Temperature and Mean Confidence Analysis of (Forest) Fires in Seven Sister States of North-East India (2000-2022*)

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Abstract

The ravaging of natural vegetation in the form of fires is an outcome of natural and anthropogenic factors which cannot be easily differentiated. The phenomena is highly inaccessible and dangerous by nature and this makes it difficult to be measured in the field. Hence, remote sensing can prove to be a highly useful tool in studying, monitoring and examining the characteristics of these. The present work is an attempt to study the issue of fires in the North Eastern part of the country- a region extremely rich in biodiversity, natural vegetation and water resources; but facing threat due to fires mainly arising out of human activities. The study is attempted through observations on the aspect of temperature of blazes as a proxy in observing their geographical extent using T21 high resolution channel dataset of MODIS FIRMS. Results indicate that almost all of the region experiences fires which are basically recorded in the forested region with the eastern and southern part exhibiting maximum activity for the time period of study. The trend is fluctuating with the mean confidence percentage also indicating that large percentages of these fires confirm to high burning incidences of natural vegetation in a distinct pattern.

Keywords: *Forest Fire, Seven Sister States, Remote Sensing, FIRMS*

1. Introduction

Forest fires are highlighted as the most rampant hazard in a forest ecosystem across the forest biomes of the world and threaten the existing life forms in a serious manner (Kumar, Phukon, & Singh, 2021). These are also called grass fires and peat

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fires (Eclipse, 2022), bush fires, wild fires or vegetation fires (UN, n.d.). Although quite common and having history simultaneous with the forest itself, they have the capacity to gravely disrupt the ecosystem of the forest due to their uncontrolled nature (UN, n.d.) and are unpredictable in nature (WHO, 2022). With immense potential as demonstrated to cause harm in their path, the vulnerability and threat concerns have potential to cross the threshold and become a disastrous event (Kumar, Phukon, & Singh, 2021).

The causes of forest fires can range from natural to anthropogenic to both, but in any case it is not easy to identify them singularly (Szmyt, 2018). Naturally occurring forest fires can have a wide range of causes ranging such as volcanoes and hot lightning bolts (Eclipse, 2022) to dryness in vegetation (SOS, 2020).

Human induced causes have become the most dominant cause of forest fires in the world (WWF, 2017; Anthropocene, 2022). The nature of these fires lends them catgeories as:

a. Crown fires: The highest risk category of fires which have a tendency to burn the entire tree with high intensity (Canada, 2021). They can spread fast from one tree to the other (Calgary, 2019).

b. Ground fires: They occur in deep layers of dry dead vegetation, humus, litter, peat and other such matter (Calgary, 2019) and are dangerous as they can 'hibernate' during seasons (Canada, 2021). They can cover large areas and move slowly (Calgary, 2019). They can also turn into surface fires (Cache, 2022) and it is difficult to control them (Secretariat, 2018). They can also be classified further as underground fires (Secretariat, 2018).

c. Surface fires: These fires have intensity which can be of low to high (Cache, 2022). They can also develop from ground fires, can spread slowly or rapidly depending upon the slope of land and can lead to the creation of crown fires (Cache, 2022). They can be doused easily (Calgary, 2019).

Human induced causes include burning of wastes, fireworks, machine caused accidents (Eclipse, 2022), camp fires (National Geographic, 2022) to negligence (WWF, 2020). These can be accidental as well owing to causes such as forest activities, throwing of matches, campfires, vehicle sparks, tapping of resin, making of charcoal, wine extraction, cooking activities in the forest, road construction and others (Secretariat, 2018).

Literature Review

The popular 'Fire Fundamentals Triangle' given by Patricia Andrews (1996) highlights the basic components that cause the forest fire to expand (Allgower, 2003). The continuation of a forest fire depends upon fuel, oxygen supply and heat continuity which make up the 'fire triangle' (Canada, 2021). Although these are a segment of an ecosystem (USDA, n.d.; Verma, Singh, Mani, & Jayakumar, 2017), they shape an ecosystem by completely destroying it and can also be beneficial for it for regeneration (USDA, n.d.; Verma, Singh, Mani, & Jayakumar, 2017). They can affect the constitution of an ecosystem, its processes, growth and development (Flannigan, Stocks, & Wotton, 2000; Verma, Singh, Mani, & Jayakumar, 2017). Besides, they release vast amounts of particulate matter and can hamper development at a broader scale (UNEP, 2020), particularly in the light of climate change (Hua & Shao, 2016). The effects of such fires can be in the form of immense air pollution, contribute to heating of the atmosphere, hampering sustainable development, causing homelessness, despair, and emotional conflict; can affect women, children and elderly with an ultimate economic loss of various types (Sunar & Özkan, 2010; UNEP, 2020). Climate change has made forest fires more in number and magnitude as well (Jha, 2022). Global warming and rising temperatures have augmented the problem and in turn, forest fires and also contribute to the same besides adding particulate matter in the environment (Goman, 2020). For India, forest fires are not a rare phenomena (Secretariat, 2018).

As is the trend across the world (Barmpoutis et al., 2020), India is similarly facing an issue of enhanced forest fire activity as well as higher forest temperatures (Jha, 2022). The management of forest fires is important for reasons more than one, ranging from economic to environmental and social and also due to the fact that human activities are the predominant cause of these fires in the current context (Çolak & Sunar, 2020), accounting to nearly 90% of the contribution (Chandra, 2004).

Remote Sensing is comparatively advantageous in monitoring and preparing for forest fire management (Sunar & Özkan, 2010; Çolak & Sunar, 2020). Satellite derived data is unique in many aspects for the study of this phenomena (White et al.,1996; Justice & Korontzi, 2001). Analysis generated through remote sensing can assist in examining the fire hotspots, risk of spreading of fires, mapping, calculating and generating parameters (Calle & Casanova, 2008). Satellite monitoring can provide information in many useful

ways, although there do exist issues in acquired satellite data in detection of fires (Hossain et al., 2020; Gale et al., 2021). In this category, real time information has proven to be very helpful in multiple ways (Calle & Casanova, 2008; Wahl, et al., 2010). Forest fires raise temperature of the surroundings (Malmström, 2008).

The study of forest fire temperatures is less observed in studies (Johnson & Miyanishi, 2001). Fire flame temperature characteristics are very significant in understanding the nature of forest fires (Saito, 2001) and vary also according to the nature of vegetation (Williamson & Black, 1981). Smoke generated by fires and flames are taken as their signatures (Hossain et al., 2020).

Remote sensing methodologies apply for maximum pixel values method to detect fires in forests and are able to separate smoke and flame as advancement has taken place in sensors (Davies et al., 2009; Hossain et al., 2020). In this category of analysis, NASA's MODIS FIRMS dataset examines active fire phenomena at a coarse resolution of 1 km (NASA, 2019). It provides temperature data of fires recorded in Kelvin along with mean confidence values which can be generated for further examination (NASA, 2019). The data is near real time and along with mean confidence, can provide a substantial information on the topic of research (NASA,2019). MODIS data is helpful in this regard (Justice et al., 2002; Banerjee, 2021). The Seven Sister States of India form the study area with characteristics of naturally flourishing vegetation and practice of slash and burn agriculture with about 55% of country's recorded fires detected in the region annually (NESAC, 2014).

Most of the fire pixels observed by MODIS are indicative of slash and burn or shifting cultivation as thermal output from thee fires is high. The T21 channel is a high range detection channel for fires and their characterisation using the fire algorithm (NESAC, 2014). Certain works can be observed on analysing forest fires in the country using remote sensing techniques but no direct work focussing on these in the Northeast could be observed along with lack of information of a time period as taken in this paper. Besides, recent data analysis on the same is absolutely missing. One reference in this regard can be given as that of North Eastern Regional Node for Disaster Risk Reduction Program (NER-DRR) report titled 'Forest Fire Assessment in Northeast India', 2014 which has been referred to here as well. It tends to provide a detailed information on 'Forest fire Scenario since 2001- 2014' along with the analysis of the issue.

Study Area- Depicted in Figure 1., the Seven Sister States of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura along with Sikkim (Dash, Sharma, Pattnayak, Gao, & Shi, 2012) comprise of North East India (NEI) as a region (Das et al., 2016).The approximate location of the study area states is from 20°N-30°N latitudes and 87°E-98°E longitudes (Agrawal, Gupta, Dixit, & Dash, 2021). The region is extremely rich in biodiversity and is one of the highest rainfall regions in the world alongside being a biodiversity hotspot (Chakraborty, 2009). It is mainly mountainous with two thirds of space covered by hills and mountains giving it the shape of an 'amphitheatre', nearly 30 % by plains and the remaining by plateau region (Dikshit & Dikshit, 2013). The mighty Brahmaputra river flows just through the middle of the region forming significant river basins and lending hydrological richness to the region (Ahmad & Lodrick, 2021). Hills and mountains form the dominant topography of the region at about 75% of the region, followed by plains at 30% and the remaining by plateau region (Dikshit & Dikshit, 2013).

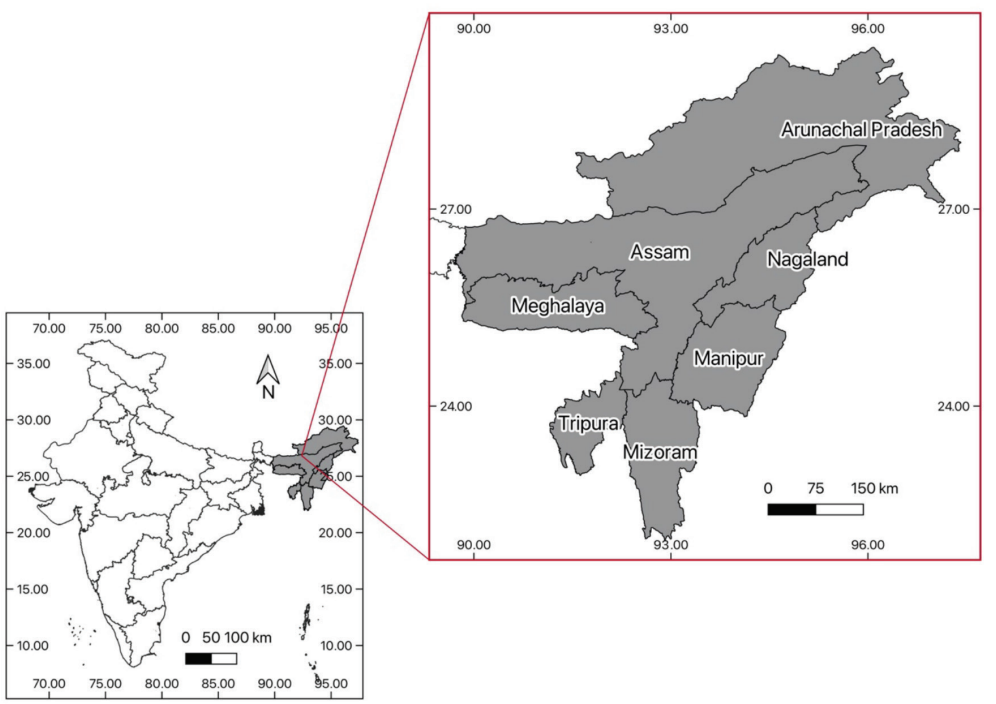


Figure.1. India- Location of Seven Sister States

Source- Author, 2022

The region experiences heavy monsoonal rainfall from May to September (NESAC, 2014). Forest fires have become a major environmental problem for every season of the year in the study area (NESAC, 2014). Shifting cultivation is a major activity of the ethnically diverse region (NESAC, 2014), is defined as a way of life but has generated negative externalities for these states (Maithani, 2005; NESAC, 2014). More than 15,000 yearly incidents on an average of forest fires have been reported in the states from 2003-2016 (Sharma, 2018). Many incidents of forest fires range for days (Agarwala, 2021). The region tends to exhibit the highest probability of forest fires as per the Ministry of Environment, Forest and Climate Change (Odyuo, 2021). The situation turns to be so pathetic that it is recorded that in the absence of any control, forest fires can ruin the whole biodiversity of the region (Choubey, 2021). In the light of discussed perspectives, remote sensing appears to be of great help in assessing forest fire activity. The same is attempted here for the study area in the light of the fact that more than half of the forests in India face the threat of forest fires (Chandra, 2004).

Methodology- The research design involves an analysis of the geographical and temporal trend of fires in the Seven Sister Sates of North East India and checking whether these correspond to forest fires or other kinds of fires. The study utilises MODIS FIRMS data which provides information on fire activity in a region through Near Real Time fire data. The spatial examination involves mapping and graphically depicting the trends of fire activity for the selected time period form 2000* (From 11 Nov. onwards due to FIRMS initiation date and consequent data availability) -2022* (Till June) on a five yearly basis for the average values. Along with spatial and temporal trend mapping and depiction, the mean confidence intervals have also been examined to determine the strength of recorded data. However, the attempt is aimed towards the totality of data and does not try to distinguish the nature of these fires for their source/s.

Research Questions- The study revolves around the following research questions:

a. What is the geographical trend of forest fires in the Seven Sister of India from 2000-2022?
b. What is the temporal trend of forest fires in the Seven Sister of India from 2000-2022?
c. What is the observed correlation between these two trends?
d. Does the mean confidence interval of recorded fires show any trend or correlation with the spatio - temporal trends of forest fires in the region?

To attempt the research design, data source is NASA's Fire Information for Resource Management System (FIRMS). Data generation is done through the Google Earth Engine Code Editor. The dataset provides Near Real Time fire information on active spots of fire in a region at a resolution of 1km (NASA, 2019). The version in the Earth Engine has information on active fires in raster format from LANCE fire detection. It utilises the standard MODIS MOD14/MYD14 Fire and Thermal Anomalies product and depicts active fire locations as a centroid of pixel of 1km, supported by an algorithm operating on the basis of one or more pixel fire concentration (Engine, 2022). Mapping and graphical representation generated from the Earth Engine Code Editor is processed in QGIS 3.26. This database gives near real time data for active fires from MODIS (Moderate Resolution Imaging Spectroradiometer) and VIIRS (Visible Infrared Imaging Radiometer Suite) within three hours after the satellite has passed over the area. The data is a component of NASA's Land, Atmosphere Near Real Time Capability for EOS (LANCE) (NASA, 2019). In case of intersecting pixels, the one with more confidence value is selected and in case of tie, the one with more brightness is recorded (Engine, 2022). The dataset uses the T21 channel of MODIS using the brightness temperature of a fire pixel. Temperature is recorded in Kelvin. Besides, a detection confidence is also generated, which is used in the current analysis as well. It enables to check the quality of active fire pixels and ranges from 1-100%.

Elevation and land use mapping is attempted to observe trends. Elevation map has been derived from ALOS World 3D - 30m (AW3D30) global digital surface model (DSM) dataset given by the JAXA Earth Observation Center with a horizontal resolution of approximately 30 meters and is derived from the Google Earth Engine. It depicts height above sea level in meters derived from the ellipsoidal height based upon ITRF97 and GRS80, using EGM96+1 geoid model (Engine, 2022). Land use map is derived from the Google Earth Engine using the ESA World Cover 10m 2020 database which provides land cover map at 10 m resolution from Sentinel-1 and 2 data. The land use map is taken as a representative to distinguish land uses and particularly identifying the natural vegetation cover.

The data is subjected to geographical and temporal examination through mapping and diagrammatic presentation for the time period of study. To attempt this, the Elevation Model of the area has been depicted. This will facilitate analysis by highlighting helping in identifying the fire activity in the respective topography and identifying its nature.

Analysis and Results- Following interpretations were derived:

a. **Geographical Observations**- This is initiated by observing the topography through elevation and land use through mapping as shown in Figures 2a. and b. It is then extended to mapping of forest fires/fires on a spatial basis for the time period of study from 2000-2022 as shown in Figure 3. This is done to check geographic similarity, if any, in the same. Physiographic analysis indicated there exists a great range in the relief of the study area. The minimum value in this continuous classification stands at 45 mts. increasing gradually outwards from the central region of river Brahmaputra. The north to north western and southwestern regions mark an increasing elevation with the maximum relief attained in the extreme northern part of the region.

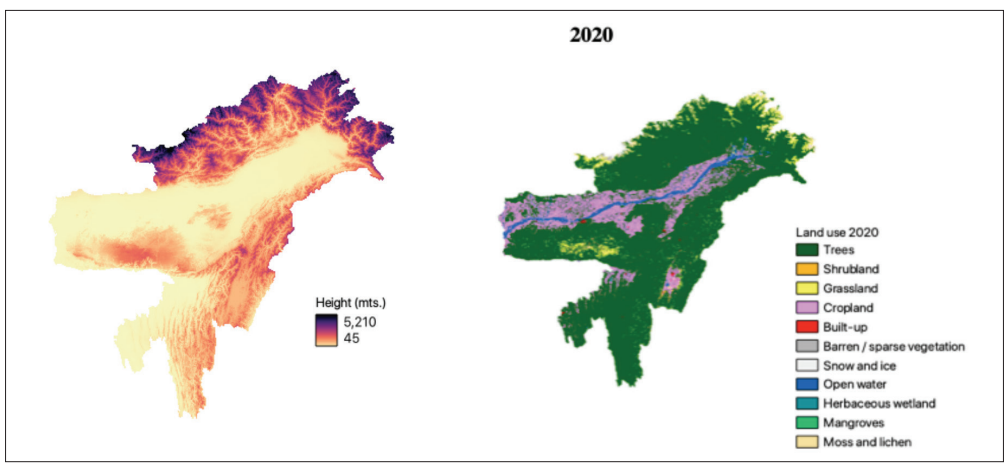
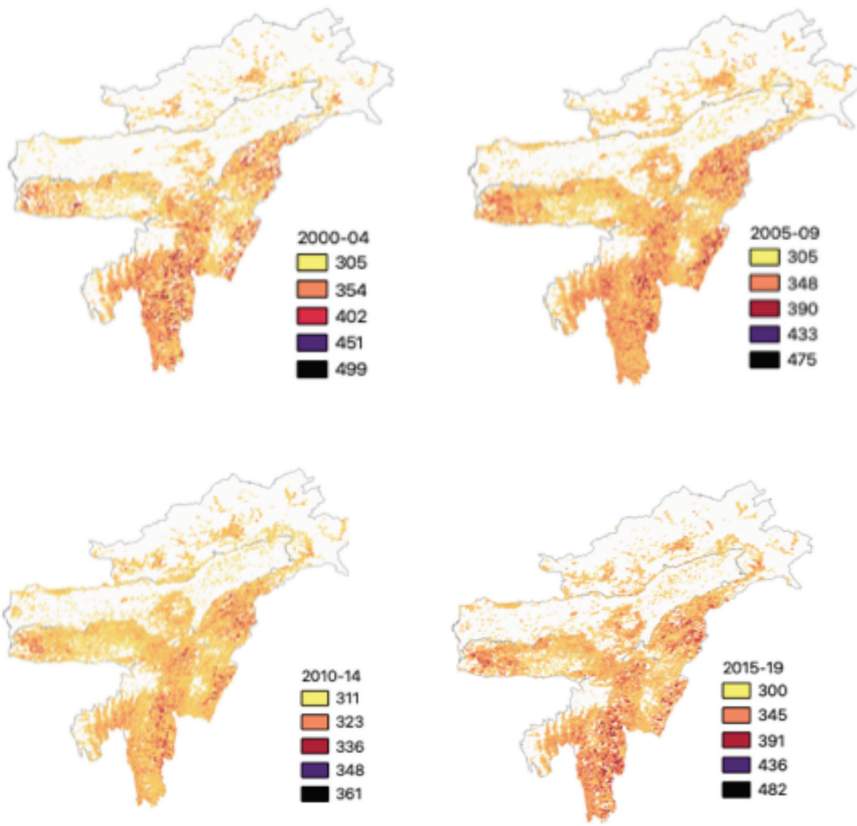


Figure 2a and b Seven Sister States- Elevation and Land Use

Source- Google Earth Engine Code Editor (a. JAXA Earth Observation Center and b. ESA World Cover 10m 2020)

Land use mapping indicates that natural vegetation in the form of trees dominates the region followed by cropland. Data on forest fires is shown in Figure 3. It is clearly visible that the maximum fire activity is observed in the natural vegetation region of the states in all the time periods. It is only in highest elevations and cropland region that fire activity is minimum. This is a clear indicator of the fact that fires are majorly associated with forests across the region. In this regard, the higher elevation zones of the west and south exhibit the highest density of forest fires. The state of Nagaland and

Mizoram highlight the maximum fire activity throughout the time period of study. In this regard, an important observation is that the activity has been fluctuating in certain time periods for the whole region. Another significant aspect is that the activity has been observed in similar regions of these states but with fluctuating intensity in one year. The intensity of these fires is also fluctuating as is indicated by the temperature analysis which ranges between 300-390 Kelvin (26.85 degree Celsius- 116.85 degree Celsius) on an average in the time spans selected. The years 2020-22* have the maximum average temperatures recorded till date for these fires reaching to beyond 500 Kelvin (229.85 degree Celsius). This interpretation is significant as fire size and frequency of occurrence are also important parameters in studying the behaviour of the phenomena (Chang et al., 2015).



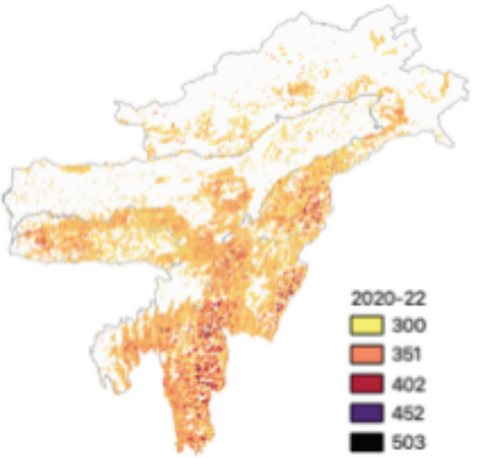
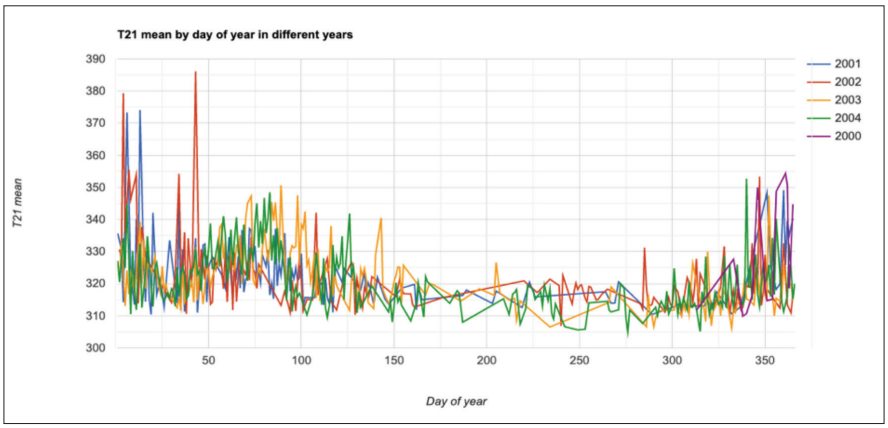


Figure 3. Seven Sister States- Trend in Forest Fires (2000-2022* till June)

Source- Author, 2022 from NASA FIRMS from Google Earth Engine Code Editor; data is in Kelvin

Thus, the geographical patterning of fires in the region is similar throughout the time period but with fluctuating intensities.

b. **Temporal Trends** - The temporal analysis is shown in Figures 4.1-4.5. Results indicate that there is a specific pattern of fire activity across the time span and the middle part of the year exhibits the minimum activity. This is a probable indicator of the fact that most probably fire activity is absent during this time of the year. It can be contributed to monsoon rainfall season as well (Puri, 2021). Besides, the first two months and the last two months of the year have the maximum activity across the time span. An alteration in this trend is visible for 2005-2009 and 2020-2022 when the period of maximum fire activity is observed also in the first four months of the years. But on the whole, fire activity is visible throughout the year in some or the other manner for the region.


T21 mean by day of year in different years
T21 mean
Day of year
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2002
2003
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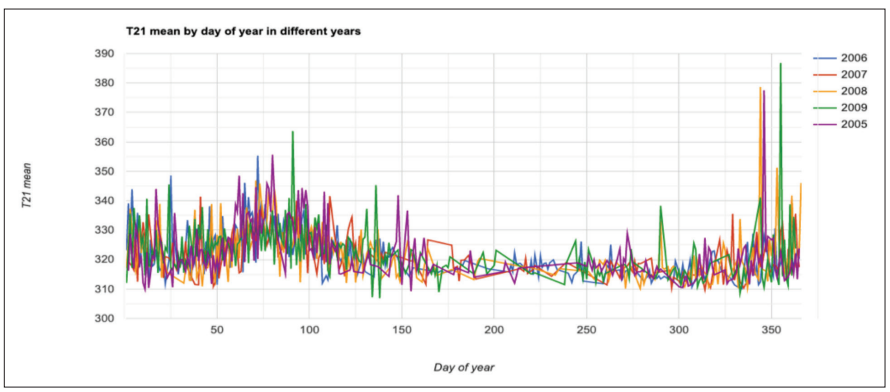
T21 mean by day of year in different years
T21 mean
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2008
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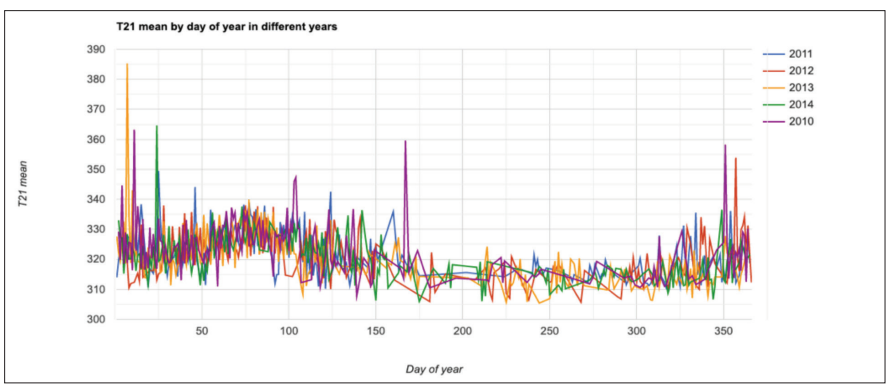
T21 mean by day of year in different years
T21 mean
Day of year
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2012
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2010

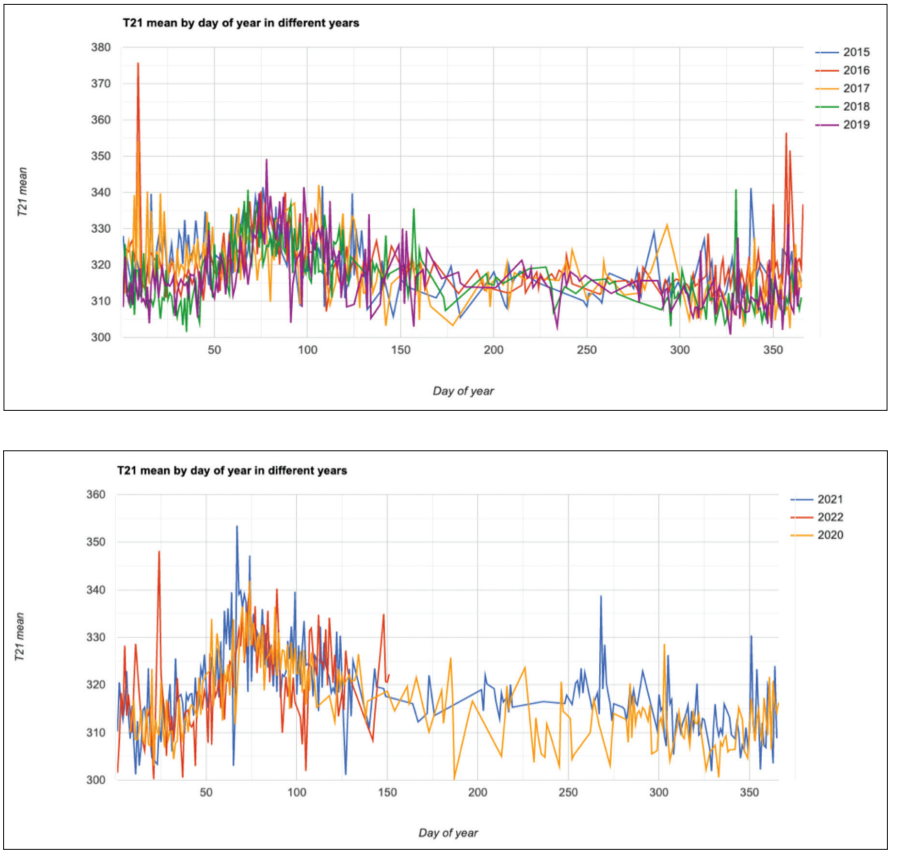


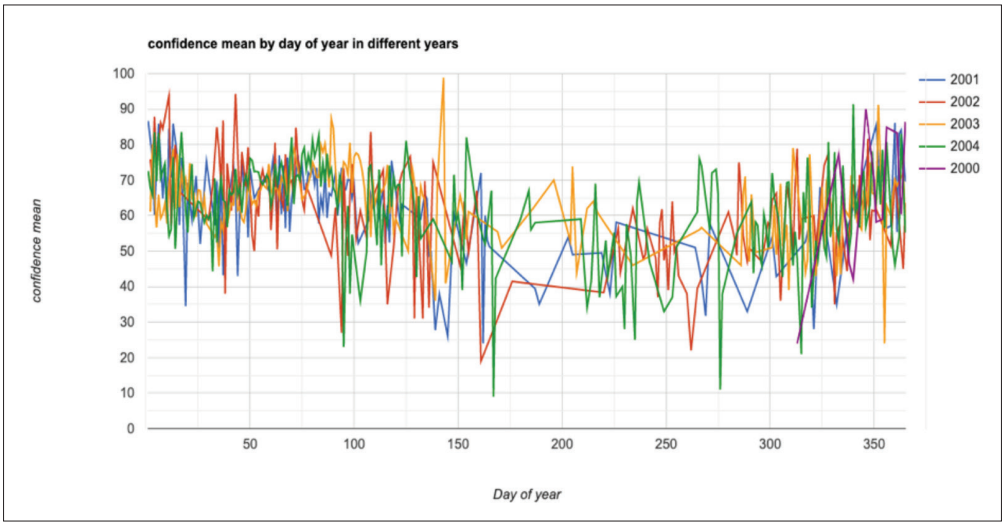
Figure 4.1.-4.5. Mean Forest Fires in Seven Sister States on the Basis of Day of the Year

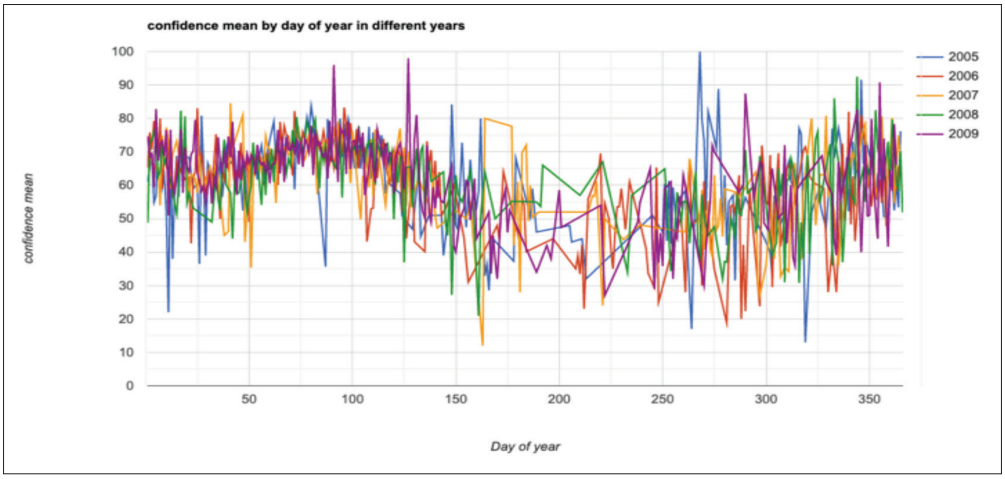
Source- Author, 2022 from NASA FIRMS from Google Earth Engine Code Editor

The above diagrams show the total yearly trend and trend on the basis of day of year. Channel T21 at 3.96 µm is a high resolution channel of MODIS FIRMS. The mean temperature indicated by T21 mean shows a peak in the first few months of the year for the time period of study. Temperature remains at a constant level during the middle part of the year and picks up again in the last three months of the year.

Combined with mean confidence of fire occurrence, it becomes evident to establish the strength of occurrence of these fires. The temporal trend also indicates a constant

fluctuation in recorded temperatures of these fires which hints towards the slowing and increasing of fires. Measured at a scale of 1-100%, the measure is also context specific when analysed. It is depicted in Figures 5.1.-5.5.





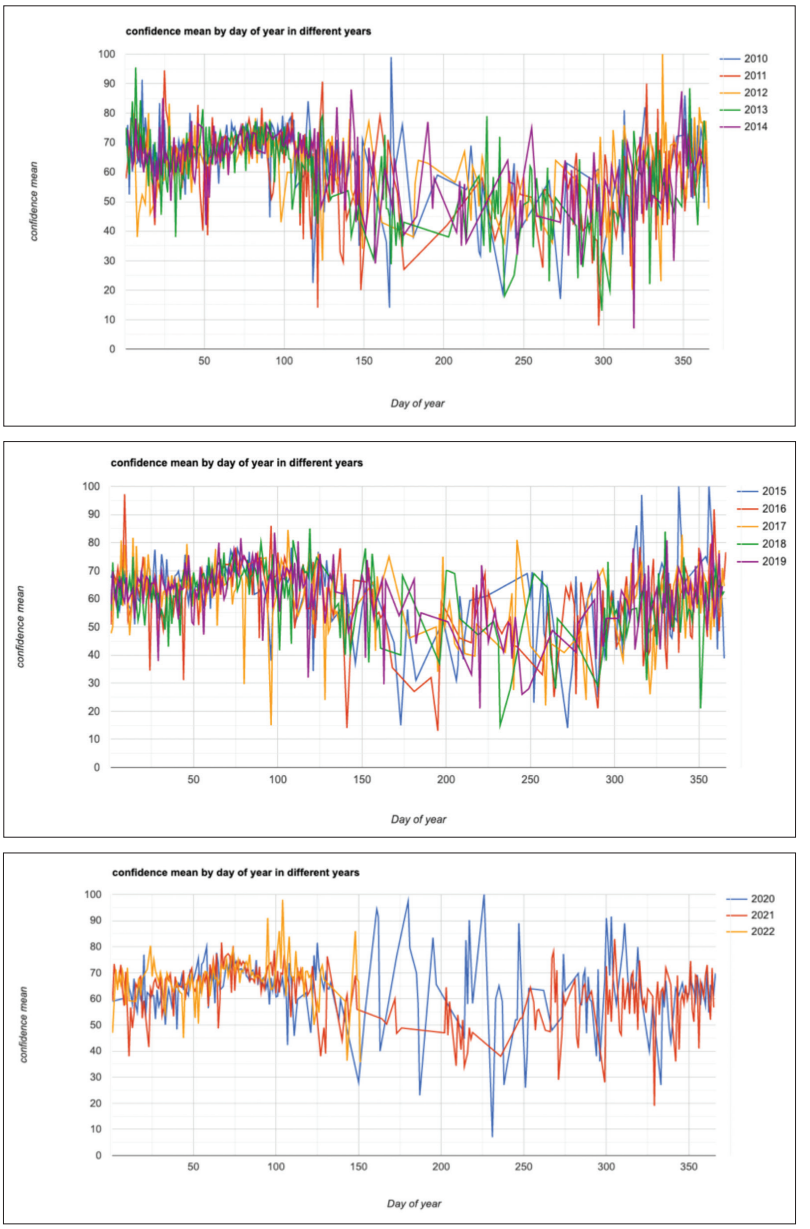


Figure. 5.1.-5.5. Mean Confidence of Forest Fires (2000-2022*)

Source- Author, 2022 from NASA FIRMS from Google Earth Engine Code Editor

Conclusions - The observations generated indicate a high level of forest fire activity in the region. This, as attempted through temperature as the basis of analysis, clearly indicates a constant burning of the natural vegetation throughout the time period of study. Besides, the activity seems to be stalled to an extent only during the heavy rainy season. The initial and the last parts of the year indicate a constant burning activity. The mean confidence of available data ranges even at 100% for many points of study in the time period of observation. About a maximum temperature of 390 Kelvin (about 116.5 degree Celsius), the forest fires exhibit a temperature range starting from 300 Kelvin (about 26.5 degree Celsius). The period from 2020-2022 exhibits the highest recorded temperatures of the time period at about a mean of 116.85 degree Celsius. All parameters indicate a geographical spread, specific patterning and concentration of forest fires in the Seven Sister States along with a high degree of confidence that the data generated pertains to the same. The research questions addressed dealt with bringing out the geographical and temporal pattering of forest fires in the region and observing correlation between their occurrence and the confidence level for examination.

Works examining the spatial and temporal extent of forest fires is limited in nature for the North east as has been mentioned earlier. The region has an undulating topography and the nature of fires is both on ground and under canopy. In the context of the rich faunal and floral biodiversity, the detection and control of fires appears to be a dire need. Further, climate change has introduced new challenges to which the region also faces due to its specificities. Forest fires seem to be the most directly observable threat to the region.

Recommendations - The geographical patterning is seen to exist in the phenomena in a specific manner across the time span of study. Further, the trends are peculiar and slightly fluctuating with increasing intensities observed without much similarity in patterns. But on the whole it can be clearly said that the information derived for forest fire activity indicates that it is rampant in the region along with a constant trend across the time span. Geographical observations as in the current context directly lead to the analysis of the issue in a proper light. It is difficult to detect forest fires at the ground level. But remotely sensed data is helpful in extracting nature of the problem which is directly inaccessible and in dealing with it. It can be clearly said that even within the limitation of temperature range in the channel, majority of the Northeast appears to be under severe threat from the hazard of fire which are largely appearing to

be anthropogenic in nature. An yearly examination can also prove helpful if a detailed scenario of the situation is to be drawn and also managed. The situation has been alarming in nature with slight fluctuations and even showing a decrease in certain time spans but the overall trends are not abating significantly.

Conflict of Interest

The author declares no potential conflict of interest. No funding was received to conduct this research.

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