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# FOREST FIRE BURNT ASSESSMENT USING DIFFERENT INDICES FOR TEHRI DISTRICT OF UTTARAKHNAD STATE INDIA- A GEOSPATIAL APPROACH FOR FOREST FIRE MANAGEMENT

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ABSTRACT

Forest fire is recognized as one of the major natural disaster damaging huge forest and grassland areas worldwide. Several million hectares of forest land are burnt worldwide annually having diverse impact on country's economics, environment, safety, human health and wildlife. It has also become a common feature in the Indian forest every year, causing incalculable damage to the forest wealth and ecosystem. Forest and wild land fires have been taking place historically, shaping landscape structure, pattern and ultimately the species composition of ecosystems. However uncontrolled and misuse of fire can cause tremendous adverse impacts on the environment and the human society by influencing the species composition and ecosystem processes. Uttarakhand State has been severely affected by forest fires from past few years resulting in prodigious loss to the biodiversity. Due to its synoptic coverage remote sensing has been actively used to detect forest fire locations in near real time. Its synergy with field data and Geographical Information System (GIS) could be critical in decision and policy making for controlling forest fire. The main aim of the present study was to find out the general trend of forest fire in the part of Central Himalaya in the years of 2001, 2004, 2008, 2012, 2016 using Multi temporal Landsat Thematic Mapper (TM,) Enhanced Thematic Mapper Plus (ETM+), and Operational land Imager (OLI) data. Forest Fire locations were taken from Moderate Resolution Imaging Spectroradiometer (MODIS) Terra and Aqua datasets along with Visible Infrared Imaging Radiometer Suite (VIIRS) product. Different spectral indices like Normalized Burn Ratio (NBR) and Normalized Difference Vegetation Index (NDVI) were found useful for detecting changes over vegetation using multi temporal image data. The total burnt area was assessed in the month of May as 271.47 Km$^2$ in 2001, 459.34 Km$^2$ in 2004, 119.42 Km$^2$ in 2008, 380.83 Km$^2$ in 2012, and 331.50 Km$^2$ in 2016.

*Key words:* NDVI, NBR, L ANDSAT, VIIRS, Remote sensing, GIS, MODIS

## Introduction

Every year in several parts of the country there is depletion of precious forest cover and destroying rich variety of flora and fauna including several species of rare plants and animals. The major change in the microclimate of the region in terms of soil moisture balance and increased evaporation is also attributed to the fire. Many believe that fires are bad but they are actually essential to promote diversity (Douglas *et al.,* 1971; Kovacic and David, 1998). Forest species alter in composition after fire, this may be good or bad depending on the utility of the stands that preceded and succeeded the fires (Lutz, 1956). Forest fire has long been integral part of the forest environment and has played a significant role in determining the flora and fauna.

In India, majority of fires are of anthropogenic origin and natural causes of fires such as lightning are very less (Bahuguna and Singh, 2002). The first forest fire in India occurred about 200 million years ago coinciding with the time of evolution of early mammals on earth (Narendran, 2001). About 55% of the forest cover is subjected to fires each year, causing an economic loss of over 440 crores of rupees apart from other ecological effects (Gubbi, 2003). In Central Himalayan region forest fires occur between April to June annually when the weather is hot and dry. Usually the south facing slopes are prone to fire due to direct sun insulation and inflammable litters of pine and dry deciduous trees at the forest floor. The presence of habitation, roads, footpaths, etc., and their distance from such sites indicate an additional yardstick for the occurrence of forest fires. Uttarakhand state is highly susceptible to forest fire. In severe fire of 1995 total of 2115 km$^2$ which is 21.5 per cent of the total geographical area of four districts had been subjected to various degrees of fire damage (Kimothi and Jadhav, 1998).

Frequent man-made fires are an integral part of the hilly zone and promote the regional domination of Chir pine (*Pinus roxburghii*) at the expense of broadleaf oak forests. These man-made forest fires can be accidental or deliberate. Forest fires can be initiated by grazers, camp fire or other adventure activities, sparks from vehicles or trains, shifting cultivation, undergrowth in the forest in search of game animals, use of fire for collecting non timber forest products like honey, gum etc. and to destroy stumps of illegal felling in the forest. Sometimes miscreants can spread fire to take revenge from forest officials. In hilly areas Chir Pine needles totally cover the ground surface inhibiting the growth of grasses as well as making the kuccha roads slippery for travel, therefore villagers burnt them for obtaining fresh flush of grasses as well as for clearing the paths. Besides these are also a major source of pollutants including black carbon which is regarded as a major cause of glacier melt in the Himalayas, and has the capacity to influence regional climate.

Fires in the Himalaya occur during the pre-monsoon summer period of moisture stress (Singh and Singh, 1992; Sharma *et al.,* 2014) which is intensified because of global warming and resultant depletion of snowmelt water. (Gaire *et al.,* 2014).

Several studies using Remote Sensing (RS) and Geographical Information System (GIS) have been performed in Himalayas regarding forest fire studies. Pant *et al.* (1996), assessed the damaged area during the ravaging fires of 1995 in Tehri using remote sensing and GIS. Kimothi and Jadhav (1998) have studied forest fires in the Central Himalaya and have developed methodology to monitor and assess the damage. A forest fire risk model was developed by Jain (1996), for Rajaji National Park. Kunwar and Kachhwaha (2003), have used remote sensing and GIS techniques in forest fire hazard mapping in Himalayan region of Uttaranchal and Sikkim.

Landsat satellites have been collecting information about forest fires since the 1970s. Its spatial and temporal coverage provided by individual Landsat-class sensors along with the availability of free data policies and the launch of new instruments by international agencies helped gradually increase the availability of Landsat-class data creating renewed opportunities for forest fire applications. Landsat plays an important role in assessing the impact of fires on forest ecosystems and human society. Landsat satellites document the location and extent of burned areas, how severely fires burn, and the subsequent regrowth of the land after a forest fire. All this information helps land managers better manage our forests and other natural resources in the context of fire.

The use of Landsat-class data to detect thermal anomalies has been successfully demonstrated in previous studies such as Francis and Rothery (1987) and Oppenheimer (1991) applied near infrared (NIR) and short-wave infrared (SWIR) Landsat-5 Thematic Mapper data to case study analyses of volcanic activity and to detect actively burning fires was also demonstrated (Giglio *et al.,* 2008; Schroeder *et al.,* 2008a). Key and Benson (2003) developed the vegetation index, normalized burn ratio (NBR), for Landsat data using near infrared and mid-infrared bands. Normalized difference vegetation index (NDVI), a commonly utilized vegetation index, uses the near-infrared and red bands (van Leeuwen *et al.,* 2010).

Change in vegetation indices such as NBR and NDVI are commonly utilized in the literature and are particularly effective indices of burn severity and forest structure. These techniques of using vegetation indices have been applied primarily to study wildfire in coniferous forests of the western United States (Wimberly and Reilly, 2007). MODIS (Moderate Resolution Imaging Spectroradiometer) Aqua+Terra thermal anomalies (MCD14DL) product provides near real time forest fire information. The thermal anomalies / active fire represent the center of a 1km pixel that is extracted by Fire and Thermal Anomalies algorithm (Giglio *et al.,* 2003) as containing one or more fires within the pixel. This is the most basic fire product in which active fires and other thermal anomalies, such as volcanoes, are identified. MODIS sensor is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon.

A primary sensor on-board the Suomi-National Polar-orbiting Partnership (SNPP) spacecraft, the Visible Infrared Imaging Radiometer Suite (VIIRS) I-band (375 m) Active Fire and Corrected Reflectance products are the newest near real-time products available. SNPP observes the Earth's surface twice every 24-hours (once in daylight and once at night) from a polar orbit 824 km (512 miles) above the planet. In India, National Remote Sensing Centre (NRSC) presently disseminates in near real time active fire alerts to forest departments during the fire season using MODIS TERRA and AQUA satellite datasets acquired at the NRSC Earth station.

Therefore viewing the multiapplicability and timeseries (temporal data) availability of the RS and GIS data the present study is conducted for Tehri District of Uttarakhand from duration of 2001 to 2016 using remote sensing data and using various indices with an objective getting general trend of forest fire in the year of 2001, 2004, 2008, 2012, 2016 based on using different indices i.e. NDVI, NBR and Spectral Reflectance. This work will help in knowing the trend the forest fire and also management practices based on technological back foot.

## Study Area

Tehri Garhwal is one of the important mountainous

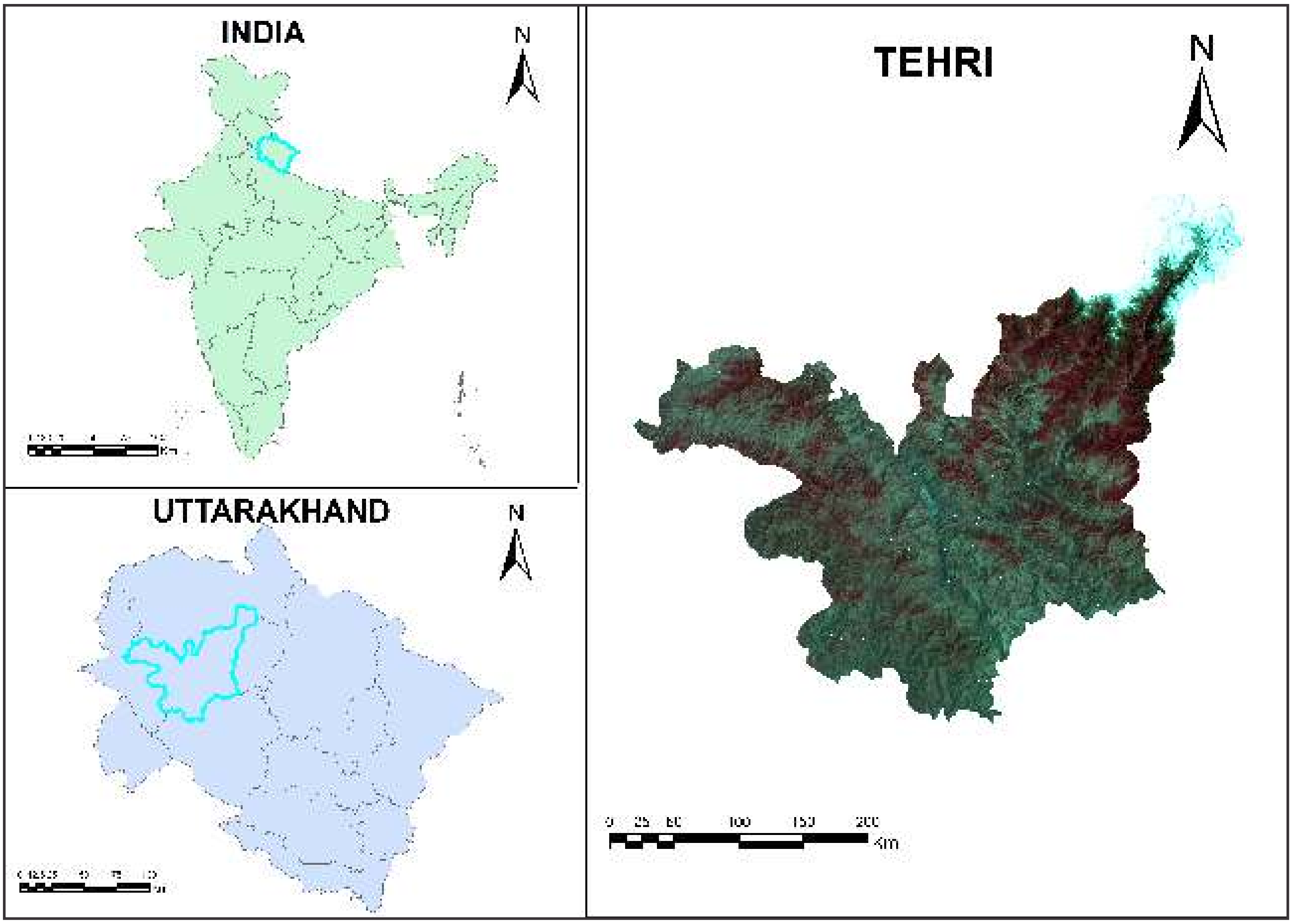


Fig. 1:

districts of Uttarakhand State (Fig.1). The district lies between latitudes 30°03' and 30°53' N and longitudes 77°56' and 79°04' E. It is bounded by Uttarkashi district in the north, Rudraprayag district in the east, Pauri Garhwal district in the south and Dehradun district in the west. The geographical area of the district is 3796 $km^2$.

## Material and Methods

A set of images of Landsat 8 (with 11 spectral band and 30 m spatial resolution), Landsat 7 (with 8 spectral band and 30 m spatial resolution) and Landsat 5 (with 7 spectral band and 30 m spatial resolution) was used for the present study. These images are acquired in the month of May and June and some images are acquired in April and August for knowing Vegetation health pre and post fire for every study year.

Table 1: Showing data sets

| Data | Spatial resolution | Date |
|---|---|---|
| LANDSAT 5 (TM) | 30 m (MSS) | 31-05-2004 |
| | 120 m (Thermal) | |
| LANDSAT 7 (ETM+) | 30 m (MSS) | 04-05-2001 |
| | 15m (PAN) | 28-05-2004 |
| | 30 m (Thermal) | 29-06-2004 |
| | | 03-06-2012 |
| LANDSAT 8 (OLI) | 30m (MSS), | 15-03-2016 |
| | 15m (PAN) | 12-06-2016 |
| | 30 m (Thermal) | 12-09-2016 |
| MODIS/VIIRS | 1000 m /375 m | 2001-2016 |

## Methodology

The methodology involves the Image Pre-Processing, DN to Spectral Radiance, Top of Atmosphere Reflectance, Image Processing, Calculate the Normalized Burnt Ratio (NBR), Image Classification and Validation. The following flow chart of methodology is given below (Fig. 2).

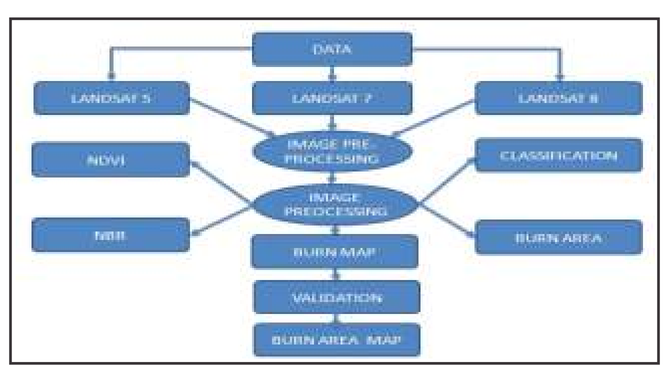


Fig. 2: Flow chart of methodology.

## Results

In summer season the fires were said to be more prevalent when both air and soil temperatures gets high. This is generally in the months from April to June. Temperature influenced on fire behavior by reducing the moisture content of the fuels. With a temperatures decrease, the moisture content of the fuels is high making the ignition difficult while when temperatures are high, the moisture content of the fuels is reduced resulting into easy ignition of the fire (Goldammer and de Ronde, 2004).

Fire front are increased in the wind increase. The stronger the wind, the faster will be the spread of a head fire whilst a decrease in the wind results into a reduced spread of fire. An increased wind speed in the summer season (April to June) confirms that fires are frequent during this time due to the effect of wind that makes the fire spread faster.

The use of remote sensing methods in fire effects assessment has grown notably in the last decade, using both high and low-resolution satellite sensors (Ahern *et al.,* 2001). For global applications, the use of NOAA-AVHRR data was extensively tested in the 1990s. Most commonly, burn scar areas were discriminated from a multitemporal comparison of NDVI or other spectral indices (Kasischke and French, 1995; Martín and Chuvieco, 1995; Pereira, 1999), although some combination of thermal and optical channels have also been undertaken (Fraser *et al.,* 2000; Sukhinin *et al.,* 2004). The research showed that Landsat TM is more accurate in fire scar mapping with different indices used in it.

Therefore, the spatial distribution of fire scars mapped from Landsat TM from different year were taken was beneficial in assessing the accuracy of the fire scars validated from Fire Information for Resource Management System (FIRMS-NASA). FIRMS distribute Near Real-Time (NRT) active fire data within 3 hours of satellite overpass from both MODIS and VIIRS. It was observed that the trend in the size of fire scars increased with time at a every 4 to 5 year gap. This might be due to fuel load and other biomass accumulation. These results are in agreement with what Pereira *et al.* (2005) found in the Iberian forests of Portugal.

Multi temporal Landsat TM, ETM+, and OLI data (Verbesselt *et al.* (2010); Broge and Leblanc (2001); Chuvieco and Congalton (1989); Pettorelli *et al.* (2005); Röder *et al.* (2008); Van Wagtendonk *et al.* (2004); Vogelmann *et al.* (2011); Van Wagtendonk *et al*., 2004) were used to get a trend of forest burnt area based on different indices.

The classification method is found best for estimation of burnt and unburnt area. The burnt assessment through difference of NDVI and NBR produced very similar result across vegetation type but for knowing the general trend of fire, classification method was found more relevant. The study suggest that the total burnt area was assessed in the month of May as 271.47 $Km^2$ in 2001, 459.34 $Km^2$ in 2004, 119.42 $Km^2$ in 2008, 380.83 $Km^2$ in 2012, and 331.50 $Km^2$ in 2016 (Fig. 3). The validation of bunt area was also marked using FIRMS location on the satellite imagery (Fig. 4). Apart from that, in this present study index used i.e. NBR and NDVI (Fig. 5 and 6), both were gradually increased before fire and rapidly decreased after fire. So NBR and NDVI model is useful tool for detecting changes over vegetation using multi temporal image data.

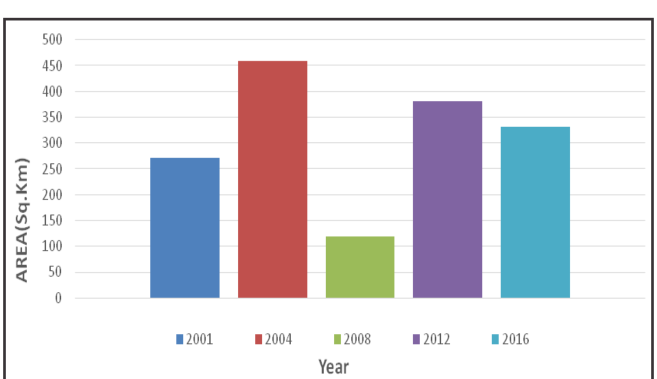


Fig.3: Forest fire trend in the year of 2001, 2004, 2008, 2012, 2016.

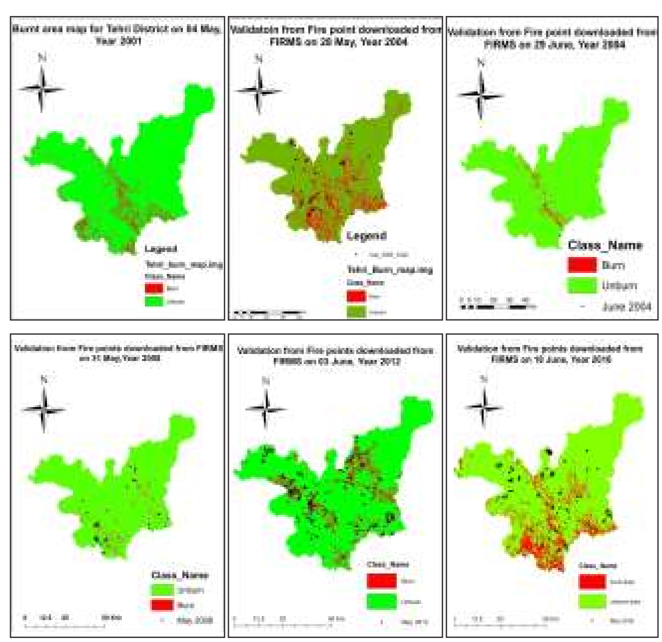

Fig. 4: Burnt area with FIRMS validation for the years 2001, 2004, 2008, 2012, 2016.

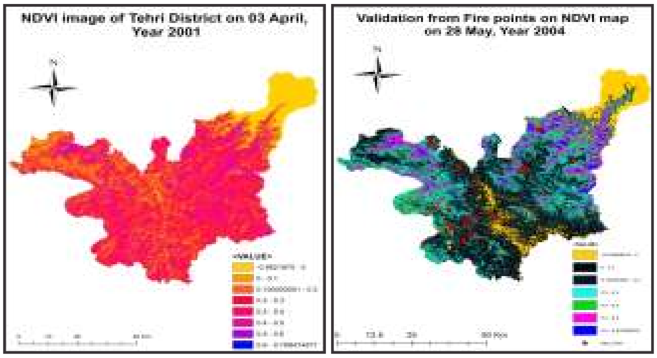

Fig.5: Example of NDVI image and validation from Fire Points.

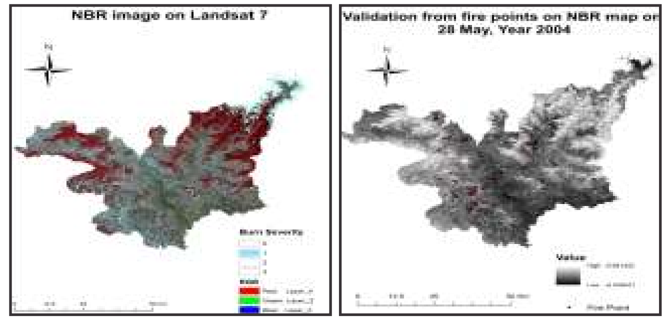

Fig.6: Example of NBR image and validation from Fire points.

## Discussion and Conclusion

The scientific and day by day advances in image processing of medium and low-resolution satellite data makes it possible to observe the entire area practically of data very close. This is the case, where for instance the burn scar mapping has carried out for a district for a given time series can help in knowing the temporal condition. These techniques from a desktop view can help in fire management and other planning purpose too. The different effects, of fire damages on post fire reflectance, especially when forest is stratified in different vertical layers can be assessed by using these used indices.

## उत्तराखण्ड राज्य, भारत के टिहरी जिले के लिए विभिन्न सूचंकाकों का उपयोग करके भूस्थानिक वनाग्नि ज्वलित मूल्यांकन-वनाग्नि प्रबंधन के लिए एक भूस्थानिक एप्रोच

नीलम रावत, किशोर कांडपाल, सौरभ पुरोहित, अरविन्द पाण्डे, गोविन्द सिंह नेगी और दुर्गेश पंत

**सारांश**

वनाग्नि को प्रमुख प्राकृतिक आपदा में से एक के रूप में माना गया है, जो विश्वभर में विशाल वन और घासभूमि क्षेत्रों को क्षति पहुंचाती है, विश्वभर में सालाना लाखों हैक्टेयर वन भूमि जल जाती है जिससे देश की अर्थव्यवस्था, पर्यावरण सुरक्षा, मानव स्वास्थ्य एवं वन्य जीवों पर विविध प्रभाव पड़ता है। प्रति वर्ष भारतीय वन का यह एक आम लक्षण भी हो गया है, जिससे वन सम्पदा एवं पारितंत्र की अनिश्चित क्षति होती है। वन एवं वन्य भूमि अग्नियां ऐतिहासिक रूप से हो रही हैं, जो भूदृश्य संरचना, पैटर्न का आकार लेकर अन्त में पारितंत्रों का प्रजाति संयोजन करती हैं। तथापि, अनियंत्रित एवं आग के दुरूपयोग प्रजाति संयोजन और पारितंत्र प्रक्रियाओं को प्रभावित करके पर्यावरण एवं मानव समाज पर अत्यधिक प्रतिकूल प्रभाव डाल सकते हैं। उत्तराखण्ड राज्य गत कुछ सालों से वनाग्नियों से अत्यधिक प्रभावित है जिसके फलस्वरूप जैवविविधता की असाधारण क्षति हुई है। इसके संक्षिप्त कवरेज के कारण वास्तविक समय में वनाग्नि स्थानों को खोजने हेतु सूदूर संवेदी का सक्रिय रूप से उपयोग किया गया। क्षेत्र आँकड़ों और भौगोलिक सूचना प्रणाली (जी आई एस) के साथ इसकी सहक्रिया वनाग्नि नियंत्रण हेतु निर्णय एवं नीति निर्माण में अहम हो सकती है। वर्तमान अध्ययन का मुख्य ध्येय मल्टि टैम्पोरल लैण्ड सैट थीमेटिक मैपर (टी एम), वर्धित थीमेटिक मैपर प्लस (ई टी एम +) और संचालनीय भू इमेजर (ओ एल आई) आँकड़ों का उपयोग करके वर्ष 2001, 2004, 2008, 2012, 2016 में मध्य हिमालय के भाग में वनाग्नि के सामान्य रूझान का पता लगाना था। मॉडरेट रीजॉलूशन इमेजिंग स्पेक्ट्रोरेडियोमीटर (एम ओ डी आई एस) टेरा तथा विजिवल इन्फ्रारेड इमेजिंग रेडियोमीटर सूट (वी आई आई आर एस) प्रोडक्ट के साथ एक्वा डाटा सैटों से वनाग्नि स्थानों को लिया गया। बहु कालिक इमेज आँकड़ों का उपयोग करके वनस्पति में हो रहे परिवर्तनों का पता लगाने के लिए प्रसामान्यीकृत दहन अनुपात (एन बी आर) एवं प्रसामान्यीकृत अन्तर वनस्पति तालिका (एन डी वी आई) जैसे विभिन्न स्पैक्ट्रीमी सूचकांकों का उपयोगी पाया गया। 2001 में 271.47 वर्ग कि.मी., 2004 में 459.34 वर्ग कि.मी., 2008 में 119.42 वर्ग कि.मी. 2012 में 380.83 वर्ग कि.मी. एवं 2016 में 331.50 वर्ग कि.मी. के रूप में मई के महीने में कुल ज्वरित क्षेत्र मूल्यांकित किया गया।

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