



EXPLORING THE INFLUENCE OF METEOROLOGICAL FACTORS ON SCRUB TYPHUS INCIDENCE: AN ECOLOGICAL TIME SERIES ANALYSIS IN KERALA, INDIA

Dhanya KM¹, E Pushpalatha^{2*}, Eldho Varghese³, MA Sarath Chandran⁴

¹Government Medical College, Thrissur, India

²University of Calicut, Malappuram, India

³ICAR-Central Marine Fisheries Research Institute, Ernakulam, India,

⁴ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India

Received : 11th October, 2024

Accepted : 04th November, 2024

ABSTRACT

Background: Scrub typhus, a re-emerging neglected tropical disease, now poses public health concerns in tropical and subtropical countries. Kerala, situated in the southwestern part of India, has been showing an increasing incidence of scrub typhus over the last few years. The dynamic nature of meteorological parameters such as temperature and rainfall influence the survival and activity of chiggers as well as the abundance and distribution of their rodent hosts. Consequently, elucidating these associations can

**Corresponding Author:*

Dr E Pushpalatha; Email: drepushpalatha@gmail.com

Cite this article as:

Dhanya KM, Pushpalatha E, Varghese Eldho, Sarath Chandran MA.; Exploring the influence of meteorological factors on scrub typhus incidence: an ecological time series analysis in Kerala, India. *J Med Arthropodol & Public Health*. 2024; 4(2): 15-28.

aid in the development of early warning systems, targeted interventions and resource allocation to mitigate the impact of scrub typhus outbreaks in Kerala. In this study we aimed to analyse the relationship between meteorological factors (maximum temperature, minimum temperature and rain fall) and scrub typhus incidence in Kerala from 2012-2020.

Methods: Number of monthly reported scrub typhus cases for the period of 2012-2020 was obtained from Integrated Disease Surveillance Project (IDSP) of Directorate of Health Services, Kerala. Monthly district wise weather parameters viz. rain fall, maximum and minimum temperatures were obtained from India Meteorological Department (IMD), Pune. IMD daily gridded data was converted to district level. Influence of meteorological parameters on occurrence of scrub typhus was studied through correlogram using time series analysis technique.

Results: The present study shows that the maximum and the minimum temperatures negatively correlate with the scrub typhus incidence in Kerala. Rainfall has no influence on the scrub typhus incidence in Kerala. Temperature plays a more crucial role in predicting scrub typhus occurrence than seasonality or trends.

Conclusion: The study suggests a model of predicting the possibility of a scrub typhus incidence some three months in advance by observing the temperature conditions prevailing in a given area and also found that the climatic factor like rainfall do not show any significant influence on the occurrence of scrub typhus incidence in Kerala.

Keywords: Scrub typhus, temperature, rainfall, correlation

INTRODUCTION

Scrub typhus, a re-emerging neglected tropical disease, now poses public health concerns in tropical and subtropical countries. This disease is caused by *Orientia tsutsugamushi*, a bacterium belonging to the family Rickettsiaceae. The pathogen is transmitted from man to man by the bite of larvae of infected trombiculid mites (chiggers), which are ectoparasites of rodents and shrews¹. The pathogen is transmitted from one stage to another through transstadial and trans

ovarian transmission^{2,3} The term “scrub typhus” originates from the presence of chiggers and rodents in scrub vegetation (shrub vegetation)³.

Kerala, situated in the southwestern part of India, has been showing an increasing incidence of scrub typhus over the last few years⁴. The dynamic nature of meteorological parameters such as temperature and rainfall influence the survival and activity of chiggers as well as the abundance and distribution of their rodent hosts⁵⁻⁷ Consequently, elucidating these associations can aid in the development of early warning systems, targeted interventions and resource allocation to mitigate the impact of scrub typhus outbreaks in Kerala.

In this study we aimed to analyse the relationship between meteorological factors (maximum temperature, minimum temperature and rain fall) and scrub typhus incidence in Kerala from 2012-2020.

Incidence of scrub typhus is highly influenced by meteorological factors like temperature, humidity and rainfall⁸. A study from China described the temperature and the scrub typhus association as initial elevated – descendent pattern. They found that heavy rainfall was associated with a sharp increase in scrub typhus risk⁹. In Japan, during 1984-2014, the average temperature in July and August of the previous year, cumulative rainfall in the September of previous year, snowfall throughout the winter and maximum depth of snow cover in January and February were positively correlated with number of scrub typhus cases⁵. Scrub typhus outbreak was reported in cooler months in Southern India¹⁰.

Only a few studies have explored the influence of meteorological factors on the incidence of scrub typhus in India^{7,10,11}. Given the variation in climatic factors from place to place and the re-emergence of scrub typhus in Kerala, we conducted a study on the influence of weather conditions on scrub typhus incidence in Kerala.

MATERIAL AND METHODS

The month wise data of scrub typhus cases in Kerala from 2012 – 2020 was obtained from the Integrated Disease Surveillance Project (IDSP) of Directorate of Health Services (DHS), Kerala⁴. The daily gridded rainfall, maximum and minimum temperature data from 2012–2020 was obtained from India Meteorological Department (IMD), Pune. The daily gridded weather data was

converted into district level data using Thiessen polygon approach using an area weighted average approach^{12,13}. Further the district level data was compiled to get the state level data and the study design is ecological time series analysis.

STATISTICAL ANALYSIS

Influence of weather variables namely maximum temperature, minimum temperature and rainfall on the occurrence of scrub typhus in Kerala was studied through correlogram using time series analysis in R Statistical Software.¹⁴ Trend analysis using decomposition of additive time series method was done from 2012 to 2020. Mann Kendal test was performed to check the trend of the occurrence of scrub typhus. Cross correlation plots of total monthly rainfall, monthly average maximum and minimum temperatures with number of reported cases were prepared.

RESULTS

In this study, we conducted a statistical analysis to explore the correlation between monthly scrub typhus cases and meteorological factors, including total rainfall, average maximum temperature, and average minimum temperature from 2012 to 2020. The results are summarized below.

Total number of scrub typhus reported in Kerala from 2012 to 2020 was 4064 (Table 1). Maximum number of cases were reported in December and January (Fig.1).

Table 1. Year-wise Incidence of Scrub Typhus in Kerala from 2012 to 2020

Year	No. of scrub typhus cases
2012	39
2013	68
2014	433
2015	1149
2016	633
2017	340
2018	400
2019	579
2020	423
Total	4064

Source: Directorate of Health Services, Kerala⁴

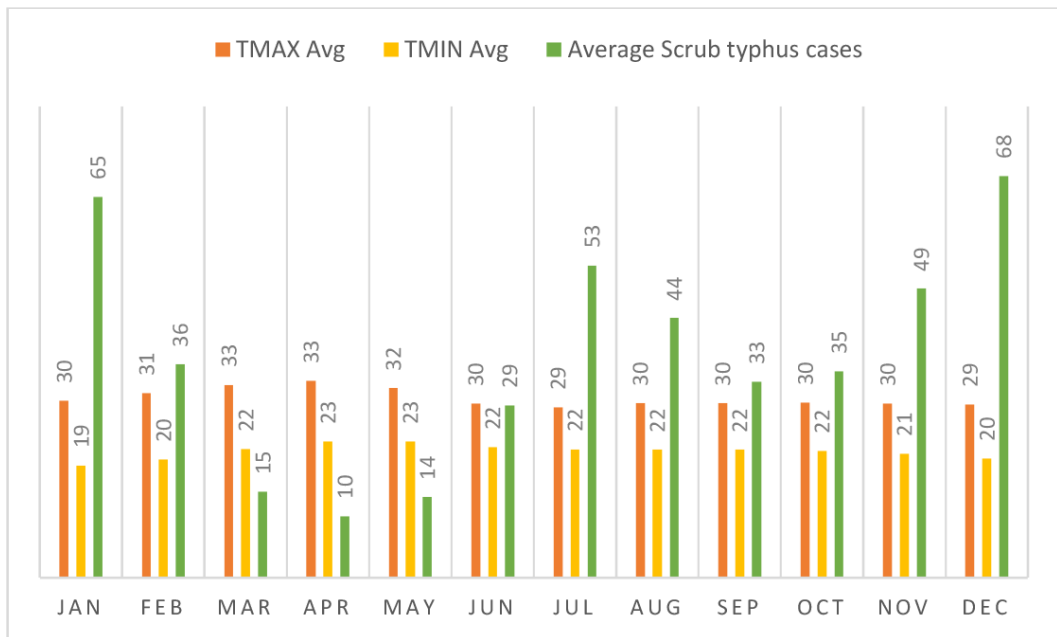


Fig. 1. Data on Maximum and Minimum Temperatures and scrub typhus incidence in Kerala from 2012 to 2020

CROSS-CORRELATION ANALYSIS OF AVERAGE MAXIMUM AND MINIMUM TEMPERATURES AND SCRUB TYPHUS INCIDENCE

Our analysis revealed a significant negative correlation between scrub typhus occurrence and the average maximum and minimum temperatures of the preceding three months. Specifically, an increase in both the average maximum and minimum temperatures during the previous three months was associated with a decrease in scrub typhus cases in the subsequent month. This relationship indicates a lag time of one month, meaning the effect of temperature changes manifests in scrub typhus incidence after a delay of approximately four weeks (Fig.1 and Fig.2).

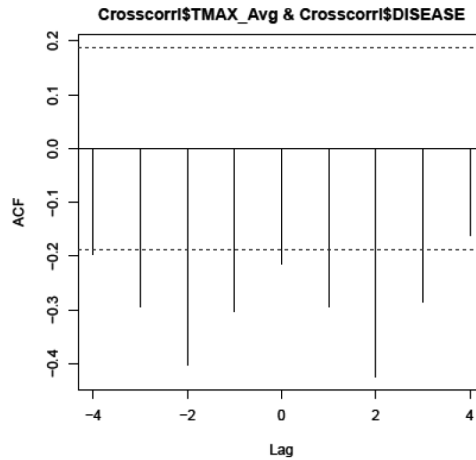


Fig. 2. Cross correlation plot of monthly average maximum temperature and average number of scrub typhus cases from 2012-2020

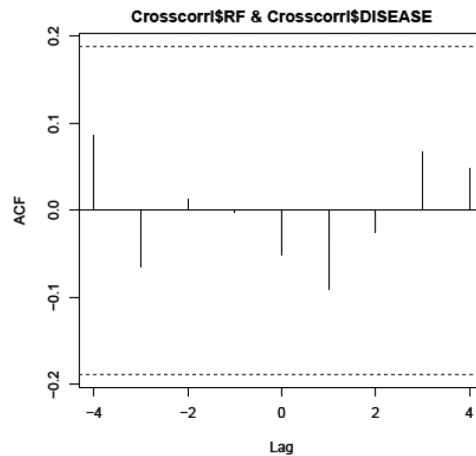


Fig. 3. Cross correlation plot of monthly total rainfall and average number of scrub typhus cases from 2012-2020

The analysis shows an evident trend and seasonality in scrub typhus occurrence in Kerala (Fig. 4). Further statistical testing using the Mann-Kendall test resulted in a tau value of 0.182, with a two-sided p-value of 0.0055516. This significant p-value indicates a statistically meaningful increasing trend in scrub typhus cases over time in the region (Fig.5)

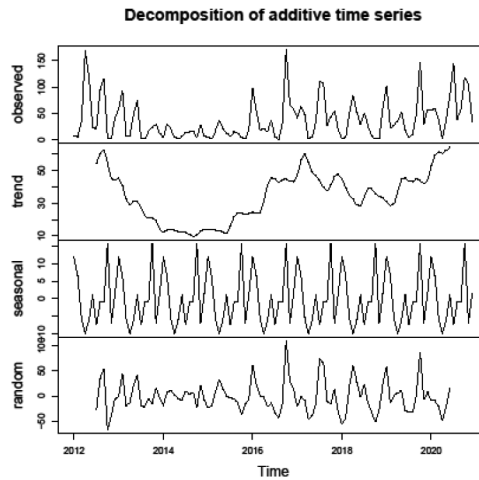


Fig. 4. Decomposition of Additive time series showing trend and seasonality of scrub typhus incidence in Kerala

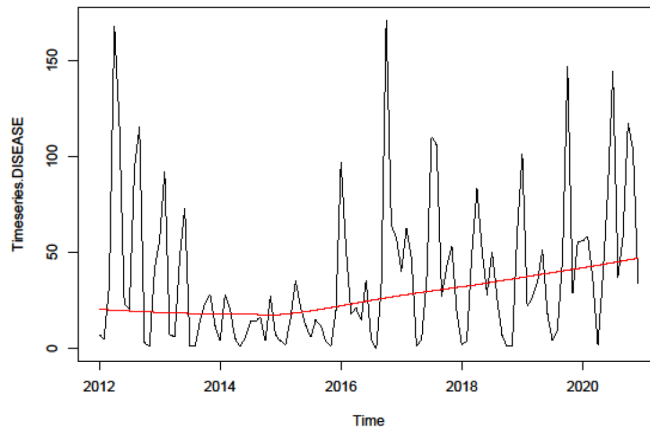


Fig. 5. Time Series Plot with trend showing increasing trend of scrub typhus incidence in Kerala

The results suggest that scrub typhus is becoming more prevalent in Kerala, with an upward trend. This trend should be closely monitored to assess the potential impact of climatic and environmental changes on disease transmission and to develop timely public health interventions.

Table 3. Impact of Relative Humidity on Disease Transmission across Regions

Region	Relative Humidity Range (%)	Scrub Typhus Incidence Rate (per 100,000)	Seasonal Trends	Reference
Global	60-90	5-20	Higher in monsoon season	CDC, WHO
Southeast Asia	70-85	15-30	Peaks in wet season	
India (Northeast)	75-95	25-40	Monsoon and post-monsoon	NCVBDC, India
India (North)	60-80	10-20	Monsoon and post-monsoon	Local epidemiology reports
China	65-85	8-15	Summer and monsoon	Local health reports, WHO
Japan	60-70	3-10	Early summer	Local epidemiology reports
Australia	50-70	2-5	Summer	WHO, Local government health reports
Indian Subcontinent	65-90	20-35	Monsoon	CDC, WHO

The table 3 indicate a strong correlation between higher relative humidity, typically above 60%, and increased scrub typhus incidence. Regions like Southeast Asia and Northeast India, where humidity levels often range between 75-95%, report incidence rates reaching 30-40 cases per 100,000 individuals, suggesting that high humidity may create favorable conditions for the vectors and hosts of *Orientia tsutsugamushi*, the bacterium responsible for scrub typhus. Seasonal patterns also influence incidence rates, with regions experiencing wet or monsoon seasons, such as India, Southeast Asia, and parts of China, seeing more cases during these periods. In India’s Northeast and North regions, cases surge during the monsoon and post-monsoon months, likely due to the lifecycle of the mites that transmit scrub typhus, which thrive in warm, humid environments. Globally, there is significant variation in incidence rates, with Southeast Asia and parts of India exhibiting the highest rates, while Japan and Australia report lower rates, potentially due to differences in vector distribution, environmental conditions, and

public health measures. Notably, Japan’s incidence peaks in early summer when humidity is moderate, underscoring regional variability in seasonal patterns. These findings highlight the importance of factoring in environmental aspects such as humidity and seasonal climate for public health strategies. Areas with high humidity and predictable monsoon seasons could benefit from targeted interventions, including awareness campaigns, surveillance, and preventive actions during peak transmission times, to help mitigate the spread of scrub typhus.

Table 4: Impact of Temperature on Disease Transmission across Regions

Region	Optimal Temperature Range (°C)	Disease Incidence Rate (per 100,000)	Transmission Pattern	Source
Tropical Regions	25-30	20-50	High year-round due to consistent warmth	WHO CDC
Southeast Asia	24-28	30-60	Peaks in summer and monsoon	Local health agencies
India (Northern)	20-35	10-40	Increases in summer and monsoon	National Centre for Vector Borne Diseases Control (NCVBDC)
Sub-Saharan Africa	22-32	15-45	High during warmer months	Local epidemiology reports
South America	23-29	10-30	Peaks during warmer, wetter months	WHO, Local health agencies
Temperate Regions	15-25	5-15	Peaks in summer	Local health agencies

The table 4 illustrates the impact of temperature on disease transmission across various global regions, highlighting optimal temperature ranges for vector activity and corresponding disease incidence rates. In tropical regions, where temperatures consistently range between 25-30°C, disease incidence remains high year-round, with rates from 20 to 50 cases per 100,000 as the warmth supports continuous vector breeding. Southeast Asia and Northern India show similar patterns, where temperatures between 24-35°C during summer and monsoon seasons result in heightened disease rates, peaking between 30-60 and 10-40 cases per 100,000 respectively. Sub-Saharan Africa, with an optimal range of 22-32°C, experiences higher transmission during warmer months, with incidence rates from 15 to 45 per

100,000 as noted in local reports. South America sees a spike in cases, 10-30 per 100,000 during warmer, wetter months, aligning with its 23-29°C range. In temperate regions, where ideal temperatures fall between 15-25°C, disease incidence peaks in summer but remains lower, between 5 and 15 per 100,000.

DISCUSSION

Scrub typhus is an emerging vector borne disease in Kerala⁴. Its incidence is influenced by many factors like vector population¹⁵ and meteorological factors⁹.

The present study provides valuable insights into how climatic factors impact the incidence of scrub typhus in Kerala. The findings have significant implications for public health planning and disease prevention in the region. In this study we assessed the impact of temperature and rain fall on the occurrence of scrub typhus in Kerala using data from 2012 to 2020 of the State. The study shows that the number of scrub typhus cases are showing increasing trend and seasonality in Kerala.

In our study average maximum temperature and average minimum temperature had a negative correlation with number of scrub typhus cases. The same trend was found in Vellore, Tamil Nadu⁷. A study from China shows scrub typhus incidence was positively correlated when mean temperature was at 19-20°C and in Japan, scrub typhus cases increased when average temperatures were at 22.5°C and 24.1°C.^{5,16} The present study also shows that the maximum number of cases occurred when average maximum and minimum temperatures were at 29°C and 20°C respectively. The average minimum temperature at which maximum number of cases occurred in the present study is in agreement with the above reported studies. A multi-centric study in Taiwan reported a positive correlation between scrub typhus cases and temperature, with the highest number of cases occurring when the temperature ranged between 25°C and 30°C¹⁷. Similarly, in China, the association between temperature and scrub typhus followed an initial elevated–descendant pattern, with the highest number of cases occurring at 24.5°C⁹. The favourable temperature for scrub typhus occurrence in the present study is in conformity with the findings from the above referred studies conducted in various geographical locations. One reason for the impact of temperature on scrub typhus incidence is its influence on chigger activity. The favourable temperature for egg laying of mites was between 23°C and 25°C. There was no egg laying when

temperature was less than 20°C and more than 30 °C¹⁸. Frances *et al.* reported that scrub typhus infection increases when chigger population is high and more chiggers were attached to *Rattus rattus* during wetter months of the year¹⁹. This suggests that temperature plays a more crucial role in predicting scrub typhus occurrence than seasonality or trends.

Many studies have reported a positive correlation between rainfall and scrub typhus occurrence^{7,9,16}. In Japan, cumulative rainfall in September of the previous year showed a positive correlation with scrub typhus incidence. But cumulative rainfall in July of the previous year showed a negative correlation with disease incidence. According to authors, too much rainfall in July might interfere with fertilization by washout of male mites or spermatophores around the females⁵. Studies from China reported that there was a sharp increase in scrub typhus incidence with a heavy rainfall^{9,16}. The present study found no relationship between scrub typhus incidence and monthly average rainfall in Kerala. This could be due to the fact that averaging rainfall across all districts could potentially mask localized relationships. Rainfall can indeed vary significantly across Kerala due to its diverse topography, ranging from coastal to mountainous regions.

The results suggest that scrub typhus is becoming more prevalent in Kerala, with an upward trend. This trend should be closely monitored to assess the potential impact of climatic and environmental changes on disease transmission and to develop timely public health interventions. The data underscores the role of temperature in influencing vector-borne disease transmission, with warmer climates and seasons creating higher risk periods and highlighting the need for climate-sensitive public health responses.

Climatic and environmental changes play a crucial role in disease transmission by creating favorable conditions for vectors and pathogens. Warmer temperatures, increased humidity, and heavy rainfall can accelerate vector breeding and prolong pathogen survival, leading to higher incidences of diseases like malaria, dengue, and scrub typhus. Urbanization and deforestation further increase human exposure to wildlife reservoirs and vectors. Timely, adaptive public health interventions—such as vector surveillance, early-warning systems, and community-level measures like insecticide-treated nets and improved sanitation—are essential to mitigate these risks. Aligning public health strategies with environmental changes enables more effective disease prevention and protection for vulnerable populations.

While most studies have reported a positive correlation between rainfall and scrub typhus occurrence, our study did not find any significant association^{7,9,16}. This discrepancy may be influenced by region-specific environmental factors, human outdoor activity and vector biology. In the future, incorporating vector biology alongside meteorological factors will be crucial for improving scrub typhus prediction models.

We could not analyse the correlation between district wise disease incidence and meteorological parameters. Bionomics of the vector also plays an important role in disease re-emergence. However, we observe that the incidence of scrub typhus occurrence is showing an increasing trend in the last few years in Kerala and the future research on the influence of weather parameters on vector bionomics could give more clear information on this increasing trend of scrub typhus incidence in Kerala.

CONCLUSION

The present study demonstrates an increasing trend in scrub typhus cases in Kerala over the period of study. Both maximum and minimum temperatures were found to be negatively correlated with scrub typhus occurrence. Our findings suggest that temperatures three months prior to disease incidence significantly influence the likelihood of scrub typhus outbreaks. Therefore, it may be possible to predict scrub typhus outbreaks up to three months in advance. However, no significant relationship was observed between cumulative rainfall and the occurrence of scrub typhus in Kerala. Understanding the influence of weather factors on disease dynamics can help to develop predictive models for forecasting outbreaks.

REFERENCES

1. Philip Samuel P, Govindarajan R, Krishnamoorthi R, Rajamannar V. A study on ectoparasites with special reference to chigger mites on rodents/shrews in scrub typhus endemic areas of Kerala, India. *Entomon.* 2020 Dec 1;45(4):285–94.
2. Rapmund G, Upham RW, Kundjnf WD, Manikumar C, Chan TC. Transovarial development of scrub typhus rickettsiae in a colony of vector mites. *Trans Roy Soc Trop Med Hyg.* 1969;63(2).

3. Elliott I, Pearson I, Dahal P, Thomas N V., Roberts T, Newton PN. Scrub typhus ecology: A systematic review of *Orientia* in vectors and hosts. Parasit Vectors. 2019 Nov 4;12(1).
4. Directorate of Health Services Kerala. Data on communicable diseases [Internet]. [cited 2024 Mar 29]. Available from: <https://dhs.kerala.gov.in/data-on-communicable-diseases/>
5. Seto J, Suzuki Y, Nakao R, Otani K, Yahagi K, Mizuta K. Meteorological factors affecting scrub typhus occurrence: A retrospective study of Yamagata Prefecture, Japan, 1984-2014. Vol. 145, Epidemiol Infect. Cambridge University Press; 2017. p. 462–70.
6. Sharma P, Kakkar R, Kaore SN, Yadav VK, Sharma R. Geographical Distribution, Effect of Season & Life Cycle of Scrub Typhus [Internet]. Vol. 12. Available from: www.jkscience.org63
7. D’Cruz S, Sreedevi K, Lynette C, Gunasekaran K, Prakash JAJ. Climate influences scrub typhus occurrence in Vellore, Tamil Nadu, India: analysis of a 15-year dataset. Sci Rep. 2024 ; Dec 1;14(1).
8. Wei Y, Huang Y, Li X, Ma Y, Tao X, Wu X, et al. Climate variability, animal reservoir and transmission of scrub typhus in Southern China. PLoS Negl Trop Dis. 2017 Mar 8;11(3).
9. Han L, Sun Z, Li Z, Zhang Y, Tong S, Qin T. Impacts of meteorological factors on the risk of scrub typhus in China, from 2006 to 2020: A multicenter retrospective study. Front Microbiol. 2023;14.
10. Mathai E, Rolain JM, Verghese GM, Abraham OC, Mathai D, Mathai M, et al. Outbreak of Scrub Typhus in Southern India during the Cooler Months. Ann.N Y Acad Sci. 2003;990.
11. Varghese GM, Raj D, Francis MR, Sarkar R, Trowbridge P, Muliyl J. Epidemiology & risk factors of scrub typhus in south India. Indian J Med Res. 2016 Jul 1;144:76–81.
12. Pai DS, Sridhar L, Rajeevan M, Sreejith OP, Satbhai NS, Mukhopadyay B. Development of a new high spatial resolution (0.25° × 0.25°) Long Period (1901-2010) daily gridded rainfall data set over India and its comparison with existing data sets over the region. Mausam. 2014;65(1):1–18.
13. Srivastava AK, Rajeevan M, Kshirsagar SR. Development of a high resolution daily gridded temperature data set (1969-2005) for the Indian region. Atmos Sci Lett. 2009 Oct;10(4):249–54.
14. R: The R Project for Statistical Computing [Internet]. [cited 2024 Apr 11]. Available from: <https://www.r-project.org/>
15. Lee IY, Kim HC, Lee YS, Seo JH, Lim JW, Yong TS, et al. Geographical distribution and relative abundance of vectors of scrub typhus in the Republic of Korea. Korean J Parasitol. 2009 Dec;47(4):381–6.
16. Luo Y ZLLHZCALQYYNZLWJ and TW. How meteorological factors impacting on scrub typhus incidences in the main epidemic areas of 10 provinces, China, 2006–2018 [Internet]. Available from: <https://www.rdocumentation.org/>

17. Chang YC, Kuo KC, Sun W, Lin JN, Lai CH, Lee CH. Clinicoepidemiologic characteristics of scrub typhus and murine typhus: A multi-center study in southern Taiwan. J Microbiol Immunol Infect. 2019 Oct 1;52(5):769–78.
18. Takahashi M, Machida K, Murata M, et al. Seasonal Development of *Leptotrombidium pallidum* (Acari: Trombiculidae) Observed by experimental rearing in the natural environment [Internet]. J Med Entomol. 1993; 30. Available from: <http://jme.oxfordjournals.org/>
19. Frances SP, Watcharapichat P, Phulsuksombati D, Tanskul P, Linthicum KJ. Seasonal occurrence of *Leptotrombidium deliense* (Acari: Trombiculidae) attached to sentinel rodents in an orchard near Bangkok, Thailand. J Med Entomol. 1999;36.

