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ABSTRACT

Forest fires have been regular in Uttarakhand for a long time. This is one of the major disasters occur in the time of summers. We had studied the fire activity for a period of two years and three months (i.e. JAN 2019 to MAR 2021). We have collected satellite data through GIOVANNI and FIRMS NASA using VIIRS, OMI and AIRS aboard Soumi NPP, Aura and Aqua satellites, respectively, for forest fire counts and their respective brightness, NO_2, SO_2, Ozone, and air temperature, for the rectangular area covered between coordinates 77.583E, 28.733N, 81.016E, 31.466N enclosing Uttarakhand state of India. We observed the year 2019 was a relatively quiet year as far as forest fire incidents are concerned. Fire events were detected in the months of May and June in 2019 but with a very high fire counts of nearly 2000 on some days. On the other hand, due to COVID-19 lockdown in the year 2020, with less human interventions, there are a less number of forest fires in summer. instead more fire events observed in winter due to an instant increase in the variables causing the fire, that continued in 2021 as well. These forest fires affect our atmosphere by releasing various pollutants such as NO_2 and SO_2 in addition to increasing the air temperature of the surrounding. We tried to understand the causes and the effects of forest fires along with their high activity period in the hilly areas of Uttarakhand having dense forest area that faces a high number of fires annually, either naturally occurring or of anthropogenic. It will help authorities and disaster management group to plan and prevent such events.

Keywords: *Forest Fire, SO_2, NO_2, Ozone, Air Temperature, Covid-19, Uttarakhand*

INTRODUCTION

Forests are valuable natural resource of vegetation and wealth that provide habitat to animals, birds, insects etc. These provide livelihood to the people living there and play vital role in the economy of the region. Climatic conditions and the environment are also dependent on the forest cover. However, these forests are prone to fires, of natural or anthropogenic origin. High temperature and dryness during summer associated with winds can cause forest fires very occasionally. Sometimes forest fires may occur due to Lightning but that is subsided by subsequent rain resulting in less loss.

Global studies reveal that most of the forest fires are human derived which spread very fast due to dry flammable vegetation lying in the adjoining areas and/or associated with strong winds. Tremendous amount of energy is released in a very short time.

The world had been hit by major forest fires in the recent past. Major wildfires episodes occurring in California (USA) had turned nearly 10,000 buildings to ash [1] and bush fires in Australia left 180 ha of grass land burnt, including 2000 houses and killing 33 people in the year 2020 [2]. Similarly, Amazon fires in South America in 2019 had caused of 900,000 ha of burnt area [3].

Globally, the frequency of wildfires has gone up due to climate change. Hotter and drier conditions are prevailing for longer period annually [4]. These release various pollutants including CO, CO_2, NO_2, CH_4 and O_3, along with particulate matter which can cause respiratory health problems [5]. With the development in technology, it will, now, be possible to predict these types of fires in advance so that the loss can be minimized [6]. Smoking and subsequently throwing the cigarette butts and/or burning of mosquito coils and candles near the dry vegetation, is among the main causes of the human triggered forest fires. Another leading cause of forest fire is intentional by poachers to trap the endanger species [7]. Tribal ritual (tradition) [8] may be another major cause of occurrence of forest fires.

Effects of forest fires

Forest fires are a naturally occurring phenomenon of many ecosystems. For example, in cold and dry climate, where decomposition is limited, forest fires provide proper temperature and mineral rich ashes for

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Vol. 3 Issue No.3, July-September 2021

the germination of seeds and prepare future generation of trees. In this way, they act as an agent of renewal [9]. Nearly 46% of the regions around the globe are considered to be such fire dependent ecosystems whereas 36% are fire sensitive systems. The whole world can be divided into various fire regimes depending on fire frequency, seasonal pattern and the intensity of fire.

These fire regimes are now greatly influenced by human interventions causing the development of altered fire regimes that may pose serious threat to global diversity. Some of the adverse effects of forest fires on the surroundings are as:

It releases many harmful gases like NO_2, SO_2, O_3, CO and CO_2 in addition to dust particles like $PM_{2.5}$, PM_{10} etc. which are harmful to human. It decreases the level of ozone in the stratosphere as well. Many endangered wildlife species too get affected by the fires. A large amount of vegetation is burned which affects the oxygen level near it.

In India, nearly 25% of its geographical area is under forest cover having 5 types of forests, namely, coniferous, broadleaved, evergreen, wet evergreen, deciduous, and mangrove forests. In the Himalayan Mountainous region of Uttarakhand, coniferous forests are found which are affected mostly by ground fires during February to June which are more damaging than the surface or crown fires as it affects the roots and herbaceous vegetation. This type of fires usually not detected in the beginning phase, causing a considerable damage until the fire controlling measures are employed. According to the state forest department, forest fires that started in Uttarakhand on October 15, 2020, were still burning on April 5, 2021, showing evidence of climate change. According to forest service data, there were 989 fire occurrences in the state between October 1, 2020 and April 4, 2021 which destroyed 1,297.43 hectares of woodland. [10]

In this paper, we have presented the study of the fire activity in the forests of Uttarakhand and its adjoining areas and its impact on the air quality, especially during the COVID-19 affected period. We have studied average daily fire occurrence and brightness in the study area using the data recorded by VIIRS on FIRE MAP. Subsequent effect on air quality is studied by determining the daily average variations of NO_2, SO_2, O_3 recorded by OMI through GIOVANNI. The variation of air temperature using AIRS data is also studied.

REVIEW OF LITERATURE

Forest fire is one of the major natural disasters that causes environmental pollution and affects the livelihood of people. The increasing frequency, intensity and the extent of loss of forest cover, flora and fauna, loss of lives of people have attracted attention of scientific community for the last few decades. Many research papers and review articles are available in literature covering these aspects of forest fires along with the chemistry of forest fires, especially for Uttarakhand region [11].

Forest fire is a combination of complex physical, chemical and biological processes and in the tropical region, it is responsible for nearly 80% of the total global biomass burnt and generally associated with haze due to resulting air pollution [12]. The vegetation/biomass which is mainly composed of cellulose along with lignin, nucleic acid, amino acids, alcohols, aldehydes, minerals and water with little amounts of nitrogen, Sulphur, potassium and phosphorous, is approximated by the empirical formula CH_2O. The combustion of biomass during forest fires thus produces mainly CO_2, CO, NO_x, SO_2 etc. Fire is initiated by some external agent like cigarette, match stick, lightning etc. that heats the fuel (biomass) until the ignition temperature is attained and combustion begins. This is followed by the transport of heat to adjacent fuel causing spread of fire. [13,14,15]

Fire is one of the major causes for the decrease in forest land in India, and has significant environmental, monetary and social effects. In Uttarakhand, Chir Pine woods spread over approximately 16% of the entire woodland of the region lying at an altitude of 1000 AMSL to 1800 AMSL, that are fire prone because of gum rich leaf litter collection on the backwoods floor during summer. Since the formation of the state in 2000, more than 44,518 ha of forest land has been lost due to forest fires [16]. Year 2016 (April-early June), witnessed a significant forest fire in the Chir Pine forest of Uttarakhand with 2069 Woods fire episodes influencing 4423 ha woodlands and had Killed seven persons [17, 15].

METHODOLOGY

Study Area: The area considered for the present study is the area enclosed between 77.583E, 28.733N, 81.016E, 31.466N covering Uttarakhand and the adjoining areas.

Period: January 1, 2019 to March 31, 2021

e-ISSN 2456-7701
Vol. 3 Issue No.3, July-September 2021

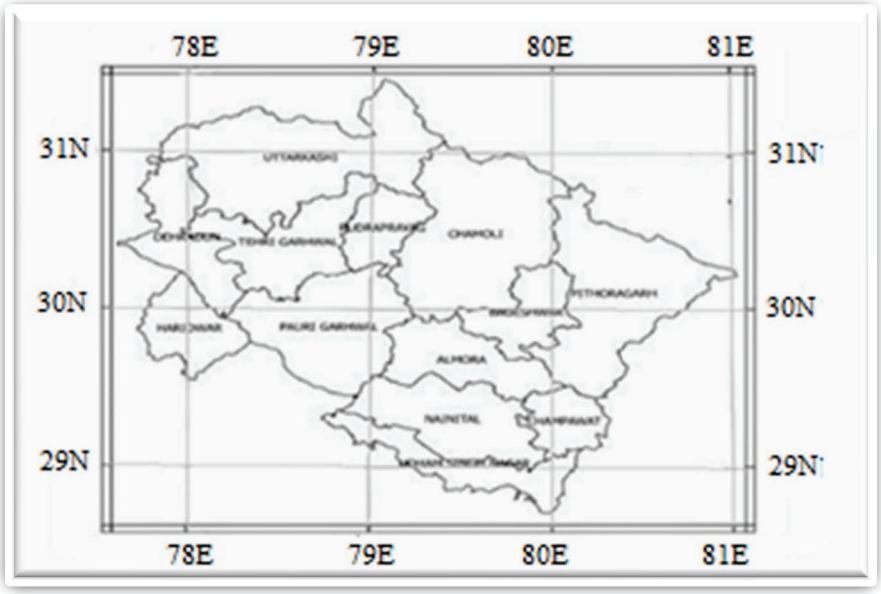

Fig 1. Uttarakhand and its adjoining area used in study (Long. 77.583E, 81.016E, Lat. 28.733N, 31.466N)

4.1 DATA EXTRACTION:

We have extracted datasets utilizing NASA GIOVANNI [18] (National Aeronautics and Space Administration GES- DISC Interactive Online Visualization and analysis Infrastructure) and FIRE guide NASA [19] utilizing the different instruments on board satellites as given in Table 1.

Table 1. Details of Datasets Extraction Sites and Instruments and Satellites Names

Dataset	Site	Satellites
Fire Counts	FIRE MAP (FIRMS NASA)	VIIRS on Suomi NPP
Brightness	FIRE MAP (FIRMS NASA)	VIIRS on Suomi NPP
NO2	GIOVANNI (NASA)	OMI on Aura
SO2	GIOVANNI (NASA)	OMI
Ozone	GIOVANNI (NASA)	OMI
Air Temperature	GIOVANNI (NASA)	AIRS on Aqua

We have studied the forest fire activity and various gaseous emissions during the forest fires in Uttarakhand and its adjoining areas. We have extract the fire and pollutant data between 28°43' N to 31°27' N (longitude) and 77°34' E to 81°02' E (latitude) over Uttarakhnad [20, 21]. For this, area averaged daily fire occurrence and brightness are determined for the study area using the data recorded by VIIRS (Visible Infrared Imaging Radiometer Suite) aboard the joint NASA/NOAA Suomi NPP). Subsequent effect on air quality is studied by determining the area averaged daily variations of NO_2, SO_2, O_3 from the data recorded by OMI (Ozone Monitoring Instrument) through GIOVANNI. The area averaged daily variation of air temperature is also evaluated using AIRS (Atmospheric Infrared Sounder) data.

For the fire occurrence and the brightness, a total of 13478 data sets are analyzed whereas for various gaseous emissions 841 data sets were compiled for the period from January 1, 2019 to March 31, 2019.

e-ISSN 2456-7701
Vol. 3 Issue No.3, July-September 2021

RESULTS AND DISCUSSION

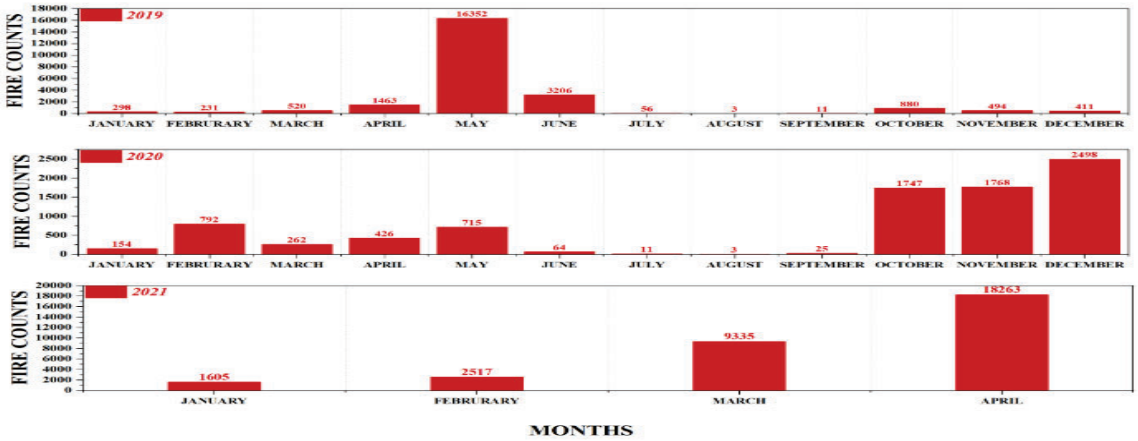

Fig 2. Year-wise monthly fire counts

The monthly fire occurrence is plotted in Fig. 2 for the period from January 1, 2019 to April 30, 2021 which shows the year-wise highest fire counts for May 2019, December 2020 and April 2021. We observed the year 2019 was a relatively quiet year as far as forest fire incidents are concerned. Fire events were detected only in the months of May and June in 2019. In Fig. 3 fire maps are depicted for the maximum fire event days i.e. May 8, 2019 (3a), December 27, 2020 (3b) and April 3, 2021(3c) with fire counts of 1833, 191 and 1855, respectively. The reason behind the least fire activities in 2020 may be the covid-19 lockdown with less human interventions, which is one of the main causes for the occurrence of forest fires. More fire events observed in winter when the lockdown lifted however the maximum number of fire counts was around 200, one tenth of that during 2019 summer. As well as impact on lockdown on air quality is also reported by many researchers [22, 23, and 24] in India.

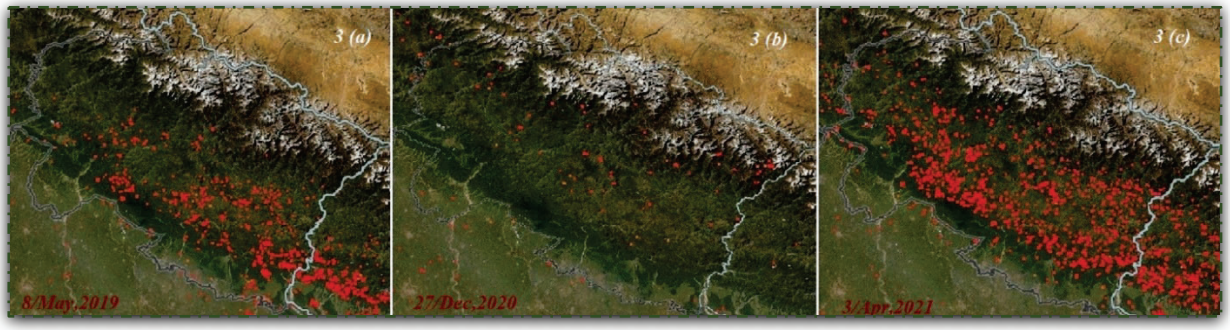

Fig 3. Fire maps for the maximum fire event days (Source: FIRMS NASA)

These forest fires affect our atmosphere by releasing various pollutants such as NO_2 and SO_2 in addition to increasing the air temperature of the surrounding. We tried to understand the causes and the effects of forest fires along with their high activity period in the hilly areas of Uttarakhand having dense forest area that faces a high number of fires annually, either naturally occurring or of anthropogenic. It will help authorities and disaster management group to plan and prevent such events.

The evaluated values of area averaged daily fire occurrence, its brightness (Kelvin) are plotted along with NO_2 (cm^{-2}), total column SO_2 (DU), total column O_3 (DU) and air temperature (Celsius) as a function of 'date of the year' 2019, 2020 and 2021(up to April 30) in Fig. 4, 5 and 6, respectively. The area averaged air temperature variation shows temperature above 20℃ for the period roughly between May to October which corresponds to seasonal variation for the area under study and not exactly related to forest fire episodes. In all these Figures, it is found that in general brightness decreases during the high fire count days.

We find less number of data are available for SO_2, not much can be inferred about the correlation of SO_2 with the fire events. However, wherever, available it shows an increase with fire counts. The NO_2 and O_3

e-ISSN 2456-7701
Vol. 3 Issue No.3, July-September 2021

values show positive correlation with fire events. However, their high values during no or least fire days may be due to other reasons like vehicular pollution. Although ozone is not emitted directly from automobiles, it is formed via a complex chemical reactions involving hydrocarbons, oxides of nitrogen, and sunlight.

As can be seen from Fig. 3 that fire is occurring in much less portion of the area considered for the study, so area averaged values cannot give the exact correlation. To get more accurate picture of correlation, only fire affected region should be considered.

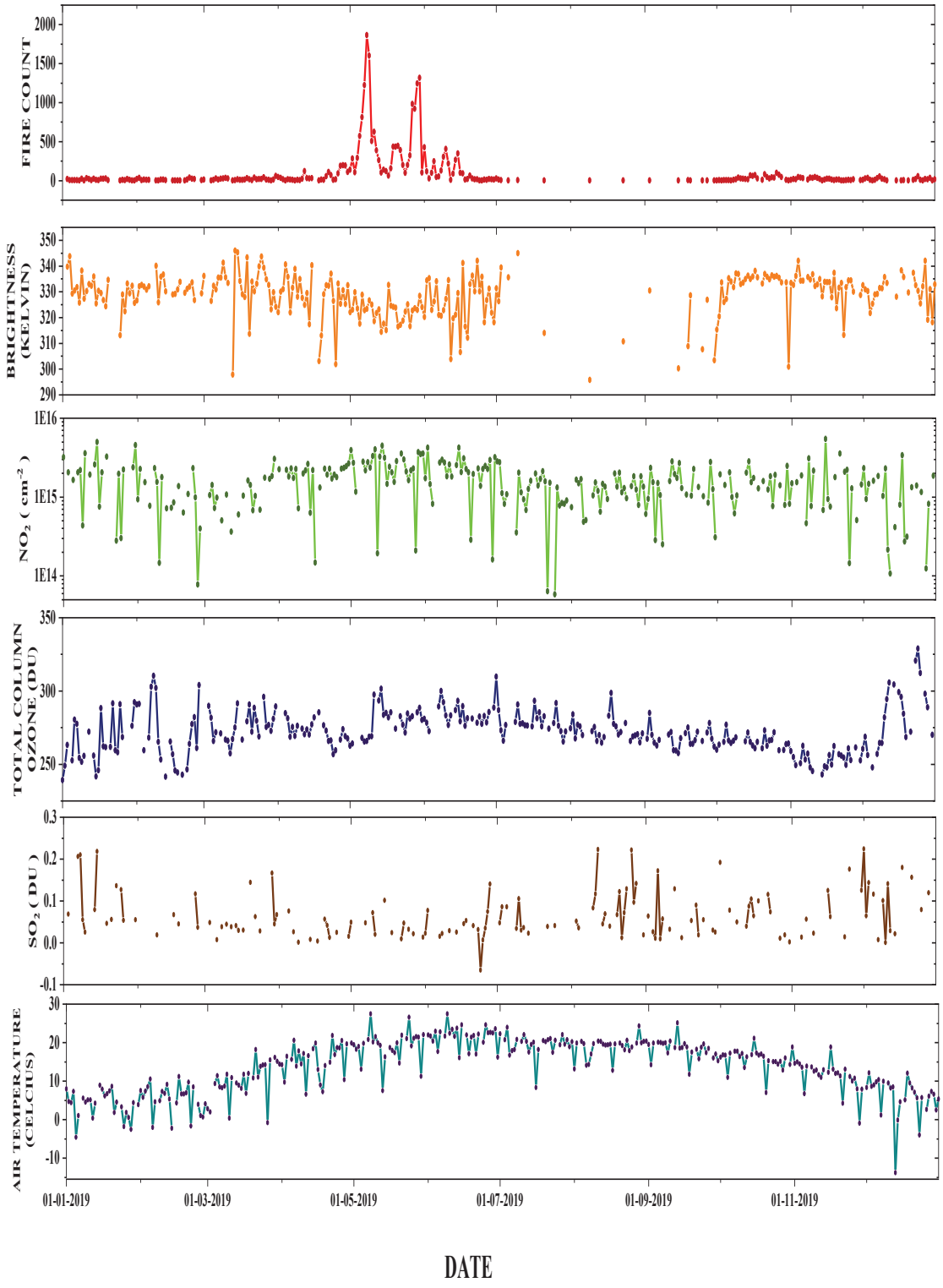

Fig 4. Graph showing plots for various variants and fire counts for year 2019.

e-ISSN 2456-7701
Vol. 3 Issue No.3, July-September 2021

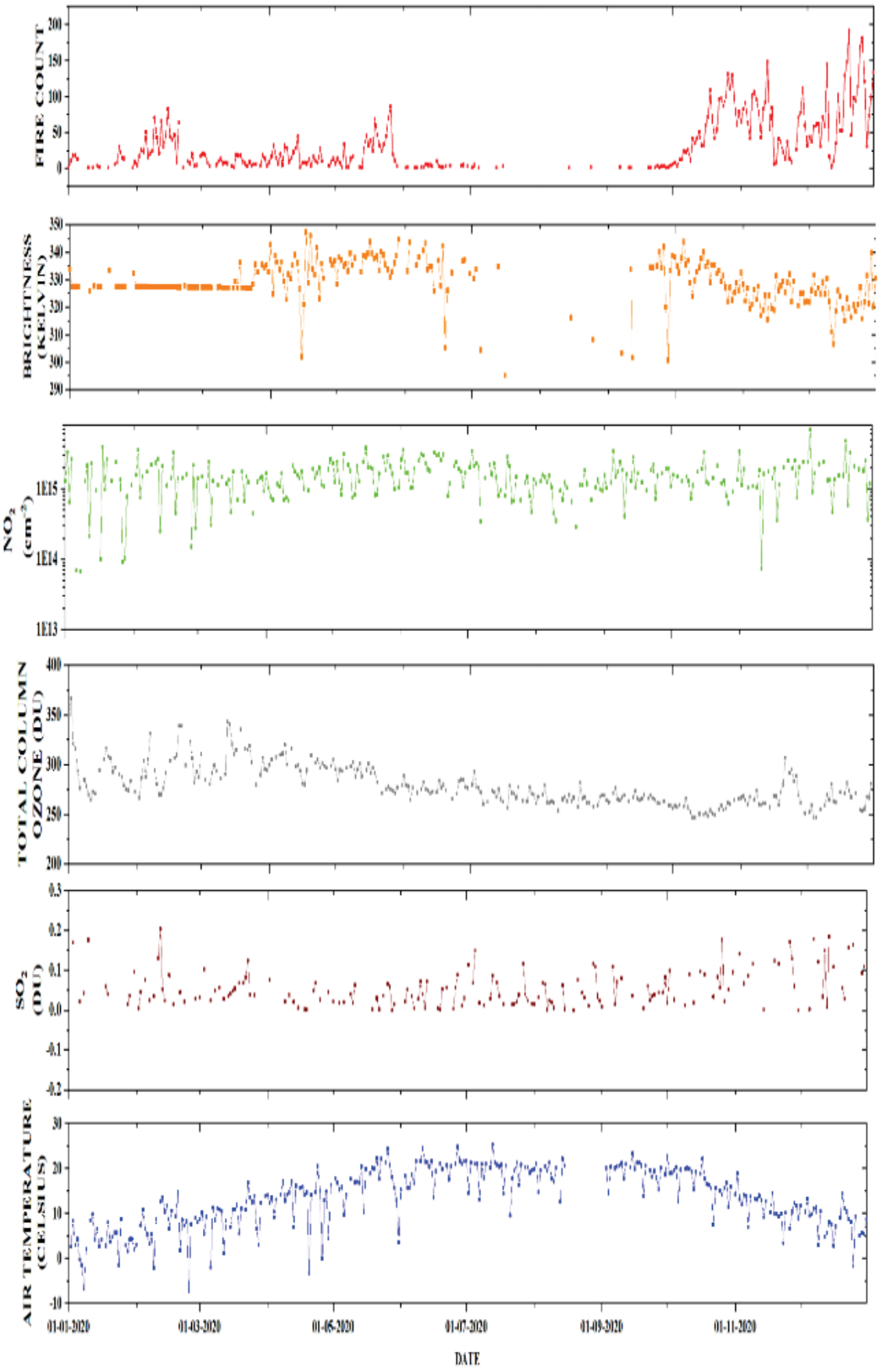

Fig 5. Graph showing plots for various variants and fire counts for year 2020.

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Vol. 3 Issue No.3, July-September 2021

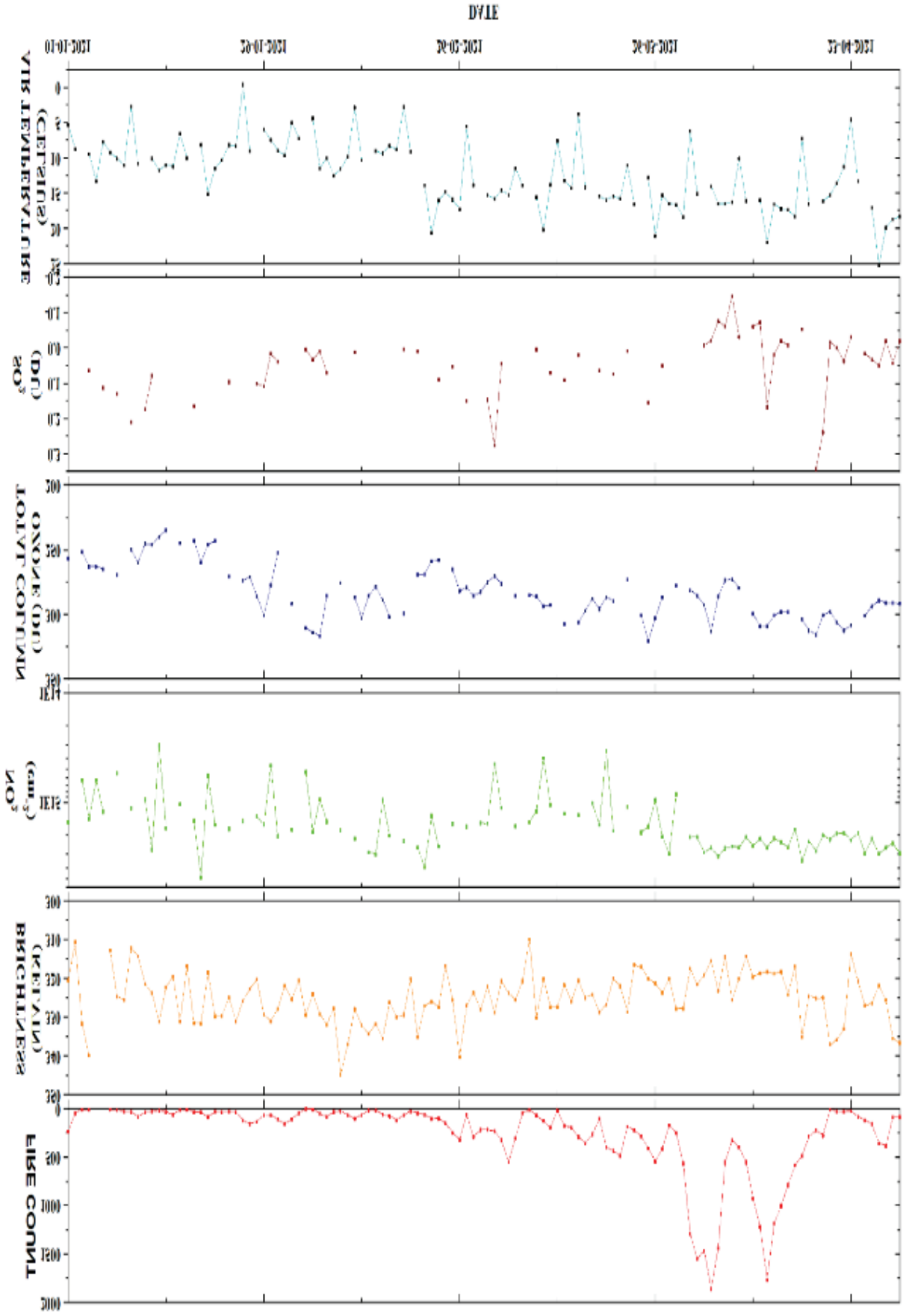

Fig 6. Showing plots for various variants and fire counts for year 2021

e-ISSN 2456-7701
Vol. 3 Issue No.3, July-September 2021

Average Values Of Different Variables and Their Standard Deviations

Table 2. Table showing means and standard deviations for variants and forest fire

Parameters	YEAR		
	2019	**2020**	**2021**
Forest Fire (Counts)			
Mean	92.37	33.19	153.14
Standard Deviation	237.71	38.379	186.62
Brightness (K)			
Mean	328.7429	329.07	325.42
Standard Deviation	8.75	8.12	6.408
NO_2 (cm^{-2})			
Mean	1.67×10^{15}	1.57×10^{15}	1.56×10^{15}
Standard Deviation	9.77×10^{14}	8.6649×10^{14}	8.47×10^{14}
SO_2 (DU)			
Mean	0.065	0.0578	0.086
Standard Deviation	0.054	0.0578	0.066
Ozone (DU)			
Mean	272.51	279.36	227.48
Standard Deviation	14.53	20.55	20.51
Air Temperature °C			
Mean	13.82	13.3662	7.23
Standard Deviation	6.96	6.52	4.41

From Table 2, we can compare the average number of forest fires that occurred in the year and about the various variants we took for our study as brightness (temperature), ozone, NO_2, SO_2, and air temperature.

The values of standard deviation for fire counts are high because the count's value varies from 0 to 1800+ and only a few entries (nearly about 50) have high values of counts, while many have the 0 value as the fire didn't occur the whole year.

CONCLUSION

The study is about forest fire and its impact on the air. The study shows that months of summer initially have the highest number of forest fires and the rainy season having the least. The year 2020 has less number of fires in summer because of the COVID-19 lockdown having least human interference due to which the pollution and the factors causing forest fires got decreased eventually. In the winters of 2020, the fire counts increased due to increase in the factors causing forest fires as COVID-19 lockdown was lifted in early August. At the time of the high fire, O_3, SO_2 and NO_2 show increase. As the fire affected portion is much less than the total area considered for this study, the area averaged values are not giving the exact correlation. To get more accurate picture of correlation, only fire affected region should be considered and that is our plan for future study.

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