Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

BURN SEVERITY ASSESSMENT IN UTTARKASHI DISTRICT, UTTARAKHAND USING SATELLITE IMAGERY AND REMOTE SENSING TECHNIQUES

SHIKHA GOSWAMI
Research Scholar, College of Technology, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Uttarakhand.

ALAKNANDA ASHOK
Dean, College of Technology, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Uttarakhand.

Abstract

The Uttarakhand region, located in the Indian Himalayas, is highly susceptible to forest fires due to its unique climatic and topographic conditions. The increasing frequency and intensity of forest fires in Uttarkashi district of Uttarakhand, driven by climate change [1] and human activities, have caused significant damage to the region's ecosystem. This research aims to utilize Landsat-8 satellite imagery to assess burn severity [18] in Uttarkashi district of Uttarakhand's Forest regions. The study employs the Normalized Burn Ratio (NBR) [6] and its derivative, the differenced Normalized Burn Ratio (dNBR) [7], to quantify fire impact. These indices, derived from multispectral Landsat [24] [29] data, are powerful tools for evaluating the extent and intensity of fires. The analysis provides spatial patterns of fire damage over time, specifically from 2020 to 2024, and helps understand post-fire [27] regeneration and recovery processes. The research provides insights into the effectiveness of satellite data in burn severity mapping, assisting local authorities in managing forest recovery efforts and mitigating future fire hazards. The study of burn severity in Uttarkashi district from 2020 to 2024 shows significant fluctuations. In 2020, unburned areas accounted for the majority, while high severity fires affected 11%. By 2021, unburned areas increased to 35.89%, while high severity zones decreased to 6.15%. By 2022, high severity fires increased to 16.77%, while unburned areas increased to 30.35%. In 2024, unburned areas expanded to 44.91%.

Keywords: Burn Severity, Uttarakhand, Landsat-8, NBR, dNBR, NDVI, Forest Fires, Remote Sensing, Fire Monitoring.

1. INTRODUCTION

Forest fires have become a recurring issue in Uttarakhand, India, especially due to its geographical features and prevailing climatic conditions. The state's forest cover, accounting for over 60% of its total area, is highly vulnerable to wildfires. The combination of steep slopes, dry seasons, and increasing human activities such as tourism and agriculture increases the likelihood of fire outbreaks. These fires cause ecological damage and socioeconomic implications for local communities that depend on forest resources for their livelihoods.

Burn severity [18] refers to the magnitude of ecological change and damage caused by wildfires. Identifying and quantifying burn severity [18] is crucial for effective post-fire management [12], ecological restoration, and hazard mitigation. Landsat-8 satellite imagery provides an accessible and accurate means of assessing fire severity [18] over

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

large areas. The study aims to utilize satellite-based indices such as NBR and dNBR [7] to analyze burn severity in Uttarakhand for forest fires occurring between 2020 and 2024.

The study aims to identify and assess burn severity [18] in Uttarkashi district using Landsat-8 satellite imagery. Key objectives include mapping burn severity, evaluating the ecological impact of fires on various forest types, monitoring post-fire recovery [11], and developing a burn severity classification system. The results will aid forest management in fire prevention, response, and rehabilitation efforts.

The study aims to identify and assess burn severity in Uttarkashi district using Landsat-8[29] satellite imagery. Key objectives include mapping burn severity, evaluating the ecological impact of fires on various forest types, monitoring post-fire recovery [11], and developing a burn severity classification system. The results will aid forest management in fire prevention, response, and rehabilitation efforts.

The research covers the Uttarkashi district, analyzing multiple years of fire data across different altitudes and forest types. Satellite remote sensing and burn indices will be utilized to assess fire impacts and support effective forest management. Also, it analyses the spatial patterns of fire severity [28] [29] and evaluates the relationship between burn severity and environmental variables, such as vegetation type and topography.

High-severity burn areas will likely take decades to fully recover, with risks of soil erosion and biodiversity loss. Restoration efforts, including controlled burns and reforestation, should focus on these high-risk areas.

The Google Cloud Platform powers the Google Earth Engine (GEE), a cloud-based computation and analysis tool for geospatial data. It has various freely available remote sensing datasets and is leveraged to gather Normalized Difference Vegetation Index (NDVI)

1.1 Background and Motivation

The recurrence of forest fires in Uttarakhand is a major environmental [4] and socio-economic issue, driven by both natural and anthropogenic factors. The forest fire season typically occurs from February to June, with peak activity seen in April and May. Rising temperatures, prolonged dry seasons, and increased human activity have contributed to the increased frequency and intensity of these fires.

Forest fires are known to alter soil composition, destroy vegetation, release stored carbon, and disrupt water cycles. The importance of accurately identifying burn severity lies in its application to forest management and restoration efforts. This is where remote sensing and satellite imagery become valuable tools.

1.2 Burn Severity and its Importance

Burn severity refers to the extent of environmental damage [2] caused by a fire, including the level of vegetation destruction and changes in soil properties. It is a key metric for understanding fire impact and planning recovery strategies.

ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

The identification and classification of burn severity are crucial for several reasons:

- **Ecological Restoration:** Burn severity maps help prioritize areas for reforestation and ecological restoration.
- **Fire Risk Assessment:** Mapping burn severity can improve the ability to predict future fire risks and help implement preventive measures.
- **Carbon Emissions Monitoring:** Estimating burn severity provides insights into carbon emissions released due to vegetation combustion.

1.3 Remote Sensing in Burn Severity Assessment

Satellite-based remote sensing, especially through the use of the Landsat [28] program, has become an essential tool for monitoring [30] and assessing wildfire damage. Landsat-8, equipped with the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), provides a valuable dataset for assessing fire impact due to its spectral resolution, coverage, and historical data availability.

By leveraging multispectral data, researchers can compute indices like the NBR and dNBR [7], which are useful in distinguishing between burned and unburned areas. This study utilizes these indices to map burn severity in Uttarakhand, which has been increasingly affected by forest fires.

2. LITERATURE REVIEW

This section reviews existing research on the use of remote sensing, specifically Landsat [29] data, for fire monitoring and burn severity assessment. Key areas discussed include fire ecology [15], remote sensing techniques, and the role of climate in fire outbreaks.

2.1 Wildfires and Burn Severity

Burn severity refers to the degree of environmental damage caused by a fire, measured by the extent to which vegetation is consumed and soil is affected. High burn severity can result in long-term ecological damage, including loss of vegetation, increased erosion, and altered hydrological patterns.

Previous studies have demonstrated that remote sensing tools, particularly satellite imagery, can be effectively used to estimate burn severity over large geographic areas (Lentile et al., 2006).

2.2 Remote Sensing for Burn Severity Assessment

Remote sensing has become an indispensable tool for monitoring wildfires. Landsat [29] satellite imagery, which provides moderate-resolution imagery of the Earth's surface, is one of the most commonly used datasets for mapping burn severity. The Normalized Burn Ratio (NBR) [6], derived from near-infrared (NIR) and shortwave infrared (SWIR) bands, has proven effective in detecting areas affected by fire.

ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

2.3 Landsat Satellites for Forest Fire Monitoring

Landsat 8, launched in 2013, continues NASA's mission of Earth observation. Its Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) capture data in multiple spectral bands, including those essential for detecting vegetation health and burn severity. The specific utility of Landsat 8 in burn severity studies has been validated through numerous global case studies, from the United States to Australia (Key and Benson, 2006).

3. STUDY AREA

Uttarkashi district is located in Uttarakhand state in the northern part of India as shown in figure 1, bordered by the Himalayas to the north. This district of Uttarakhand state is known for its rich biodiversity, encompassing a range of ecosystems from subtropical forests in the lower altitudes to alpine meadows in the higher altitudes.

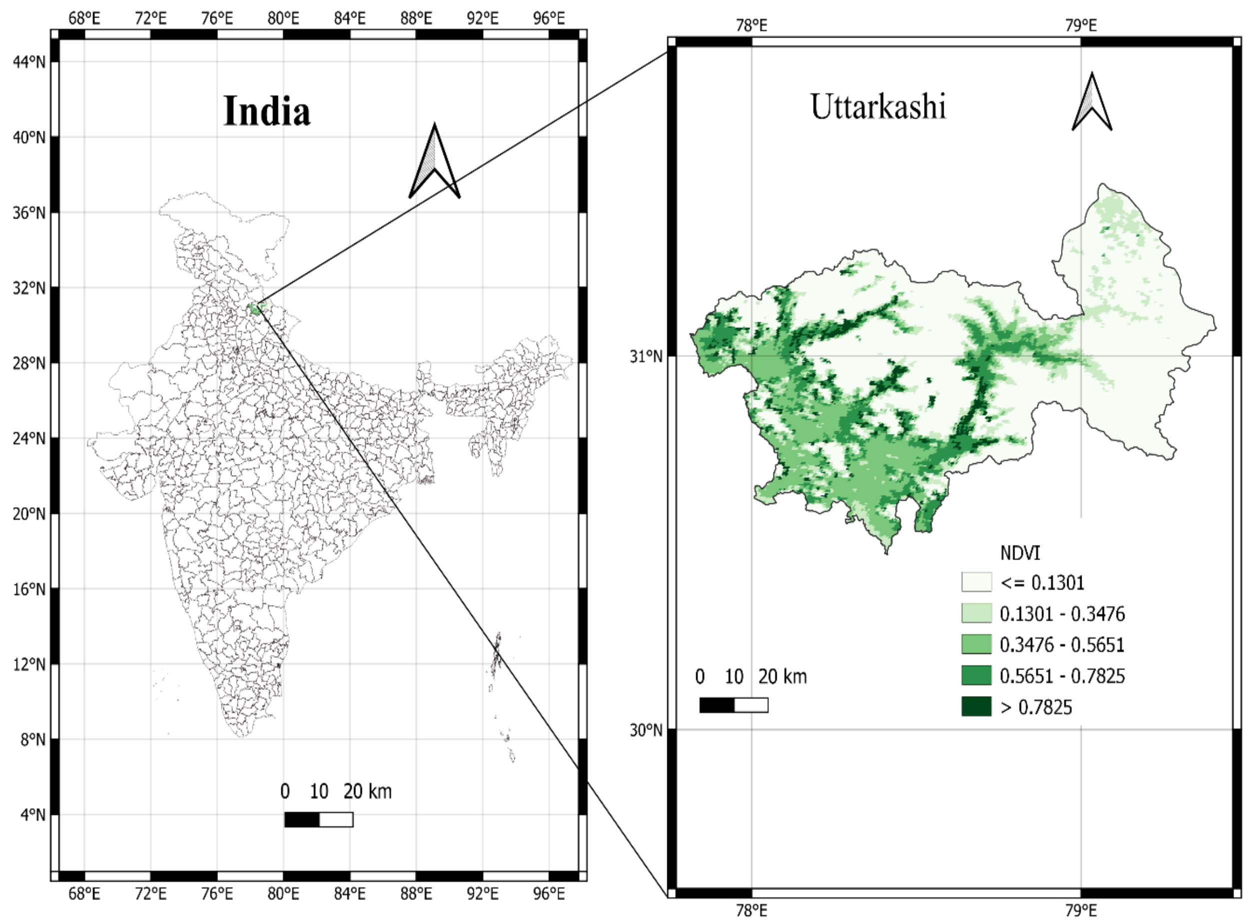

Figure 1: The study area: Uttarkashi along with its NDVI values

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

The forests in Uttarkashi can be broadly classified into several types based on altitude, climate, and vegetation.

1) **Tropical Deciduous Forests:** Found at lower altitudes (below 1000 meters), these forests are dominated by species like Sal (Shorea robusta) and Teak (Tectona grandis). They shed their leaves during dry seasons to conserve water.
2) **Subtropical Pine Forests:** Located between 1000 and 1800 meters, these forests are primarily composed of Chir Pine (Pinus roxburghii), which thrives in drier, warmer conditions.
3) **Temperate Broadleaf Forests:** Occurring between 1500 and 3000 meters, these forests are dense and contain species like Oak (Quercus leucotrichophora)[8] and Rhododendron (Rhododendron arboreum). These forests are vital for moisture retention and maintaining ecological balance.
4) **Subalpine Forests:** At altitudes between 3000 and 3500 meters, subalpine forests [8] feature coniferous trees such as Deodar (Cedrus deodara) and Blue Pine (Pinus wallichiana), adapted to the cold, harsh climate.
5) **Alpine Meadows and Scrub:** Found above 3500 meters, this zone consists of grasslands and shrubs like Juniper (Juniperus spp.), marking the transition from forests to alpine vegetation.

These forest types form a rich and diverse ecosystem, providing critical environmental services and supporting biodiversity in Uttarkashi.

3.1. Climate and Fire Season

Uttarkashi District in Uttarakhand experiences a diverse climate due to its varying altitude, from subtropical valleys to alpine peaks. The lower regions (below 1500 meters) have a subtropical climate, with hot summers reaching up to 35°C and mild winters around 5°C. Annual rainfall is moderate, mostly during the monsoon (June to September).

Mid-altitude areas (1500 to 3000 meters) experience a temperate climate, with cool summers (15°C to 25°C) and cold winters, often bringing snowfall. The higher elevations (above 3000 meters) face a harsh alpine climate, with short, cool summers and long, freezing winters, where temperatures drop below -15°C and snow is common.

The fire season in Uttarkashi typically runs from April to June, coinciding with the dry, pre-monsoon months. Rising temperatures and dry vegetation create ideal conditions for wildfires, especially in the subtropical pine forests, dominated by Chir Pine, whose resin-rich wood is highly flammable.

Human activities such as farming, grazing, and campfires can trigger fires, which are exacerbated by pre-monsoon winds that spread flames rapidly. With the onset of the monsoon rains in late June, fire risks sharply decline. Managing wildfires during this period is crucial for protecting Uttarkashi's forests and biodiversity.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

3.2 Human Activities and Fire Risks

The increasing frequency of forest fires in Uttarakhand can be partly attributed to human activities such as illegal logging, land clearing for agriculture, and tourism. These activities often lead to the accumulation of flammable material in forested areas, increasing the likelihood of accidental fires.

4. DATA AND METHODOLOGY

Satellite Data:

The Google Cloud Platform powers the Google Earth Engine (GEE), a cloud-based computation and analysis tool for geospatial data. It has various freely available remote sensing datasets and is leveraged to gather Normalized Difference Vegetation Index (NDVI)

Landsat 8 imagery from the United States Geological Survey (USGS) database was used. Both pre-fire and post-fire [27] images were selected for the years 2016 and 2020, during significant fire events.

4.1. Satellite Data: Landsat-8

Landsat 8, launched by NASA and the USGS in 2013, is part of the Landsat [28] program, which has provided continuous Earth observation data since 1972. The satellite captures high-resolution imagery, essential for monitoring land use, ecosystems, and environmental changes [2]. Landsat 8 is equipped with two key instruments: The **Operational Land Imager (OLI)** and the **Thermal Infrared Sensor (TIRS)**.

The **OLI** collects data in nine spectral bands, including visible, near-infrared, and shortwave infrared, with a spatial resolution of 30 meters for most bands and 15 meters for the panchromatic band. This enables detailed analysis of vegetation, water bodies, and urban areas. The **TIRS** measures thermal infrared radiation in two bands with a 100-meter resolution, useful for monitoring [30] surface temperatures, especially in fire-prone areas.

Landsat 8's imagery is widely used for assessing burn severity, as indices like the **Normalized Burn Ratio (NBR)** [6] can be calculated from the spectral bands. The satellite's revisit time of 16 days provides consistent data, making it a valuable tool for long-term monitoring. Its global coverage and free, open data policy have made Landsat 8 an indispensable resource for researchers and policymakers addressing issues like deforestation, urban growth, and wildfire impacts.

The primary source of satellite data for this study is the Landsat-8 satellite, which provides high-resolution multispectral imagery. Landsat-8 is equipped with the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS), making it suitable for burn severity assessments.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

4.2. MOD10A1.061 Terra Snow Cover Daily Global 500m (MODIS)

Snow cover, fractional snow cover, snow albedo, and quality assessment (QA) data are all included in the MOD10A1 V6.1 Snow Cover Daily Global 500m package. The Normalized Difference Snow Index (NDSI) and other criterion tests are used in a snow mapping technique that provides the basis for snow cover data.

4.3 MODIS(NDVI)

The Terra Moderate Resolution Imaging Spectroradiometer (MODIS) Vegetation Indices (MOD13Q1) Version 6 data is generated every 16 days at 250 meter spatial resolution. It provides two primary vegetation layers: The Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI). The HDF file includes MODIS reflectance bands, observation layers, and the best available pixel value.

4.4 Survey of India

The Survey of India (SOI), founded in 1767, is a world-renowned surveying organization with over 250 years of history. Its main duty is to prepare topographical maps of India and advise the Indian government on survey issues. The SOI produces valuable geographic information, employing a large workforce of skilled professionals. The HDF file will have four observation layers, two quality layers, vegetation layers, and MODIS reflectance bands.

Key Spectral Bands for Burn Severity Analysis:

1) Band 4 (Red): 0.64 – 0.67 µm (30m resolution)

- Application: Reflects well from vegetation, useful for distinguishing between vegetation and burned areas. It is commonly used in calculating vegetation indices like NDVI (Normalized Difference Vegetation Index).

2) Band 5 (Near Infrared, NIR): 0.85 – 0.88 µm (30m resolution)

- Application: Reflects strongly from healthy vegetation but decreases significantly in burned or stressed areas. This band is crucial for identifying changes in vegetation health pre- and post-fire.

3) Band 6 (Shortwave Infrared 1, SWIR1): 1.57 – 1.65 µm (30m resolution)

- Application: Sensitive to moisture content in vegetation and soil. SWIR1 is highly reflective in burned areas [9] due to the loss of vegetation and increased exposure of soil and charred material.

4) Band 7 (Shortwave Infrared 2, SWIR2): 2.11 – 2.29 µm (30m resolution)

- Application: SWIR2 is particularly useful for detecting burned areas, as charred vegetation and soil have strong reflectance in this band. It is critical for assessing fire damage.

ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

Commonly Used Combinations:

1) Normalized Burn Ratio (NBR):

- Formula: (NIR - SWIR2) / (NIR + SWIR2)
- Bands Used: Band 5 (NIR) and Band 7 (SWIR2).
- Application: NBR is widely used to map burn severity by comparing pre-fire and post-fire images.

2) Differenced Normalized Burn Ratio (ΔNBR):

- Formula: NBR (pre-fire) - NBR (post-fire)
- Bands Used: Band 5 (NIR) and Band 7 (SWIR2).
- Application: ΔNBR helps quantify the change in burn severity, categorizing areas into low, moderate, and high burn severity zones.

3) Normalized Difference Vegetation Index (NDVI):

- Formula: (NIR - Red) / (NIR + Red)
- Bands Used: Band 5 (NIR) and Band 4 (Red).
- Application: NDVI is used to monitor vegetation health before and after fires, indicating areas of damage.

4.2. Image Preprocessing

Before analysis, the satellite images were subjected to various preprocessing steps:

- **Cloud and Cloud Masking:** Removes clouds and their shadows, which can interfere with the accuracy of the analysis.
- **Snow Masking**: Snow masking is a process used in remote sensing to ensure accurate burn severity assessments and vegetation analysis. It helps focus on vegetation and burn areas without false signals, distinguishing fire damage from snow, and improving vegetation indicators. Snow masking involves spectral thresholds, indices, multi-temporal analysis, and satellite data. It is crucial for assessing burn severity, vegetation, ecosystem studies, and hydrological studies.

4.3. Burn Indices

Burn indices are specialized algorithms or ratios derived from satellite data to assess the severity and extent of burned areas [9] after a wildfire. These indices leverage the spectral properties of vegetation, soil, and charred areas to measure burn impact, allowing for accurate mapping and analysis. The most widely used burn indices include:

1) Normalized Burn Ratio (NBR)

- **Formula:** (NIR - SWIR) / (NIR + SWIR)
- **Bands Used:** Near-infrared (NIR) and Shortwave Infrared (SWIR).

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

- **Description:** NBR is the most commonly used index for detecting burn severity. It compares the reflectance of healthy vegetation (high NIR reflectance) to charred areas (high SWIR reflectance), helping distinguish between burned and unburned areas. It is often used with pre- and post-fire imagery to calculate the difference (ΔNBR) and classify burn severity.

2) Differenced Normalized Burn Ratio (ΔNBR)

- **Formula:** NBR (pre-fire) - NBR (post-fire)
- **Description:** ΔNBR measures the change in burn intensity by comparing NBR before and after the fire event. It is widely used to assess post-fire ecological damage and classify burn severity levels (e.g., low, moderate, high).

3) Normalized Difference Vegetation Index (NDVI)

- **Formula:** (NIR - RED) / (NIR + RED)
- **Bands Used:** Near-Infrared (NIR) and Red.
- **Description:** While NDVI is primarily used for vegetation monitoring, it is also helpful in post-fire assessment. A lower NDVI indicates damage to vegetation, and it can be compared before and after a fire to estimate the impact on plant life.

These burn indices are vital for monitoring post-fire recovery [11], assessing damage, and informing land management and restoration efforts. They help classify burned areas [9] into severity levels, which is crucial for prioritizing post-fire rehabilitation.

4.4. Classification of Burn Severity

Burn severity was classified into different categories based on dNBR values [22]

- High severity: dNBR > 0.66
- Moderate-high severity: dNBR between 0.45 and 0.66
- Moderate severity: dNBR between 0.27 and 0.45
- Low severity: dNBR between 0.1 and 0.27
- Unburned: dNBR < 0.1

These categories help in understanding the degree of ecological damage caused by the fires.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

4.5 Methodology

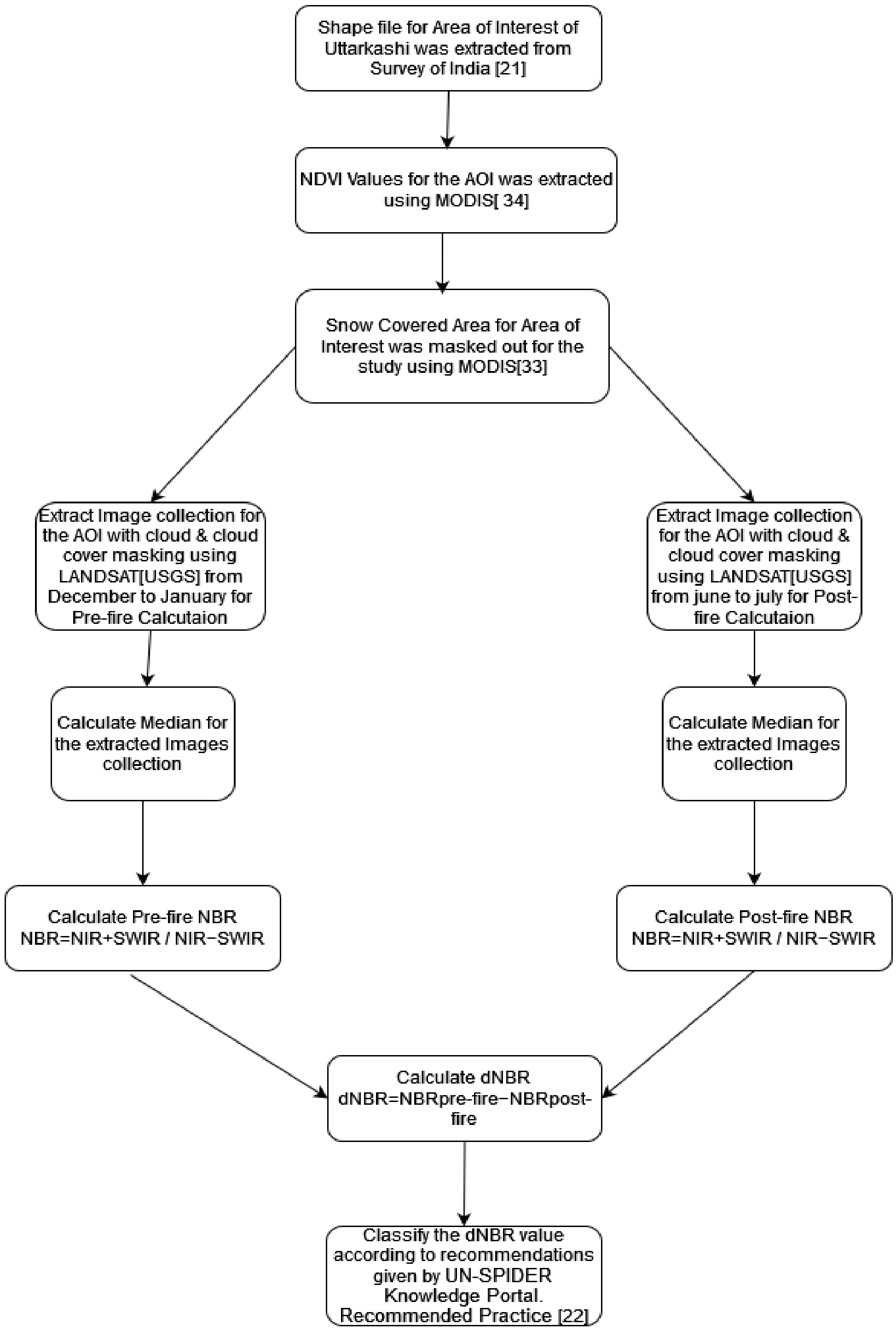

Figure 2: Steps for Burn Severity Mapping

ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

The following steps of the above figure are referred from UN-SPIDER Knowledge Portal, Recommended Practice [22] and it is modified according the study

The steps in the diagram for burn severity identification in Uttarakhand using satellite imagery can be summarized as follows:

1) **Shape File for Area of Interest (AOI):**
   - The shape file for the AOI (Uttarkashi) is extracted using data from the Survey of India.
2) **NDVI Values Extraction:**
   - NDVI (Normalized Difference Vegetation Index) values for the AOI are extracted using MODIS satellite imagery.
3) **Snow Cover Masking:**
   - Snow-covered areas in the AOI are masked out for the analysis using MODIS imagery to ensure that only relevant vegetation data is used for burn severity calculations.
4) **Pre-Fire Image Collection:**
   - Satellite images from the LANDSAT (USGS) collection are used for pre-fire analysis.
   - Cloud and cloud cover are masked, and images are collected for the period from December to January.
5) **Post-Fire Image Collection:**
   - Satellite images from LANDSAT are collected for post-fire analysis.
   - The images are gathered for the period from June to July, with cloud cover masking applied.
6) **Pre-Fire Image Median Calculation:**
   - A median value is calculated for the pre-fire images to derive a baseline for NBR (Normalized Burn Ratio).
7) **Post-Fire Image Median Calculation:**
   - A median value is calculated for the post-fire images to measure the extent of fire damage.
8) **Pre-Fire NBR Calculation:**
   - The pre-fire NBR is calculated using the formula:

$$NBR=NIR-SWIR / NIR+SWIR$$

(Where NIR is the near-infrared band and SWIR is the shortwave infrared band).

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

9) Post-Fire NBR Calculation:

- The post-fire NBR is similarly calculated using the same formula for the post-fire imagery.

10) dNBR Calculation:

- The differenced NBR (dNBR) is calculated using the formula:

$$dNBR = NBRpre\text{-}fire - NBRpost\text{-}fire$$

- This measures the change in burn severity between pre- and post-fire conditions.

11) Classification of Burn Severity:

- The dNBR values are classified into different burn severity levels according to standard thresholds provided by a reference (likely a cited research paper, denoted by [22] in the diagram).

These steps are used to systematically identify and classify burn severity in the Uttarkashi region using Landsat satellite data.

5. RESULTS AND DISCUSSION

5.1. Spatial Distribution of Burn Severity (year 2020-2024)

The spatial distribution of burn severity in Uttarkashi district from 2020 to 2024 reveals significant patterns of wildfire impact across forests as depicted in the table the Class-wise Aera of Forest Burn Severity

Using Landsat-8 satellite imagery, burn severity was assessed through indices such as the Normalized Burn Ratio (NBR) [6] and Differenced Normalized Burn Ratio (ΔNBR).

Table 1: Class-wise Aera of Forest Burn Severity for the year 2020-2025

Year 2020				
Sr. No.	**Class**	**Hectares**	**Percentage**	**Pixels**
1	High Severity	63796.95	11	708855
2	Moderate-high Severity	42877.17	7.39	476413
3	Moderate-low Severity	43268.67	7.46	480763
4	Low Severity	94288.32	16.25	1047648
5	Unburned	180710.55	31.15	2007895
6	Enhanced Regrowth, Low	89240.85	15.38	991565
7	Enhanced Regrowth, High	64983.15	11.2	722035
Year 2021				
Sr. No.	**Class**	**Hectares**	**Percentage**	**Pixels**
1	High Severity	43031.25	6.15	478125
2	Moderate-high Severity	28383.75	4.06	315375
3	Moderate-low Severity	30636.09	4.38	340401
4	Low Severity	103441.05	14.78	1149345
5	Unburned	251229.51	35.89	2791439
6	Enhanced Regrowth, Low	120949.56	17.28	1343884
7	Enhanced Regrowth, High	118037.43	16.86	1311527

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

Year 2022				
Sr. No.	**Class**	**Hectares**	**Percentage**	**Pixels**
1	High Severity	112044.15	16.77	1244935
2	Moderate-high Severity	47152.89	7.06	523921
3	Moderate-low Severity	63048.51	9.44	700539
4	Low Severity	131334.57	19.66	1459273
5	Unburned	202791.42	30.35	2253238
6	Enhanced Regrowth, Low	75427.38	11.29	838082
7	Enhanced Regrowth, High	35045.46	5.24	389394
Year 2023				
Sr. No.	**Class**	**Hectares**	**Percentage**	**Pixels**
1	High Severity	6002.91	0.98	66699
2	Moderate-high Severity	10885.23	1.78	120947
3	Moderate-low Severity	25098.03	4.1	278867
4	Low Severity	107330.31	17.52	1192559
5	Unburned	255364.29	41.68	2837381
6	Enhanced Regrowth, Low	114911.1	18.76	1276790
7	Enhanced Regrowth, High	87713.37	14.32	974593
Year 2024				
Sr. No.	**Class**	**Hectares**	**Percentage**	**Pixels**
1	High Severity	10351.08	1.34	115012
2	Moderate-high Severity	20814.39	2.7	231271
3	Moderate-low Severity	47706.84	6.18	530076
4	Low Severity	110719.89	14.34	1230221
5	Unburned	346613.76	44.91	3851264
6	Enhanced Regrowth, Low	129633.39	16.8	1440371
7	Enhanced Regrowth, High	102134.79	13.23	1134831

The analysis of burn severity over the years 2020 to 2024 reveals significant fluctuations in the fire-affected areas of the Uttarkashi district

In 2020, the unburned area constituted the largest portion (31.15%), while high severity fires affected 11% of the region. Low severity areas made up 16.25%, and enhanced regrowth was prominent, with low and high regrowth collectively accounting for over 26%.

In 2021, the unburned area increased significantly to 35.89%, while high severity zones decreased to 6.15%. Enhanced regrowth became more dominant, with 34.14% of the total area showing regrowth.

By 2022, high severity fires surged to 16.77%, while the unburned area [25] slightly decreased to 30.35%. Low severity burns accounted for 19.66%, with regrowth still playing a significant role.

In 2023, the unburned area increased dramatically to 41.68%, and high severity [12] burns dropped to a minimal 0.98%. Regrowth areas remained stable but slightly reduced compared to previous years.

In 2024, unburned areas further expanded to 44.91%, while high severity burn areas showed a slight increase to 1.34%. Regrowth continued to contribute significantly, highlighting the region’s recovery patterns [27] from fires over time. These findings indicate a general trend of decreasing burn severity and increasing regrowth.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

5.2 The following figure shows the year-wise maps of Uttarkashi Prefire, Postfire, Prefire-nbr, Postfire-nbr, dnbr_classified

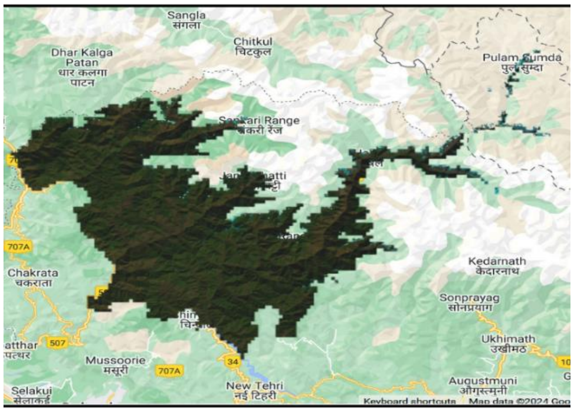

Figure 3: uttarkashi_2020_prefire

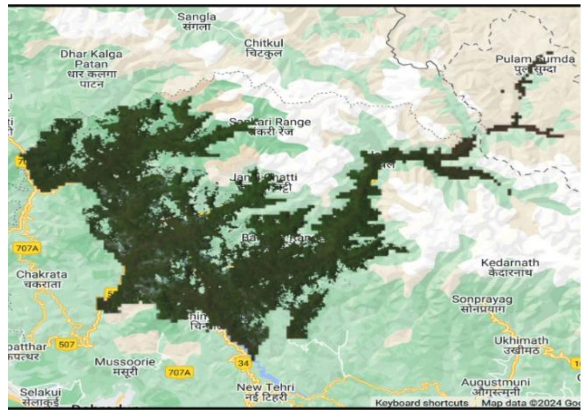

Figure 4: uttarkashi_2020_post fire

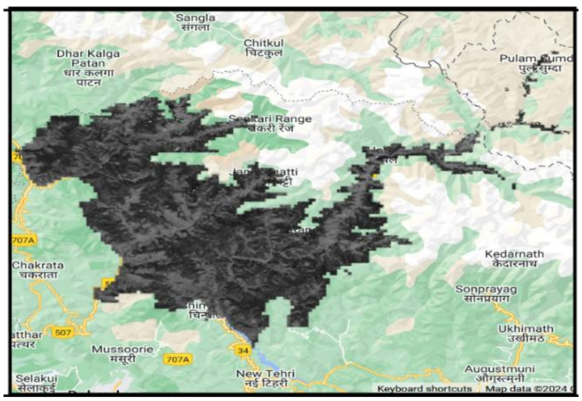

Figure 5: uttarkashi_2020_prefire_nbr

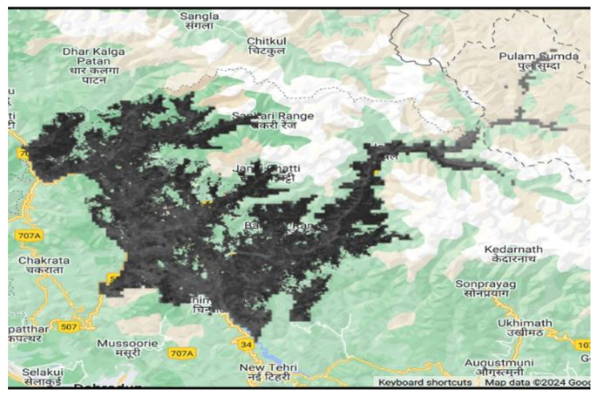

Figure 6: uttarkashi_2020_postfire_nbr

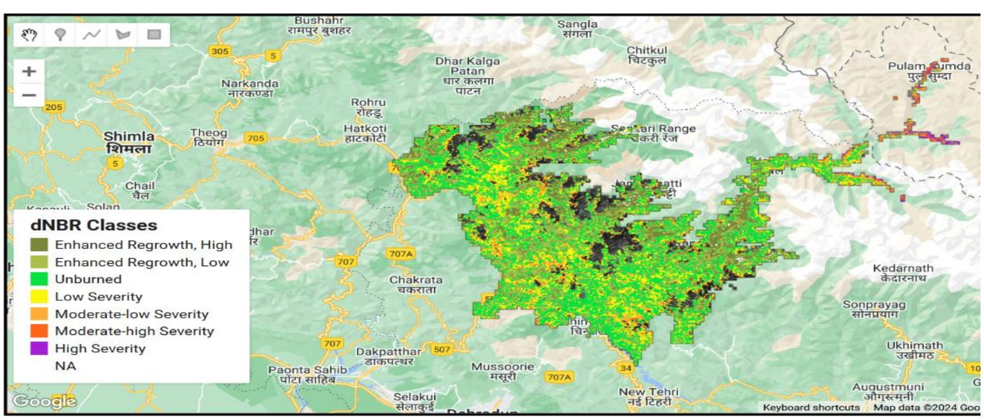

Figure 7: uttarkashi_2020_dnbr_classified

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

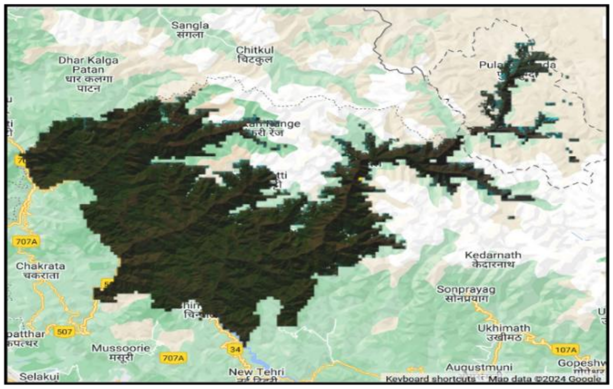

Figure 8: uttarkashi_2021_prefire

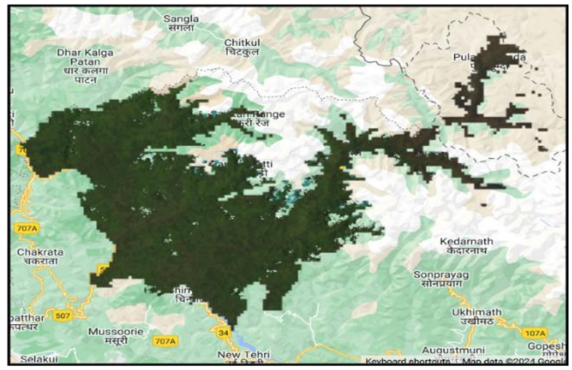

Figure 9: uttarkashi_2021_postfire

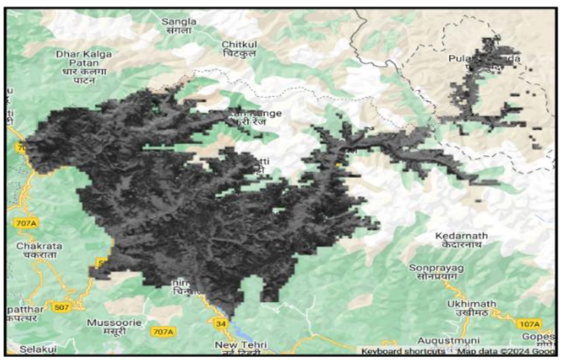

Figure 10: uttarakashi_2021_prefire_nbr

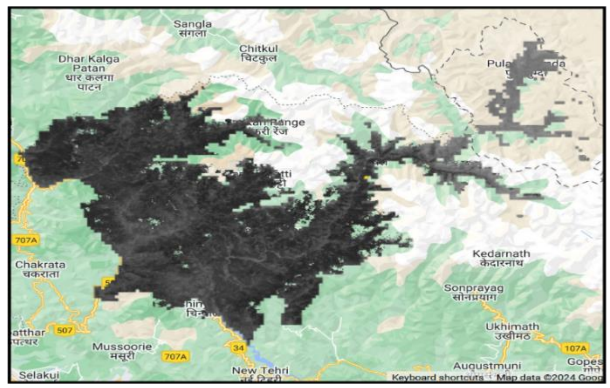

Figure 11: uttarkashi_2021_postfire_nbr

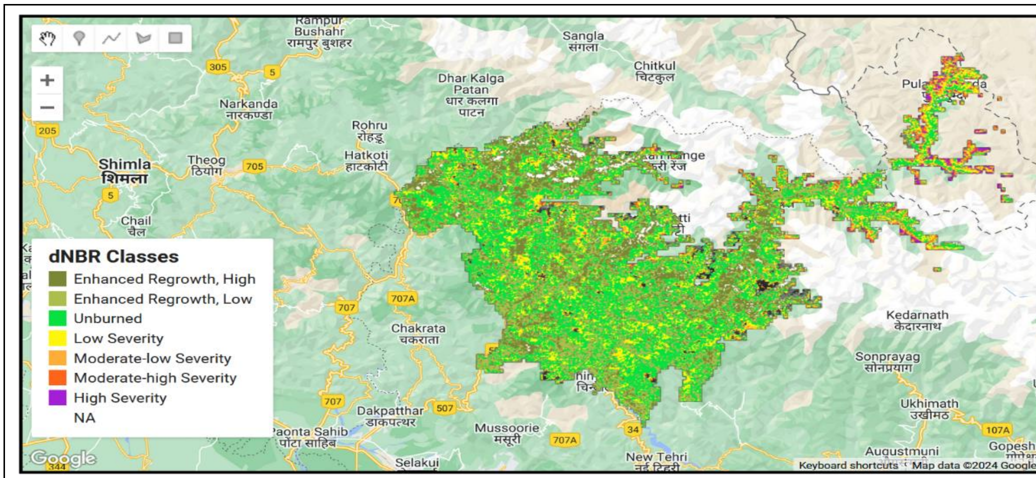

Figure 12: uttarkashi_2021_dnbr_classified

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

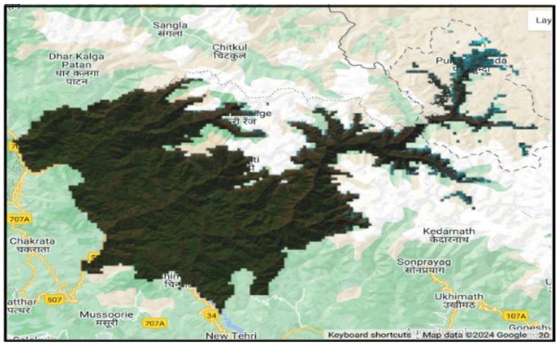

Figure 13: uttarkashi_2022_prefire

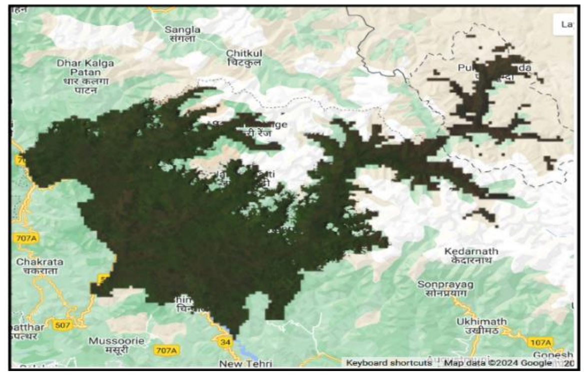

Figure 14: uttarkashi_2022_postfire

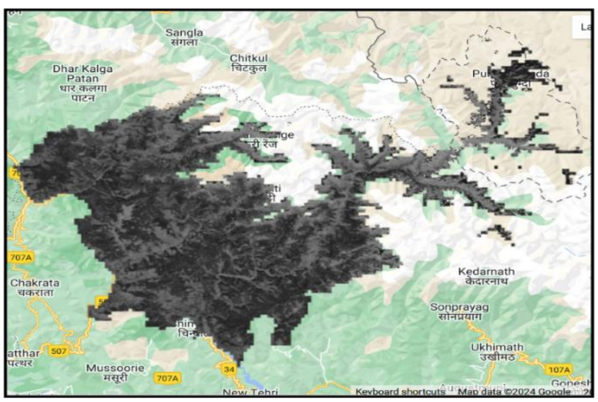

Figure 15: uttarkashi_2022_prefire_nbr

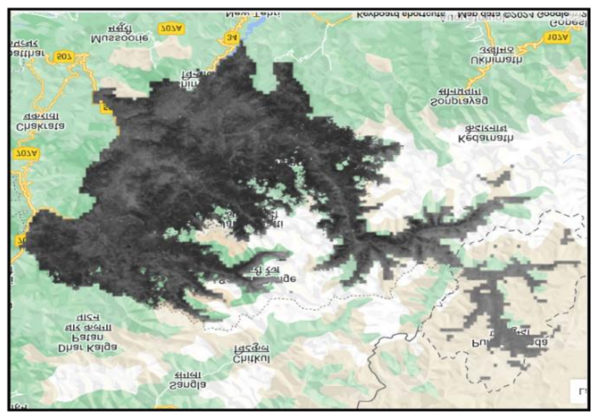

Figure 16: uttarkashi_2022_postfire_nbr

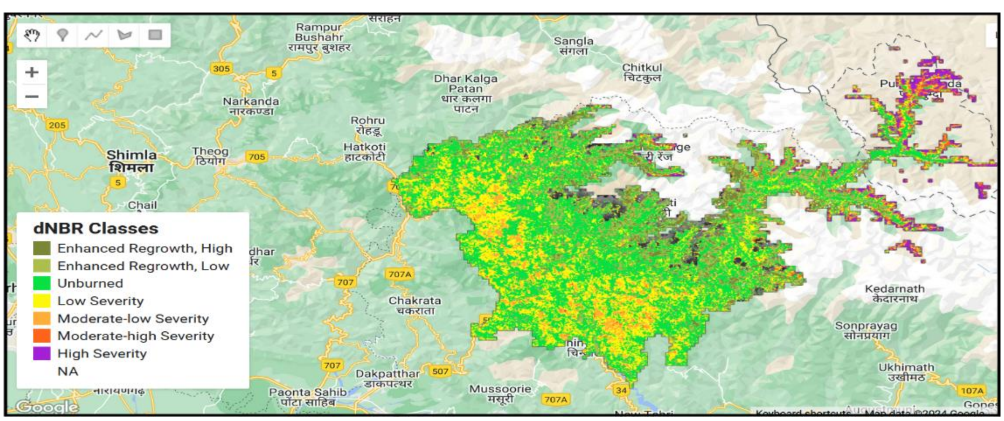

Figure 17: uttarkashi_2022_dnbr_classified

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

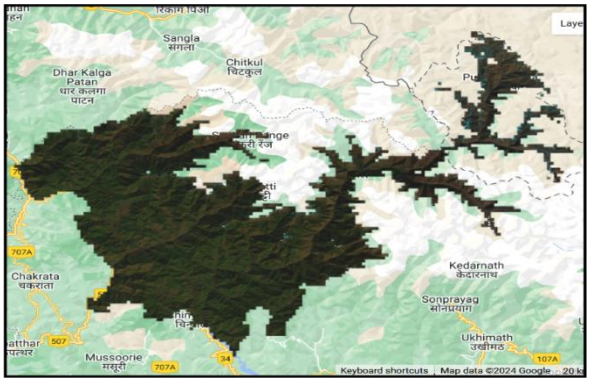

Figure 18: uttarkashi_2023_prefire

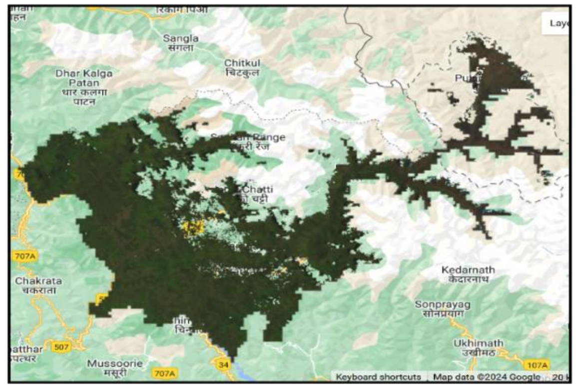

Figure 19: uttarkashi_2023_postfire

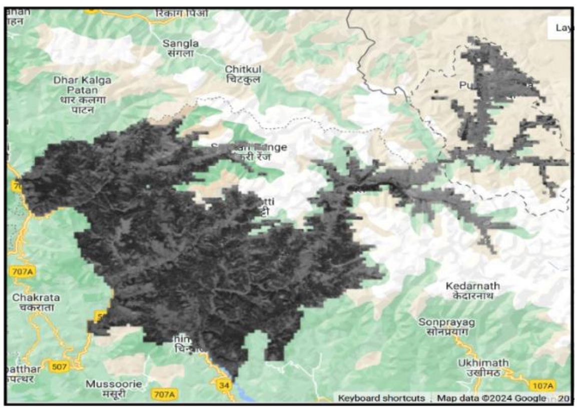

Figure 20: uttarkashi_2023_prefire_nbr

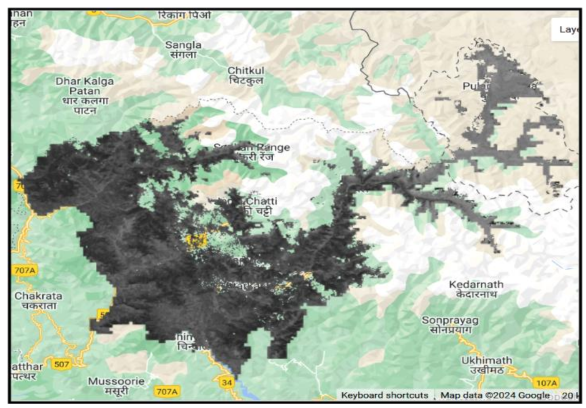

Figure 21: uttarkashi_2023_postfire_nbr

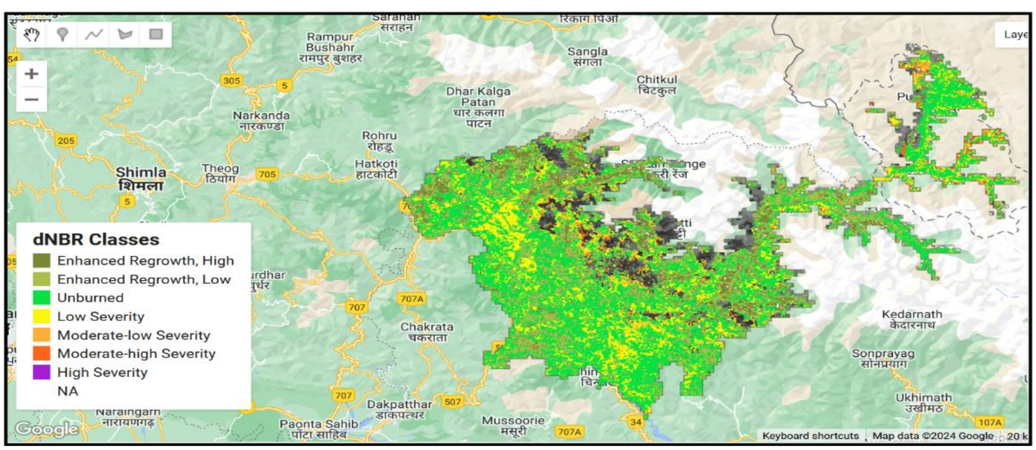

Figure 22: uttarkashi_2023_dnbr_classified

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

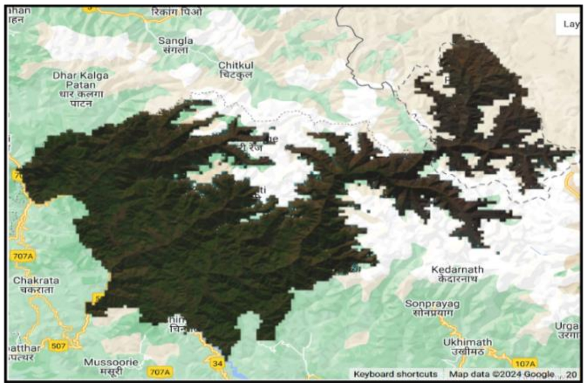

Figure 23: uttarkashi_2024_prefire

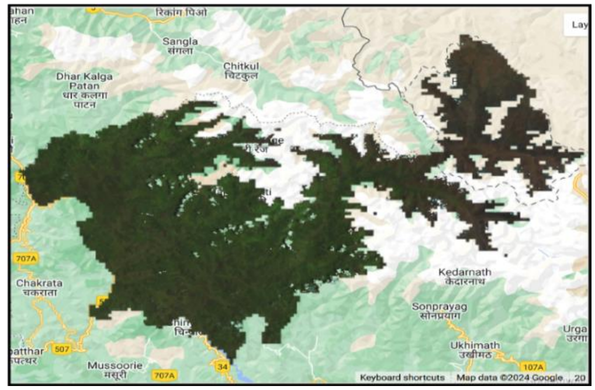

Figure 24: uttarkashi_2024_postfire

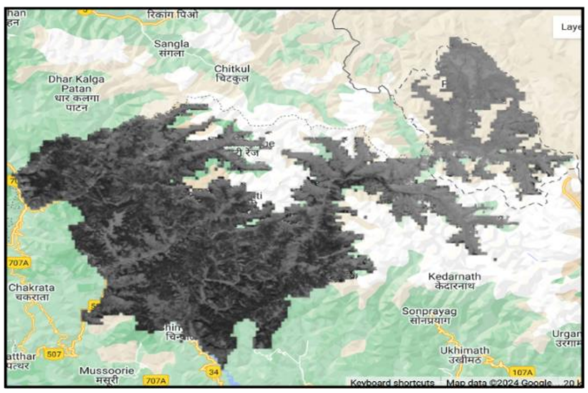

Figure 25: uttarkashi_2024_prefire_nbr

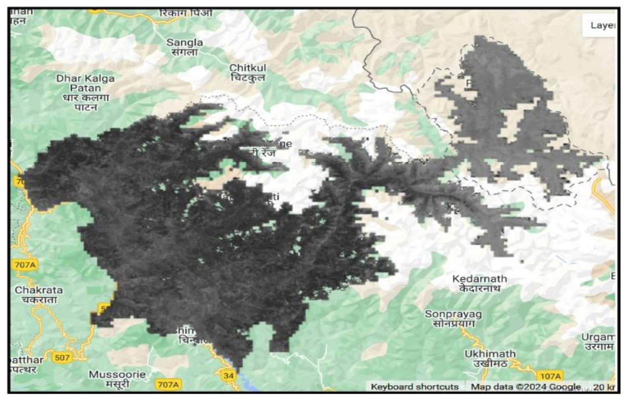

Figure 26: uttarkashi_2024_postfire_nbr

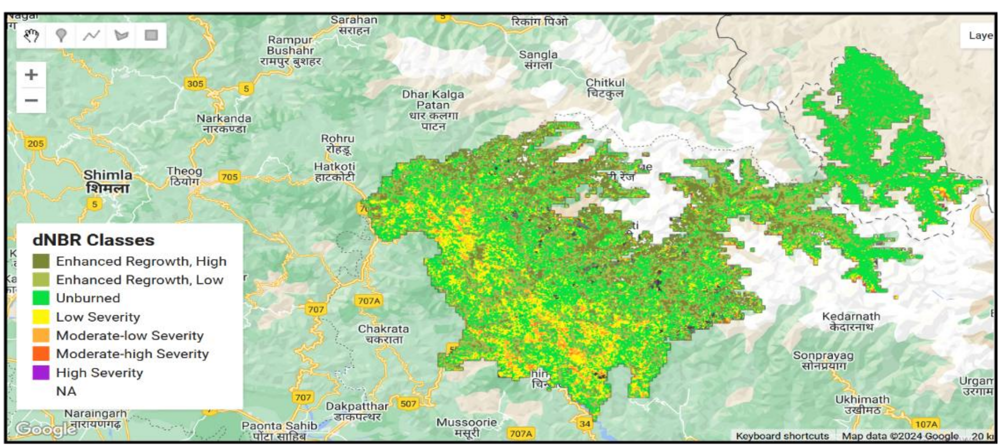

Figure 27: uttarkashi_2024_dnbr_classified

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

The study of burn severity in Uttarkashi district from 2020 to 2024 reveals significant changes in fire activity and vegetation recovery patterns. High-severity fires affected 11% of the total area, while unburned areas increased to 35.89%. By 2021, high-severity fires dropped to 6.15%, while unburned areas increased to 35.89%. By 2023, high-severity fires dropped to 0.98%, and vegetation recovery increased to 41.68%. By 2024, high-severity fires decreased to 1.34%.

5. CONCLUSION

In conclusion, there have been notable changes in fire intensity over the years, according to the study of burn severity in the Uttarkashi area from 2020 to 2024. The erratic patterns, which show a surge in high-severity fires in 2022 after a decline in 2020–2021 and 2022–2021, point to a dynamic pattern of fire occurrence and recovery. By 2024, the percentage of unburned land will have increased to 44.91%, demonstrating the benefits of both natural regeneration processes and forest management techniques. The increase of high-severity burn zones, however, emphasizes the continued requirement for improved fire mitigation, prevention, and monitoring techniques. Assessing the effects of fire has proven to be successful when done with the use of satellite images and burn severity indicators like NBR and dNBR. Moreover when report [37] was compared with the findings of the paper it can be observed that it is approximately mapping with burn severity areas. When combined with sustainable forest management techniques, this strategy can greatly lower the danger of wildfires and support the area's long-term ecological recovery. The results highlight how crucial it is to manage fires proactively and maintain ongoing surveillance in order to protect Uttarkashi's woods from potential fire threats.

6. FUTURE SCOPE

The Uttarkashi district will soon be able to identify burn severity using Landsat [29] satellite photography in several crucial regions, including:

1) Long-term Monitoring: Putting in place a program that will allow for the examination of regrowth patterns and ecosystem resilience over several years, to assess the ecological recovery of burned areas.
2) Advanced Remote Sensing Techniques: These methods can improve data accuracy by employing UAVs (drones) or higher-resolution satellite photos to assess burn intensity and post-fire recovery [11] in greater detail.
3) Machine Learning Applications: By using machine learning techniques, it is possible to identify possible fire-prone locations and increase the classification accuracy of burn severity based on historical data.
4) Biodiversity Impact Studies: Carrying out in-depth research on how fire affects local biodiversity, with an emphasis on measures to restore habitat and support species recovery.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 10-2024
DOI: 10.5281/zenodo.13901584

References

1) Roy, D. P., & Landis, D. (2015). Monitoring vegetation dynamics in a changing climate using Landsat time series. *Remote Sensing of Environment*, 161, 20-33. https://doi.org/10.1016/j.rse.2015.02.019

2) Saha, S., & Bandyopadhyay, S. (2020). Assessment of forest fire severity using satellite imagery and GIS: A case study in Uttarakhand, India. *Environmental Monitoring and Assessment*, 192(4), 1-12. https://doi.org/10.1007/s10661-020-08310-3

3) Food and Agriculture Organization. (2015). *Global Administrative Unit Layers (GAUL) Dataset*. FAO. http://www.fao.org/geonetwork/srv/en/main.home

4) Indian Ministry of Environment, Forest and Climate Change. (2021). *Annual Report on Forest Fires*. Government of India. http://www.moef.gov.in

5) United States Geological Survey. (2022). Landsat satellite data. *USGS*. https://www.usgs.gov/landsat-missions

6) Key, C. H., & Benson, N. C. (2006). *Landscape Assessment: Remote Sensing of Severity, the Normalized Burn Ratio*. USDA Forest Service General Technical Report RMRS-GTR-164-CD.

7) Miller, J. D., & Thode, A. E. (2007). Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR). *Remote Sensing of Environment*, 109(1), 66-80. https://doi.org/10.1016/j.rse.2006.12.006

8) Sharma, S., & Gairola, S. (2016). Fire severity and its impacts on vegetation and soil properties in oak and pine forests of Uttarakhand Himalayas, India. *Journal of Mountain Science*, 13(12), 2246-2258. https://doi.org/10.1007/s11629-016-4121-7

9) Hawbaker, T. J., et al. (2017). Mapping burned areas using dense time series of Landsat data. *Remote Sensing of Environment*, 198, 504-522. https://doi.org/10.1016/j.rse.2017.06.027

10) Rawat, V., & Pant, M. (2019). Analyzing forest fire vulnerability in Uttarakhand, India using remote sensing and GIS techniques. *Journal of Earth System Science*, 128(2), 1-12. https://doi.org/10.1007/s12040-019-1095-2

11) Veraverbeke, S., et al. (2010). Assessment of post-fire recovery with Landsat time series and an extended multivariate alteration detection approach. *Remote Sensing of Environment*, 114(5), 1075-1089. https://doi.org/10.1016/j.rse.2010.01.006

12) Collins, B. M., et al. (2009). Forest structure and fuel buildup following wildfire and post-fire management in Sierra Nevada mixed-conifer forests. *Forest Ecology and Management*, 257(3), 1396-1404. https://doi.org/10.1016/j.foreco.2008.10.037

13) Westerling, A. L., Hidalgo, H. G., Cayan, D. R., & Swetnam, T. W. (2006). Warming and earlier spring increase western U.S. forest wildfire activity. *Science*, 313(5789), 940-943. https://doi.org/10.1126/science.1128834

14) Lentile, L. B., Holden, Z. A., Smith, A. M. S., Falkowski, M. J., Hudak, A. T., Morgan, P., & Lewis, S. A. (2006). Remote sensing techniques to assess active fire characteristics and post-fire effects. *International Journal of Wildland Fire*, 15(3), 319-345. https://doi.org/10.1071/WF05097

15) Eidenshink, J., Schwind, B., Brewer, K., Zhu, Z., Quayle, B., & Howard, S. (2007). A project for monitoring trends in burn severity. *Fire Ecology*, 3(1), 3-21. https://doi.org/10.4996/fireecology.0301003

16) lannigan, M. D., Krawchuk, M. A., De Groot, W. J., Wotton, B. M., & Gowman, L. M. (2009). Implications of changing climate for global wildland fire. *International Journal of Wildland Fire*, 18(5), 483-507. https://doi.org/10.1071/WF08187

17) Flannigan, M. D., Krawchuk, M. A., De Groot, W. J., Wotton, B. M., & Gowman, L. M. (2009). Implications of changing climate for global wildland fire. *International Journal of Wildland Fire*, 18(5), 483-507. https://doi.org/10.1071/WF08187

18) Meng, R., Dennison, P. E., Huang, C., Moritz, M. A., & D'Antonio, C. M. (2015). Effects of fire severity and post-fire climate on vegetation recovery in Southern California. *Remote Sensing of Environment*, 169, 205-218. https://doi.org/10.1016/j.rse.2015.08.014

19) Online maps survey of India https://onlinemaps.surveyofindia.gov.in/Digital_Product_Show.aspx

20) UN-SPIDER Knowledge Portal. Recommended Practice: Burn Severity Mapping of Forest Fires. Available online: https://www.un-spider.org/es/advisory-support/recommended-practices/pr%C3%A1ctica-recomendada-mapeo-de-severidad-de-incendios (accessed on 20 September 2024).

21) UN-SPIDER Knowledge Portal. Data Application of the Month: Forest Fires. Available online: https://www.un-spider.org/links-and-resources/data-sources/daotm-fire (accessed on 20 September 2024).

22) Wimberly, M. C., & Reilly, M. J. (2007). Assessment of fire severity and forest recovery using Landsat imagery and field data in Arizona ponderosa pine forests. International Journal of Remote Sensing, 28(14), 3493-3511. https://doi.org/10.1080/01431160601086000

23) Key and Benson (2006) - Landscape Assessment: Remote Sensing of Severity, the Normalized Burn Ratio (NBR)

24) **Holden, Z.A., et al. (2005)** - A comparison of Landsat TM and ETM+ derived burn severity indices across a region of varying forest types and environmental conditions

25) **Lentile, L.B., et al. (2006)** - Remote sensing techniques to assess active fire characteristics and post-fire effects

26) **Roy, D.P., et al. (2006)** - The fire products: Algorithm, products, validation, and applications

27) **Chuvieco, E., et al. (2006)** - Remote Sensing of Wildland Fire: Modeling and Monitoring for Fire Management

28) **Eidenshink, J., et al. (2007)** - A project for monitoring trends in burn severity

29) **Miller, J.D., & Thode, A.E. (2007)** - Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR)

30) **White, J.D., et al. (2017) -** Fire severity effects on vegetation and carbon dynamics in a Southern Sierra Nevada Forest using remote sensing and GIS

31) https://developers.google.com/earth-engine/datasets/catalog/MODIS_061_MOD10A1#citations

32) https://modis.gsfc.nasa.gov/data/dataprod/mod13.php

33) **Shikha Goswami and Alaknanda Ashok (2023)** Time Series Analysis of Precipitation for Uttarakhand Region, Vol.14 / Issue 82 / Feb / 2024 International Bimonthly (Print) – Open Access ISSN: 0976 – 0997

34) **Govind Verma, Ashish Mehta, Shikha Goswami (2022)** -Trend and Time Series Analysis of Vegetation Dynamics Using Satellite Data: A Case Study of Uttarakhand, India, DOI: 10.9734/cjast/2022/v41i333947, 41(33): 14-26, 2022; Article no.CJAST.91958, ISSN: 2457-1024

35) https://forest.uk.gov.in/uploads/publications_more_information/1625726584.pdf

36) **Shikha Goswami and Alaknanda Ashok (2024)-** A Study of Urbanization in Districts of Uttarakhand Using Google Earth Engine, ISSN 2394-1537, Volume 13 Issue No 8, August 2024