Original Research Article

Spatial vulnerability assessment and diurnal climatology of lightning events in Tamil Nadu

ABSTRACT

The research probes into the seven agro climatic zones in Tamil Nadu which are highly vulnerable to lightning strikes, as well as the human fatalities caused by Cloud to Ground lightning. The purpose of the study is to find out the vulnerable hotspots and diurnal climatology of the Cloud to Ground lightning strikes during the northeast monsoon, southwest monsoon, and summer seasons. Heat maps are used for the lightning strikes using ArcGIS software and the diurnal climatology was performed by interpolating the data from the lightning location network into a 3-hour resolution. In vulnerability analysis, Northeastern zone is more prone to lightning during Southwest and Northeast Monsoon. On the other hand, High rainfall zone and Hilly zone are vulnerable to lightning in summer season. The Northeast monsoon has the highest lightning frequency ratio, followed by the summer. The maximum rate of strikes occurred between 10-15 hrs IST and showed a peak range between 10:00 to 12:00 hrs IST. A labor-intensive agricultural economy is linked to higher rates of lightning-related deaths and injuries. The results of this research could be useful in developing lightning climatology for the future climatic condition for Tamil Nadu.

Keywords: *Lightning; causalities; seasonal fluctuation; Lightning Strikes; ArcGis*

1. INTRODUCTION

Lightning is a natural phenomenon that occurs when an electric charge builds up in the atmosphere. This charge build-up can be caused by a variety of factors, including air heating and cooling, air mass movement, and the presence of thunderstorms. Lightning is an electrical discharge caused by static electricity accumulating between Inter-clouds, Intra - cloud, and the Cloud to Ground (CG). Thunderstorms are weather occurrences that produce severe rains, high winds, hail, lightning, and tornadoes [1]. The cumulonimbus clouds create the majority of the lightning; many studies on the electrical structure of clouds have concentrated on this cloud type [4-2]. Cirrus, cirrostratus, and deep convective clouds have been recognized as coexisting high clouds in the Indian monsoon zone [5-3]. During the northeast monsoon season, cumulus clouds dominate the Arabian Sea and the Bay of Bengal, whereas large-scale stratiform clouds such as stratocumulus dominate the southern Indian

Ocean [6-4]. Aside from its potentially dangerous aspects, lightning has several beneficial effects such as stimulating plant growth helps to fertilize and nourish the earth. The global economic, agricultural, health, forest fire, and human death consequences of lightning are enormous [7-5]. The number of people who survive with permanent injuries, temporary disabilities, and psychological trauma could be several times higher, surprisingly; very little systematic data on lightning deaths have been collected in many parts of the World, making it difficult to estimate global annual rates of lightning fatalities [8-6].

Summer thunderstorms are the most common cause of lightning. Other (important) elements, which contribute to thunderstorm formation, include temperature mixing, high humidity, rapid convection leading to vertical development of cumulonimbus clouds, and friction between cold and warm air. However, there is a significant paucity of lightning data, lightning detection equipment [Optical Transient Detector (OTD) and Lightning Imaging Sensor (LIS)], and lightning-identifying technologies.

The diurnal cycle is a major variation in atmospheric factors such as temperature, wind, precipitation, and in lightning. Because they are both connected with convection, diurnal precipitation and lightning are inextricably linked. Observational advances, notably satellite remote sensing, have revealed worldwide spatiotemporal structures in diurnal precipitation cycles, including unique features over land and tropical open oceans. Due to convection generated by daytime solar heating, the rain rate over land often reaches its maximum from afternoon to early evening. The diurnal cycle peaks over tropical oceans between midnight and early morning [7]. More complex diurnal precipitation systems connected with mountain-valley breezes can be caused by land topography [8].

REVIEW OF LITERATURE

The diurnal climatology of Lightning was investigated all over the world. Lanna Maier [9] investigated the diurnal fluctuation of summer thunder activity across the Florida peninsular. The findings of the study revealed that peak lightning activity occurred between the hours of 20:00 and 21:00 GMT during the summer months in Florida. Similarly, Hidayat and Ishii [10] conducted a study on lightning activity in Indonesia. The study found that lightning activity over land exhibited a peak around 15:00 local time (LT) and a slight peak in the morning around 03:00 LT and 05:00 LT.

The spatio-temporal distribution of lightning activity over the Indian subcontinent reveals a significant lightning frequency rank throughout the north western and north-eastern parts of the Indian region along the Himalayan foothills. The diurnal variability of lightning occurrences over the Indian region is very scarce and it was reported by Boeck *et al.* [11]. Ray *et al.* [12] reported that the lightning events have also increased by 30% when compared to the previous decade and four times when compared to 1987-1996 and, more than 90% of extreme events were in Maharashtra, Kerala, and Karnataka. According to the earth networks report, there are approximately 50000 Cloud to Ground lightning strikes in Tamil Nadu. Kandalgaonkar *et al.* [13] studied the spatio-temporal variability of lightning in India and found that the diurnal activity over the Indian region which was analysed for four years (1998-2001) and the study revealed that the lightning peak occurred at approximately 10:00 UTC. The diurnal climatology over three areas of India from 1996 to 2013 and revealed an increase in lightning incidents from 2008 to 2013 compared to 1996 to 2001 [14].

The precise goals of this study were to determine the lightning frequency and fatality in the previous four years, as well as to identify the most vulnerable zone, depending on divisional situations, of lightning incidents in Tamil Nadu. In addition, the study was carried out to research the diurnal climatology of lightning incidents in Tamil Nadu.

2. MATERIAL AND METHODS

2.1 STUDY AREA AND PERIOD

Tamil Nadu is India's tenth biggest state, with a total land area of 130058 square kilometers, located between latitude 11.12 °N and longitude 78.65 °E with coastline of 1076 km long and it protects a wide range of terrain forms, geology, soil, climate, vegetation, and natural resources.

2.2 LIGHTNING STRIKE DATA

The lightning strike data was obtained from the lightning location networks from the main server located at Indian Institute of Tropical Meteorology (IITM), Pune for the study period (2019- 2022).

Table 1: Lightning Location Devices across Tamil Nadu installed by (IITM)

SI. No	Sensor Location	Latitude	Longitude	Places Covered
1	Agro Climate Research Centre, TNAU, Coimbatore (WZ)	11.00° N	77.00° E	Coimbatore, Erode, Tiruppur, The Nilgiris, Salem, Dharmapuri, Namakkal, Karur, Dindugul and Krishnagiri

2	Vellore Institute of Technology, Vellore (NEZ)	12.96° N	79.15° E	Vellore, Tiruvannamalai, Chennai, Kanchipuram, Villupuram, Cuddallore, Chengalpattu, Ranipet, Villupuram, Kallakurichi and Tirupattur
3	Thyagarajar College, Madurai (SZ)	9.91° N	78.14° E	Madurai, Theni, Viruthunagar, Thoothukudi, Tirunelveli, Kanyakumari, Ramnathapuram, Sivaganagai, Pudukottai and Tenkasi
4	Central University of Tamil Nadu, Thiruvarur (CDZ)	10.81° N	79.61° E	Thiruvarur, Thanjavur, Perambalur, Nagapattinam, Ariyalur and Trichy

2.3 SPATIAL ANALYSIS

ArcGIS software was used to analyze the data and the Arcgis Heat Map: Kernel Density Tool was used as it visualizes data in a geographical region and estimates the number of lightning strikes over Tamil Nadu. To make the findings comparable on a regional and rank per Month has been determined for the study period (2019 to 2022). The following method was adopted to calculate the rate of a lightning [15].

$$LFR = \sum F/Y$$

Where, LFR = Lightning frequency rank

$\sum F$ = sum of lightning frequency

Y = number of years (2019- 2021)

These rates were computed for each month and then ordered in descending order.

2.5 DIURNAL CLIMATOLOGY OF LIGHTNING EVENTS

The Lightning Detection Sensor data collection provides a daily lightning flash count. The lightning detection sensor provides data for every 10 seconds, and the data is interpolated to a three-hour resolution for ease of presentation. The approach is used to calculate the diurnal fluctuations for various seasons: Summer, NEM, and SWM.

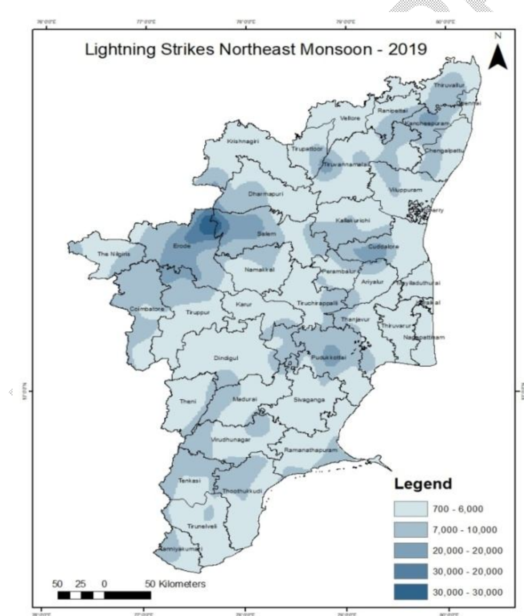
3. RESULTS AND DISCUSSION

3.1 VULNERABILITY MAPPING

During Northeast monsoon (NEM), the high lightning strikes were occurred in North Eastern Zone (Kanchipuram, Tiruvannamalai, Cuddalore, Tiruvallur, Ranipet, Chengalpattu and Villupuram) and some parts of the North Western Zone (Salem) and Southern Zone

(Pudukkottai) for the study period (Fig. 1, 2, 3). During Southwest monsoon (SWM), the highly vulnerable areas are the North Eastern Zones (Tiruvallur, Chennai, Villupuram, Tiruvannamalai, Cuddalore, Kanchipuram and Chengalpattu), Southern Zones (Sivagangai, Madurai and Virudhunagar) and some parts of North Western Zones (Salem and Dharmapuri) and Southern Zone (Pudukkottai) (Fig. 4,5,6). The common areas susceptible in the NEM and SWM are Kanchipuram, Tiruvallur, Cuddalore, Tiruvannamalai, Chengalpattu, Villupuram in the North Eastern Zone and Pudukkottai from Southern Zone.

In summer season, the highly vulnerable areas are the High Rainfall Zone (Kanyakumari), Hilly Zone (The Nilgiris), Southern Zone (Madurai, Virudhunagar, Tenkasi, Sivagangai, and Thoothukudi), and some parts of the Western zone (Erode and Coimbatore) and North Western Zone (Salem, Krishnagiri and Dharmapuri) (Fig. 7,8,9). On account of this the lightning likewise occurs the results support the findings of Choudhary *et al.* [16] as during the pre-monsoon season, this region of India has a well unstable air because of passionate surface heating and reduced-level warm moist southerly air that is to say lifted over the cool dry air from the northwest at intervening-levels resulted in the high level of lightning strikes in summer season. According to Saha *et al.* [17] the maximum lightning flashes are discovered over the northward western portions of the Himalayas and few parts of Punjab also get more lightning.



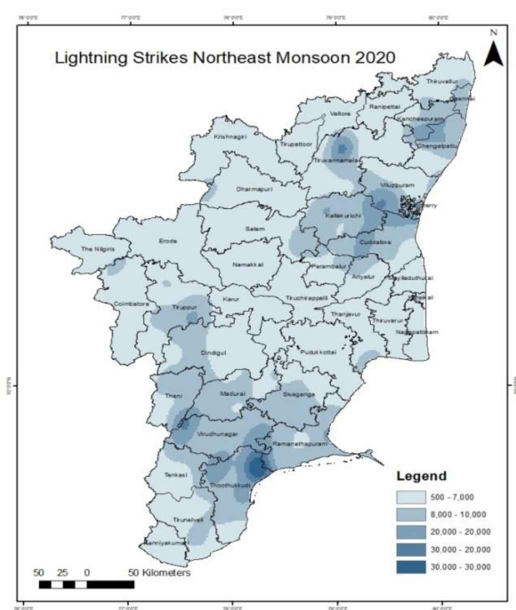


Figure 1 Lightning strikes over Tamil

Figure 2 Lightning strikes over Tamil

Nadu during NEM 2019

Nadu during NEM 2020

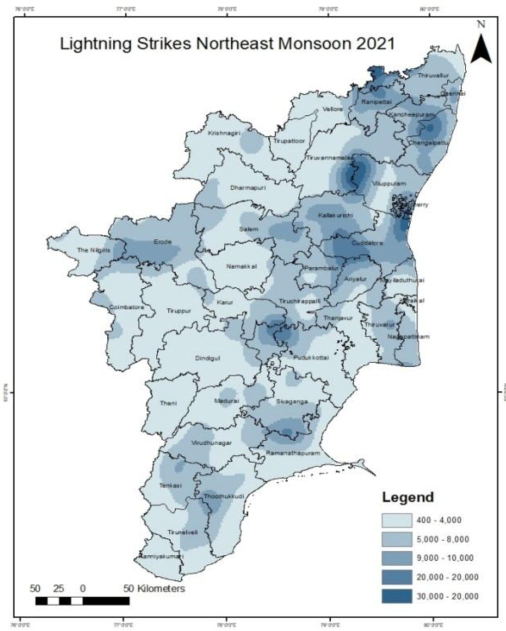


Figure 3 Lightning strikes over Tamil Nadu during NEM 2021

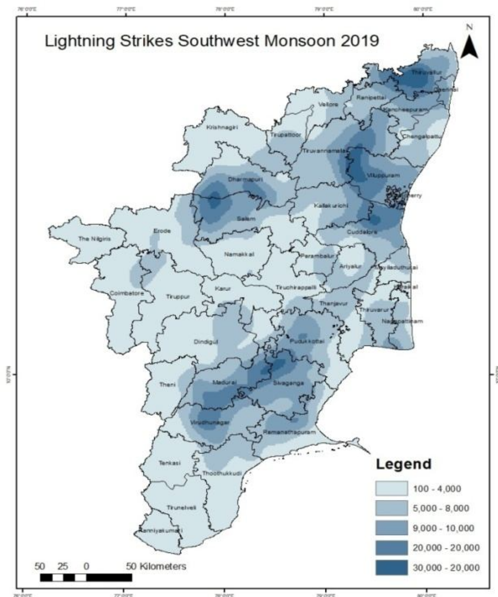


Figure 4 Lightning strikes over Tamil Nadu during SWM 2019

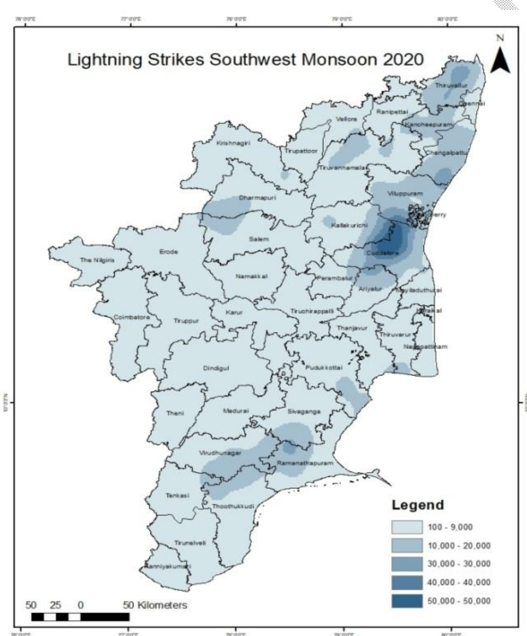


Figure 5 Lightning strikes over Tamil Nadu during SWM 2020

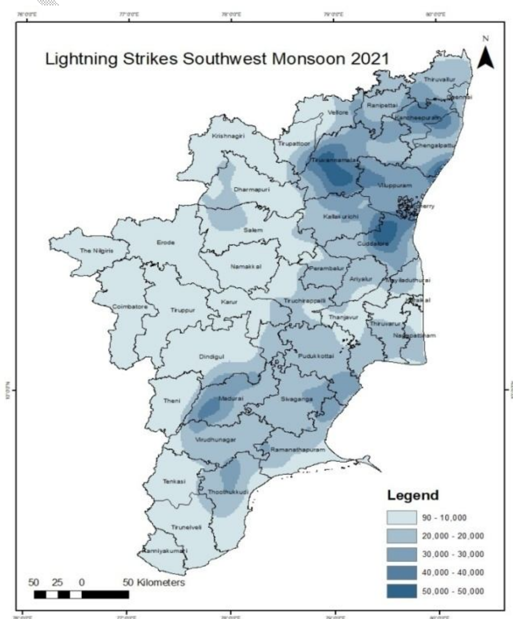
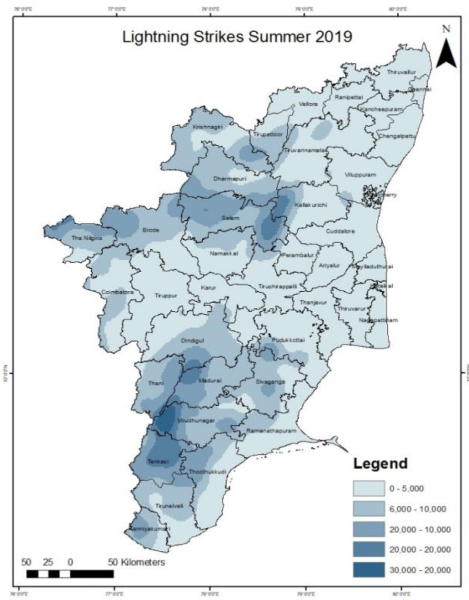


Figure 6 Lightning strikes over Tamil Nadu during SWM 2021



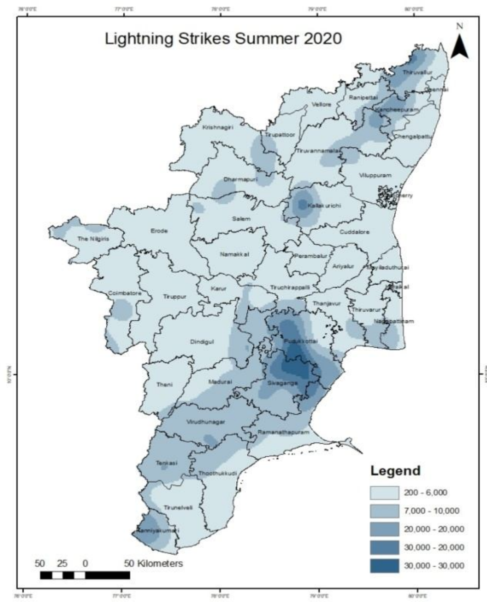


Figure 7 Lightning strikes over Tamil Nadu during Summer (Pre monsoon) 2019

Figure 8 Lightning strikes over Tamil Nadu during Summer (Pre monsoon) 2020

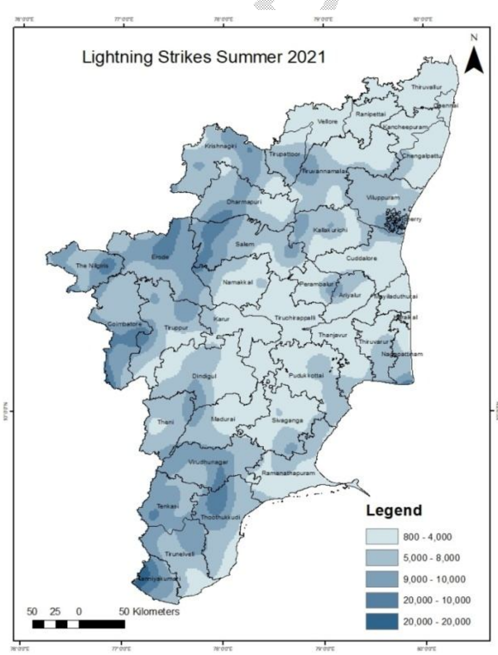


Figure 9 Lightning strikes over Tamil Nadu during Summer (Pre monsoon) 2021

3.3 LIGHTNING FREQUENCY RANK

The lightning frequency of Cloud to Ground Lightning Strikes is greater in April and May with 3, 96,069 and 3, 54,478 Cloud to Ground strikes followed by October with 23, 70,008 strikes (Fig.10).

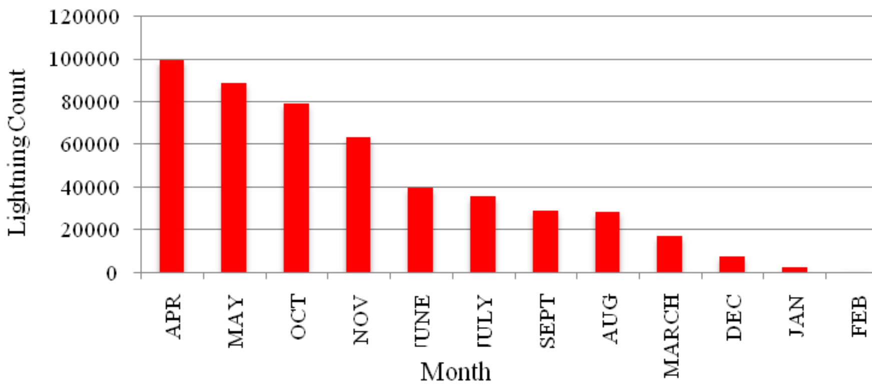


Figure 10. Cloud to Ground lightning activity over Tamil Nadu during 2019 – 2021

3.4 DIURNAL CLIMATOLOGY OF LIGHTNING

To consider the time difference of the Cloud to Ground lightning incidents, we perform constant analysis for 10 months from March to December during the study period 2019-2021. The results are divided into three various seasons such as Northeast monsoon (Fig. 11-13), Southwest monsoon (Fig. 14-17), and summer season (Fig. 18-20). We can visualize that during the northeast Monsoon season, most of the lightning activity happens during 10-15 hrs IST and the small peak occurred between 03- 09 hrs IST. In 2019, the highest peak was observed in November whereas in 2020 the highest peak was observed during the months of October and December. According to Mondal *et al*. [14] during October, in the southern part of India, *i.e.*, Tamil Nadu, and some part Orissa, Bihar, and Kashmir, has the maximum lighting than rest of India. In November, few parts of Western Ghat and Kerala received lightning. Lightning occurrences occur during October and November is on account of the northeast monsoon.

We can observe that during the Southwest Monsoon season, most of the lightning activity occurred between 10-12 hrs IST with the smallest peak between 00 – 06 hrs IST. The highest peak of 2019 was observed in June, while in 2020 it was observed in August. In the year 2021 highest number of strikes were observed in July and September. As per the findings of Lopez *et al.* [18], maximum flash counts are observed during August and September this is on par with the results obtained in this study.

During the summer season most of the lightning activity occurred all along 10-15 hrs IST. In the year 2019 highest number of strikes were observed during April and May month, while in 2021 the highest number of strikes observed in March. Our results, therefore, support the finding of Taori *et al.* [19] which performed the diurnal analysis on 3 various states for 3 different months also support the findings with Maier *et al.* [20].

A. Northeast Monsoon (October to December)

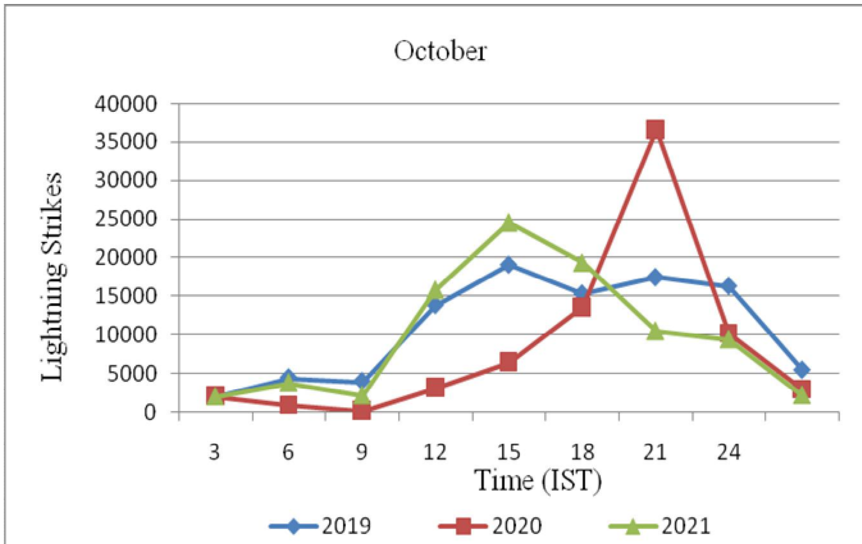


Fig. 11 Diurnal pattern of Cloud to Ground flash occurrences during October

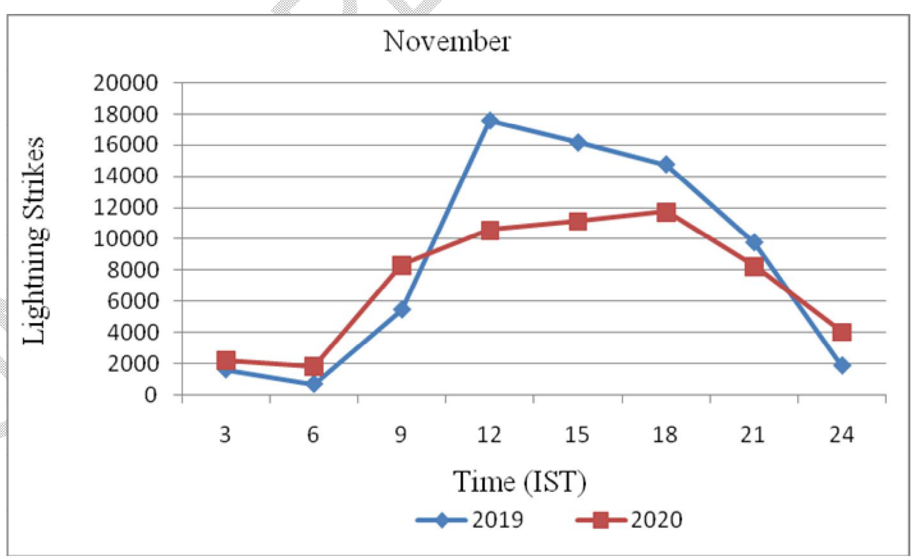


Fig. 12 Diurnal pattern of Cloud to Ground flash occurrences during November

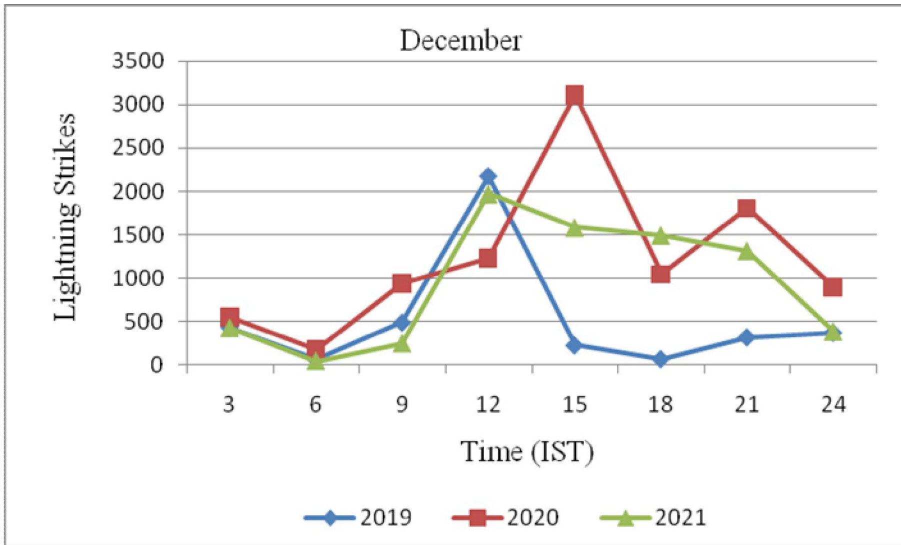


Fig. 13 Diurnal pattern of Cloud to Ground flash occurrences during December

B. Southwest Monsoon (June to September)

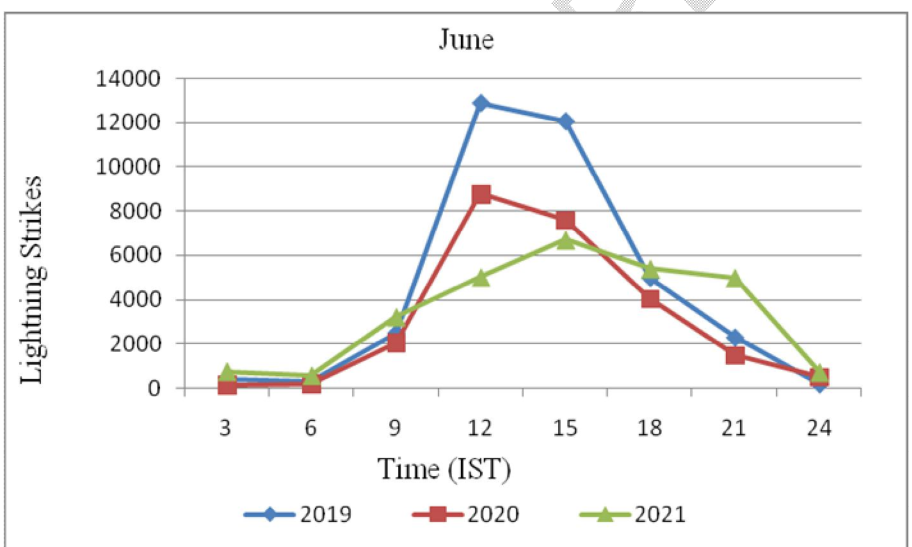


Fig. 14 Diurnal pattern of Cloud to Ground flash occurrences during June

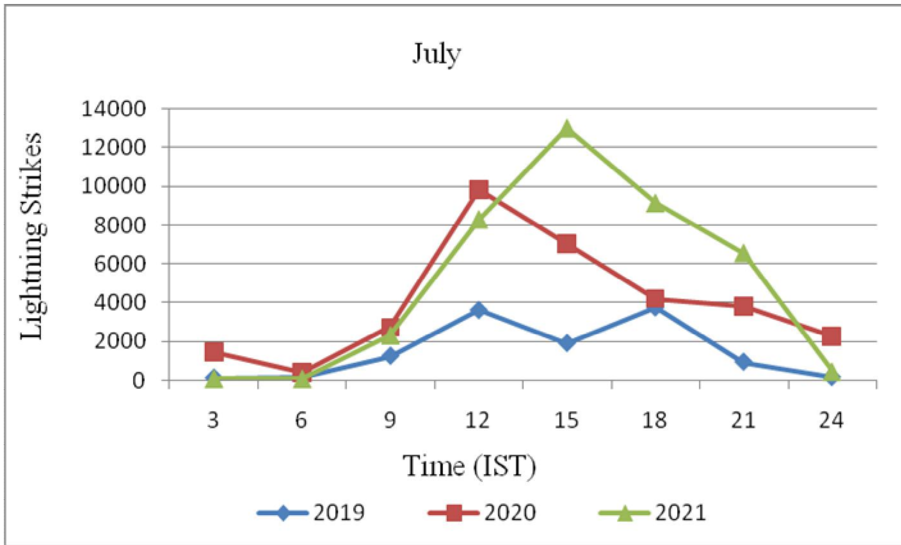


Fig. 15 Diurnal pattern of Cloud to Ground flash occurrences during July

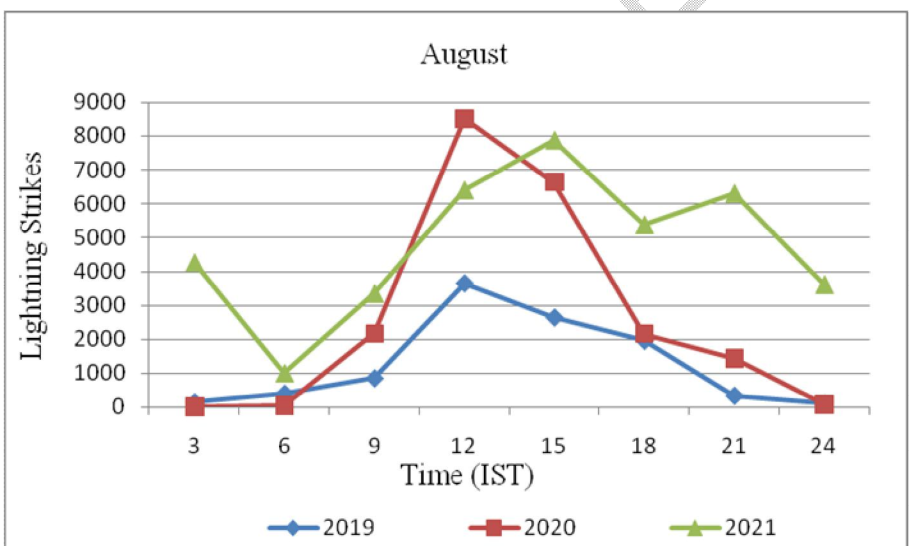


Fig. 16 Diurnal pattern of Cloud to Ground flash occurrences during August

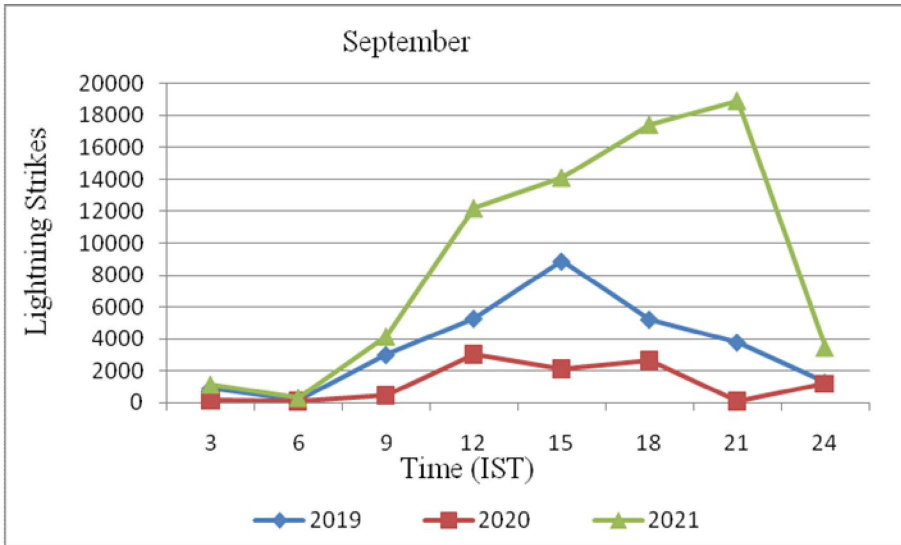


Fig. 17 Diurnal pattern of Cloud to Ground flash occurrences during September

C. Summer (March to May)

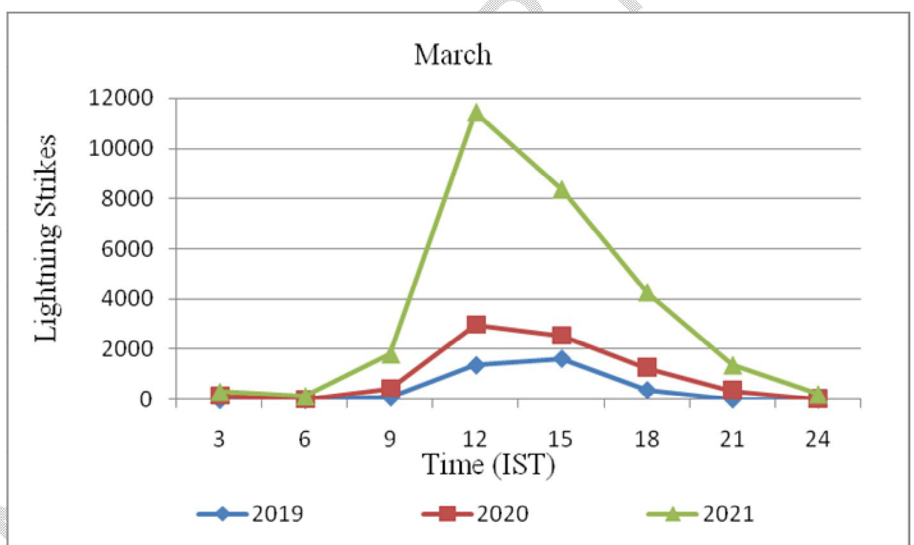


Fig. 18 Diurnal pattern of Cloud to Ground flash occurrences during March

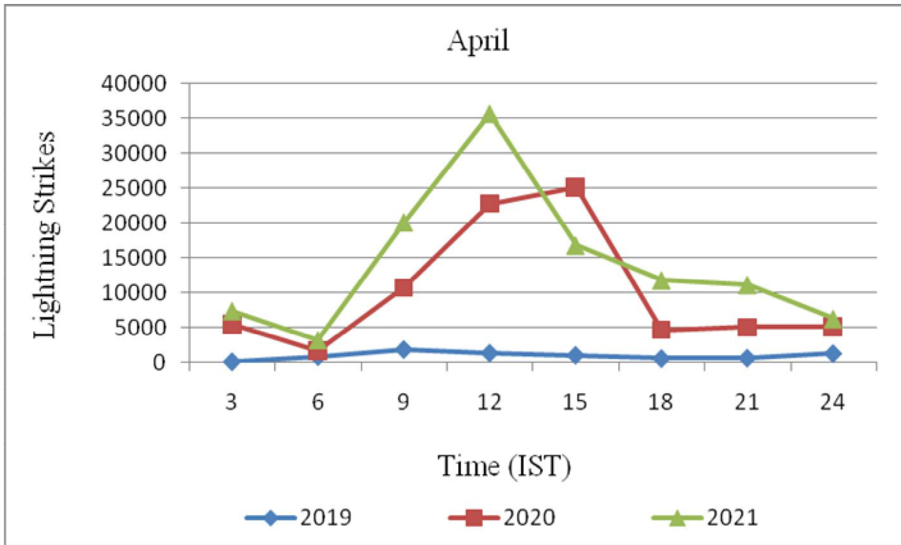


Fig. 19 Diurnal pattern of Cloud to Ground flash occurrences during April

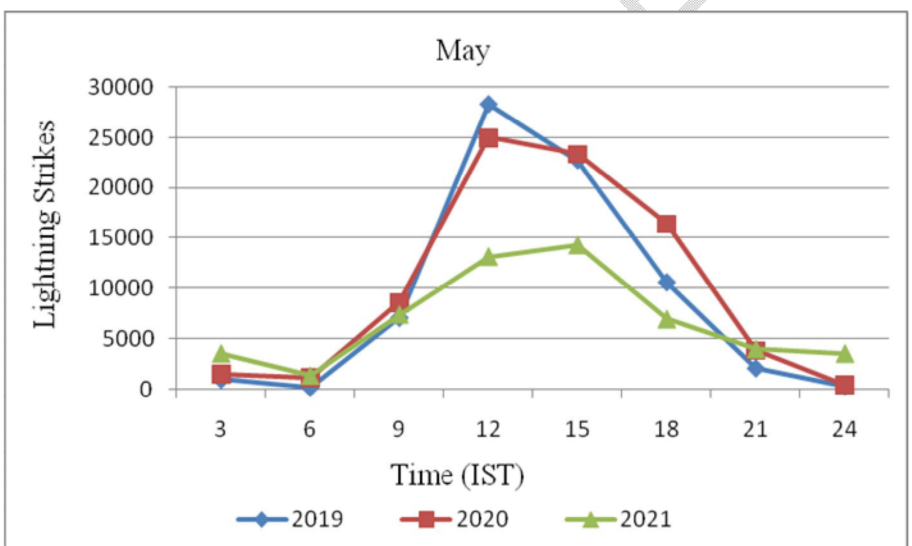


Fig. 20 Diurnal pattern of Cloud to Ground flash occurrences during May

4. CONCLUSION

During Northeast monsoon season, NEZ and NWZ were more vulnerable, and during Southwest monsoon, NEZ and SZ were particularly vulnerable. High Rainfall Zones and Hilly Zones were vulnerable throughout the summer season. The summer has the highest lightning frequency ratio, followed by the Northeast monsoon. According to the diurnal variation, the highest rate of strikes occurred between 10-15 hrs IST with low strikes rate between 00 – 09 hrs IST in all seasons. Higher incidences of lightning-related deaths and injuries are caused by a labor-intensive agricultural economy, inadequate infrastructure, illiteracy, people's lack of awareness, and a tropical environment in nations such as South Africa, Malaysia, India, and Bangladesh. The findings of this study might lead to the development of particular public policies and lightning safety education in Tamil Nadu.

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