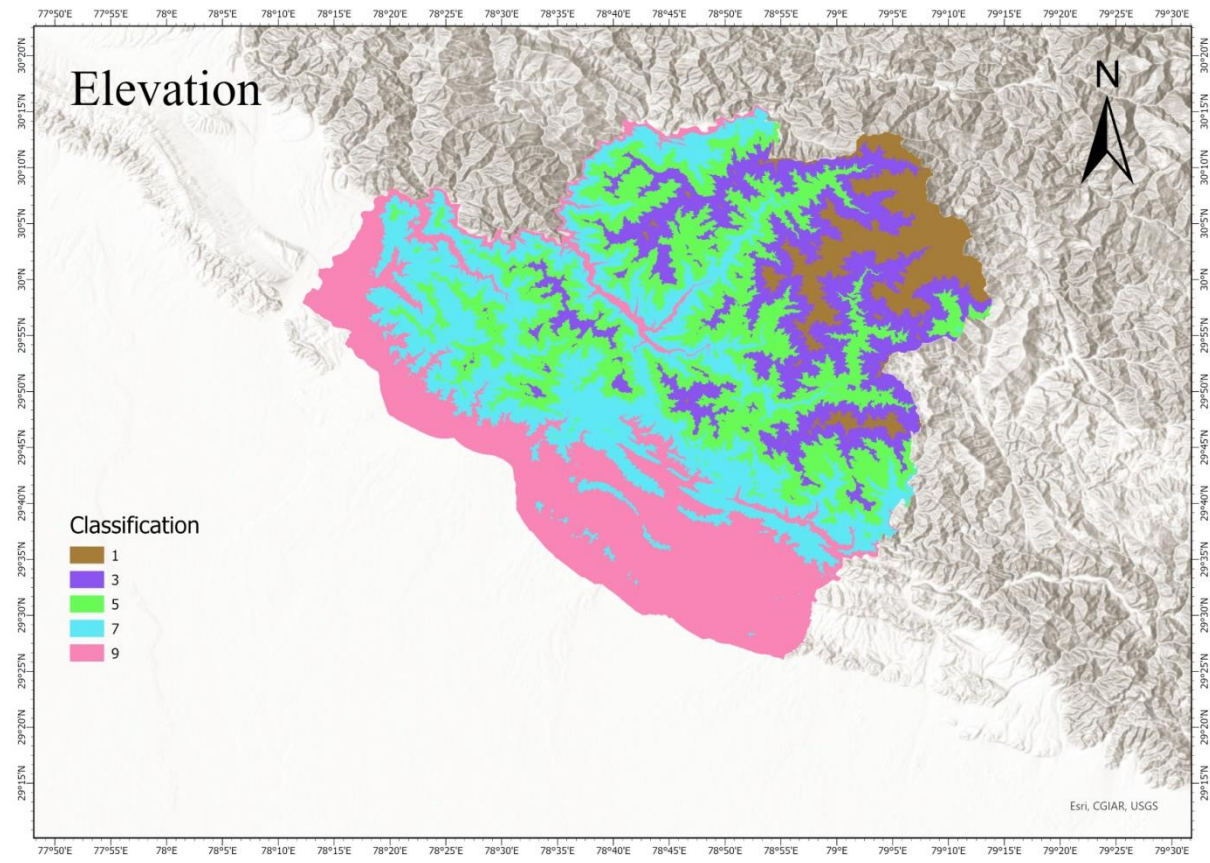# E.Reclassified wind speed data of Pauri Garhwal

F.Reclassified slope data of Pauri Garhwal

G.Reclassified Aspect data of Pauri Garhwal

H.Reclassified Elevation data of Pauri Garhwal

- ## Analytical Hierarchy Process (AHP)

  A pairwise comparison matrix was prepared using expert judgment and literature review. Weights were calculated for each factor, and the consistency ratio was checked to ensure acceptable consistency.

- ## Weighted Overlay Analysis

  All reclassified raster layers were integrated using the Weighted Overlay tool in ArcGIS Pro based on the AHP-derived weights to generate the forest fire susceptibility index.

- ## Classification of Risk Zones

  The final forest fire susceptibility map was classified into different risk zones such as very low, low, moderate, high, very high, and extreme using natural breaks classification.
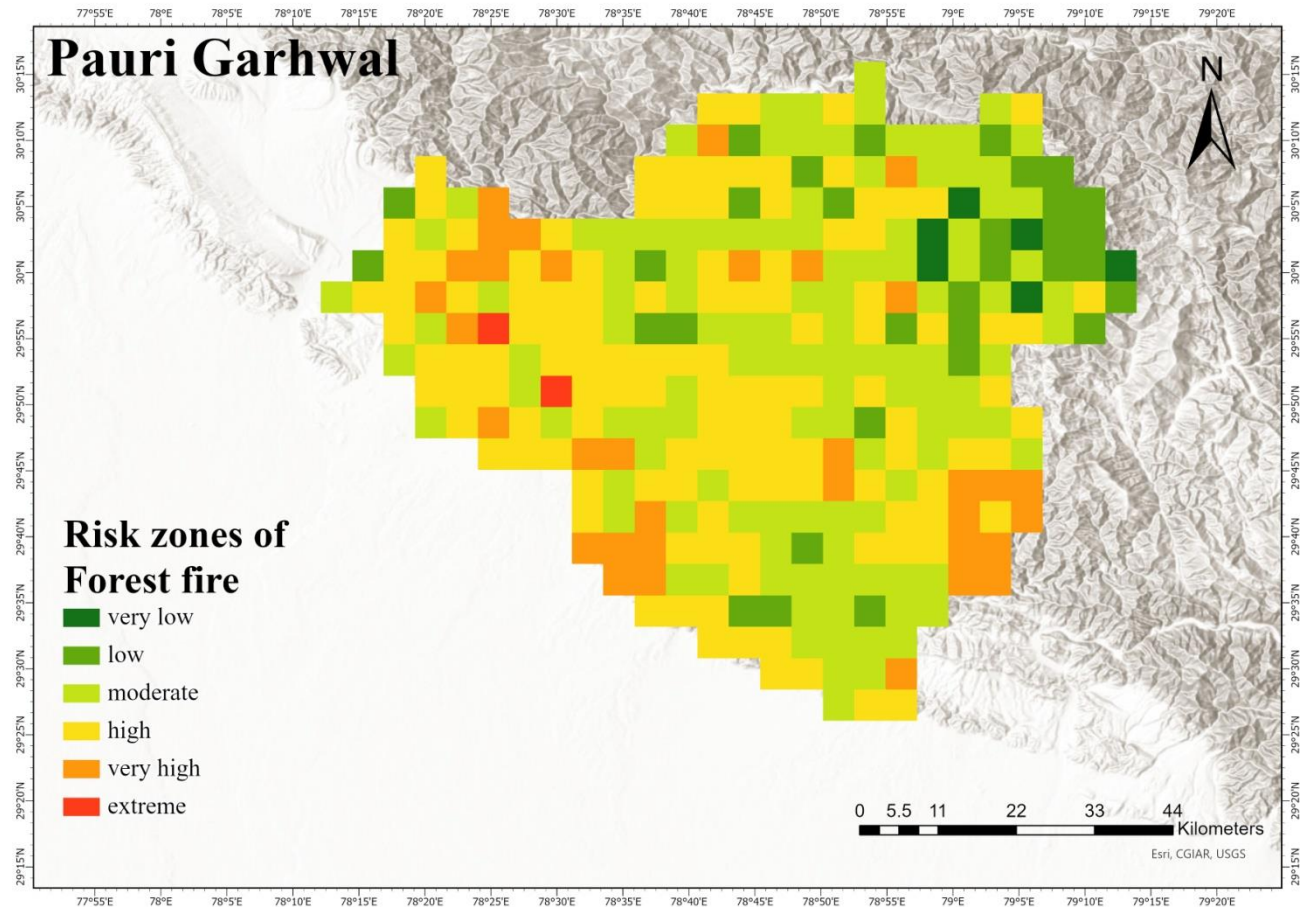
- ## Area and Percentage Calculation

  The area of each risk zone was calculated using attribute table and field calculator tools. Percentage contribution of each risk category was computed for comparative analysis.

- ## Map Preparation and Visualization

  The final forest fire risk map was prepared in Layout View by adding essential map elements such as title, legend, scale bar, north arrow, and coordinate grid for presentation

4. Results

Key Findings:

- Total area of the district = 5180.93km^2

- Table:

Risk zone	Area in km^2	Area percentage
Very low	100.6426	1.9425586126530725%
Low	506.7184	9.780452989304258%
Moderate	1968.5312	37.995712%
High	2012.4940	38.8442621958037%
Very High	558.9552	10.788705%
Extreme	33.593407	0.6484049570339245%

Statistical results:

The area statistics of forest fire risk zones in Pauri Garhwal district were calculated based on the final susceptibility map. The total geographical area considered for the analysis is 5180.93 km². The high-risk zone occupies the maximum area of 2012.49 km², accounting for 38.84% of the total area. The moderate-risk zone covers 1968.53 km², which represents 37.99% of the district area.

The very high-risk zone extends over 558.96 km² (10.79%), indicating areas with severe fire potential, while the extreme-risk zone covers a comparatively small area of 33.59 km², contributing 0.65% of the total area. The low-risk zone covers 506.72 km² (9.78%), and the very low-risk zone occupies 100.64 km² (1.94%).

Overall, the area statistics indicate that a large proportion of Pauri Garhwal district falls under moderate to high forest fire risk, emphasizing the need for effective fire prevention and management strategies.

5.Discussion

The forest fire susceptibility map generated for Pauri Garhwal district clearly shows that forest fires in the region are strongly influenced by a combination of vegetation condition, terrain, and climatic factors. The application of the Analytical Hierarchy Process allowed systematic weighting of multiple factors such as LULC, NDVI, slope, aspect, elevation, land surface temperature, rainfall, and wind, making the analysis more structured and logical.

The results indicate that a large portion of the district falls under moderate to high fire risk zones. These areas are mainly associated with dense forest cover, grasslands, steeper slopes, higher temperatures, and lower rainfall conditions, which together create favourable conditions for fire ignition and spread. Pine-dominated forest areas contribute significantly to higher fire risk due to the accumulation of dry needles during the dry season.

Low and very low risk zones are mostly concentrated in areas with water bodies, agricultural land, built-up regions, and zones receiving relatively higher moisture. The limited extent of extreme risk zones suggests that very severe fire-prone conditions are localized rather than widespread.

Overall, the results demonstrate that the GIS-based AHP approach is effective in identifying forest fire vulnerable zones in Pauri Garhwal. The generated map can support forest departments in prioritizing high-risk areas for fire prevention, monitoring, and resource allocation, thereby reducing potential environmental and socio-economic impacts.

6.Conclusion

The present study successfully applied GIS and the Analytical Hierarchy Process (AHP) to assess forest fire susceptibility in Pauri Garhwal district. By integrating multiple environmental and climatic factors, the analysis identified areas with varying levels of fire risk. The results reveal that a major portion of the district falls under moderate to high fire risk zones, particularly in forested and grassland regions. The generated forest fire risk map provides valuable information for fire prevention, planning, and management, and can assist authorities in taking timely and effective mitigation measures.

References:

- CHRS

- USGS Earth explorer

- ArcGIS Pro

- Open Topography

- NASA SRTM

- ESA Sentinel-2

Keywords:

GIS, Remote Sensing, NDVI, Forest Fire Susceptibility, AHP, Pauri Garhwal, LST, Landsat 8, DEM, Slope, Aspect, Weighted Overlay, Reclassification.