



Impact of climate change on dengue fever: a bibliometric analysis

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Abstract

Dengue is the most widespread and fastest-growing vector-borne disease worldwide. We employed bibliometric analysis to provide an overview of research on the impact of climate change on dengue fever focusing on both global and Southeast Asian regions. Using the Web of Science Core Collection (WoSCC) database, we reviewed studies on the impact of climate change on dengue fever between 1974 and 2022 taking into account study locations and international collaboration. The VOS viewer software (<https://www.vosviewer.com/>) and the Bibliometrix R package (<https://www.bibliometrix.org/>) were used to visualise country networks and keywords. We collected 2,055 relevant articles published globally between 1974 and 2022 on the impact of climate

change on dengue fever, 449 of which published in Southeast Asia. Peaking in 2021, the overall number of publications showed a strong increase in the period 2000-2022. The United States had the highest number of publications (n=558) followed by China (261) and Brazil (228). Among the Southeast Asian countries, Thailand had most publications (n=123). Global and Southeast Asian concerns about the impact of climate change on dengue fever are essentially the same. They all emphasise the relationship between temperature and other climatic conditions on the one hand and the transmission of *Aedes aegypti* on the other. A significant positive correlation exists between the number of national publications and socioeconomic index and between international collaboration and scientific productivity in the field. Our study demonstrates the current state of research on the impact of climate change on dengue and provides a comparative analysis of the Southeast Asian region. Publication output in Southeast Asia lags behind that of major countries worldwide, and various strategies should be implemented to improve international collaboration, such as increasing the number of international collaborative projects and providing academic resources and research platforms for researchers.

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Introduction

Dengue fever, one of the most widespread vector-borne diseases worldwide, is an acute infectious disease caused by the dengue virus, which is mainly transmitted by *Aedes aegypti* and *Ae. albopictus* mosquitoes. Since its first epidemic, said to have taken place around 1779 in Batavia, today's Jakarta, Indonesia, the global incidence of dengue fever has increased sharply, and approximately half of the world's population is currently at risk of infection (Messina *et al.*, 2019). In 2015, approximately 451,000 (14.1%) of all global dengue fever cases were reported in Southeast Asia (DynaMed, 2024). With around 5.2 million cases worldwide, the year 2019 had the highest number of dengue fever cases in history as reported by the World Health Organization (WHO, 2023). Approximately 1,170,000 people in Southeast Asia were infected, accounting for 22.5% of the global number (Ilic *et al.*, 2024).

Dengue fever is widespread in tropical and subtropical climates. With uniform temperature distribution, high humidity, heavy rainfall and a constant annual average temperature of around 27 °C, Southeast Asia has ideal climatic conditions for transmitting this infection (Messina *et al.*, 2019). The lack of basic health services, unplanned urban development and inadequate water storage methods make dengue fever particularly difficult to control in this region (Drugs & Diagnostics for Tropical Diseases, DDTD, 2023; Parham *et al.*, 2015; Reiter *et al.*, 2003). Climate change might exacerbate these problems as extreme weather events, such as droughts or floods, affect the endemic areas

(Muttarak & Raya, 2013). High temperatures would increase the spread of mosquito-borne diseases (McMichael *et al.*, 2006), while increased humidity could accelerate larval development (Carrington *et al.*, 2013) and adult emergence (Piovezan-Borges *et al.*, 2020), thereby expanding the global distribution of *Aedes* mosquitoes. Low-income countries are more vulnerable to the impacts of extreme weather and have a harder time recovering from the effects of climate change (United Nations, 2023b). For these reasons, understanding how climate change affects dengue fever in Southeast Asia is critical for helping countries in this part of the world to manage the threat posed by this disease.

Addressing the heavy burden of dengue fever cases in the Southeast Asia is a daunting challenge, particularly in the absence of effective treatments, comprehensive vector control and successful public health interventions. Understanding the global patterns of dengue research in the context of climate change is crucial for reliable analysis of the impact how climate change can help improve a country's response to dengue fever. To that end, we evaluated the contents in the number of publications from Southeast Asian countries on dengue fever accounting for their socioeconomic indices, such as the per capita Gross Domestic Product (GDP) and the Human Development Index (HDI). We compared the publications with those from the top three ranked countries globally (the United States, Brazil, and China) utilising bibliometric analysis (Belter, 2015) to summarise research on the

impact of climate change on dengue fever globally and in the Southeast Asian region. Materials and methods

Data collection

A literature analysis was conducted using Web of Science Core Collection (WoS) database. The advanced search option was adopted and the search strategy based on the following search terms: Topic=(“climate” OR “temperature” OR “warm*” OR “rain*” OR “flood*” OR “precipitation” OR “humid*” OR “dry” OR “drought*” OR “arid*”) AND Topic=(“dengue”). All articles published between 1974 and December 2022 were searched. Specific exclusion strategies were designed to ensure that the retrieved publications had a high degree of relevance. The Bibliometrix R package (Aria & Cuccurullo, 2017) was used to remove duplicates. Second, articles were manually screened and those that did not record in the title, abstract or text how the climate affected dengue fever were excluded. All electronic searches were conducted on 20 January, 2023. Finally, 2,055 research articles were included, with the systematic review results shown in Figure 1.

Statistical analysis

The retrieved literature was exported as files in a software-recognised format in sequence (content: full records and cited references; file format: plain text). We created a keyword co-occur-

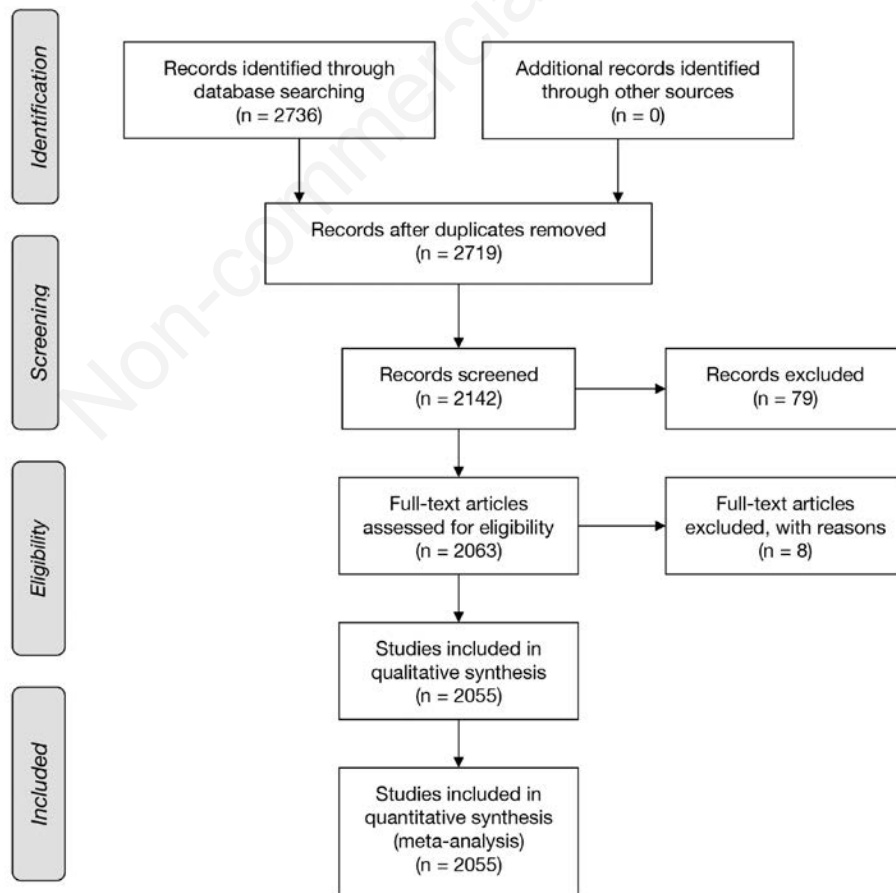


Figure 1. Article selection flowchart based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

rence network using VOSviewer (version 1.6.16; Centre for Science and Technology Studies, Leiden University, Netherlands), a software tool designed for constructing and visualizing bibliometric networks. A country collaboration network was generated using the affiliations of all authors listed in the publications. England, Northern Ireland, Scotland, and Wales were merged into the United Kingdom to consolidate the country names used in both the VOSviewer and the bibliometrix R package. The node sizes reflect the number of publications in each country.

A keyword network was created using terms with frequencies greater than 15. Similar terms were merged in the network to better analyse the distribution of the themes. In this network, the node size represents the frequency of keyword occurrence.

The Bibliometrix R package, with its ‘biblioshiny’ interface an app providing a web-interface that allows users to perform relevant bibliometric and visual analyses on an interactive web interface, were used to analyse the annual growth rate and frequency of keyword use over time. The annual growth rate was estimated by geometric progression, calculated using the compound annual growth rate (CAGR), given by the equation:

$$CAGR = \left(\frac{V_{final}}{V_{begin}} \right)^{\frac{1}{t}} - 1 \tag{Eq. 1}$$

where V_{begin} is the number of documents evaluated in the first year; V_{final} that in the last year; and t the time. The rate is a geometric progression ratio that provides a constant rate over time for a given period (<https://www.bibliometrix.org/>). The publication year was obtained using Bibliometrix, and a graph was constructed using the ggplot2 package (Wickham, 2023).

We determined the number of dengue fever cases and socioeconomic indices for each country based on the latest data released by global organisations. Dengue fever data for the past 5 years were obtained from WHO, the United States’ National Centers for Disease Control and Prevention (CDC) and the government portals of each country. GDP data were obtained from the World Bank database (<https://databank.worldbank.org/>), and HDI data were obtained from the Human Development Report (United Nations, 2023a). To evaluate the correlation between the number of publi-

cations from Southeast Asian countries and dengue cases as well as the social and economic indicators (HDI and GDP per capita), we used the country of the first author in the Pearson correlation analysis. The analysis was performed with SPSS 26.0 software.

Results

Publication by year

A total of 2,736 articles were retrieved from the WoSCC database. After deduplication and manual screening, 2,055 studies met the inclusion criteria. The number of publications increased notably, especially after 2000, with most papers (n=2,007) published in the last 22 years (Figure 2). The global average number of publications per year was 165.1 between 2010 and 2022, which is five times higher than the period between 2000 and 2011 (32.4 publications per year). The data analysis indicated a gradual increase in global dengue research publications over the past 20 years, with an annual growth rate of 11.0% between 1974 and 2020, indicating the sustained interest of journals and countries in publishing papers on climate change and dengue across different time periods and regions.

Keyword visualisation

Using the VOSviewer software, we generated a hot cluster network of keywords used in papers on climate change and dengue research (Figure 3). The network includes 206 keywords that appear more than 15 times. These clusters formed a network that could be divided into six main research directions. Cluster 1 (red) had the largest network structure, including 50 directions such as dengue, epidemic, fever, climate change, global distribution and public health. This cluster mainly focused on the close relationship between climate change and dengue epidemic transmission as well as the burden and challenges brought to public health. Cluster 2 (light blue) was based on Geographic Information Systems (GIS) and historical reviews, focusing on the role of vertical transmission in the spread of tree-borne diseases. Cluster 3 (yellow) focused on the significant effect of temperature changes on reproductive substitution patterns and species changes in various mosquito species.

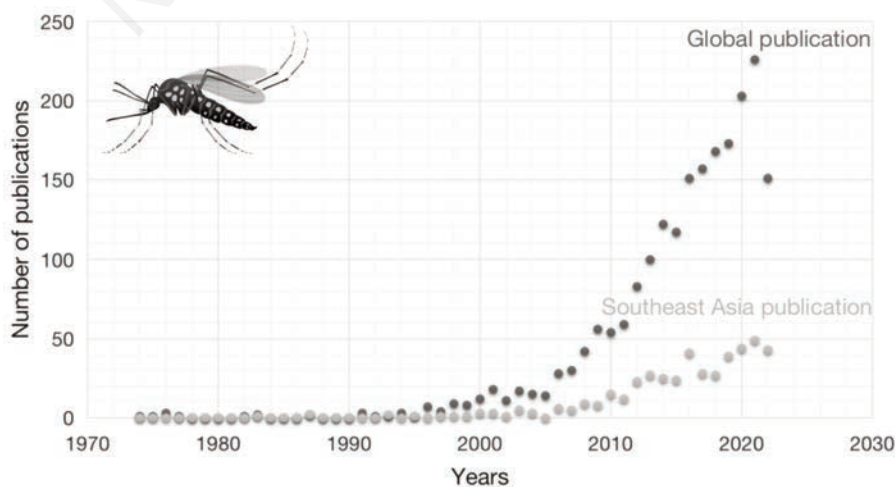


Figure 2. The annual number of publications evaluating the impact of climate change on dengue. Study period: 1974-2022.

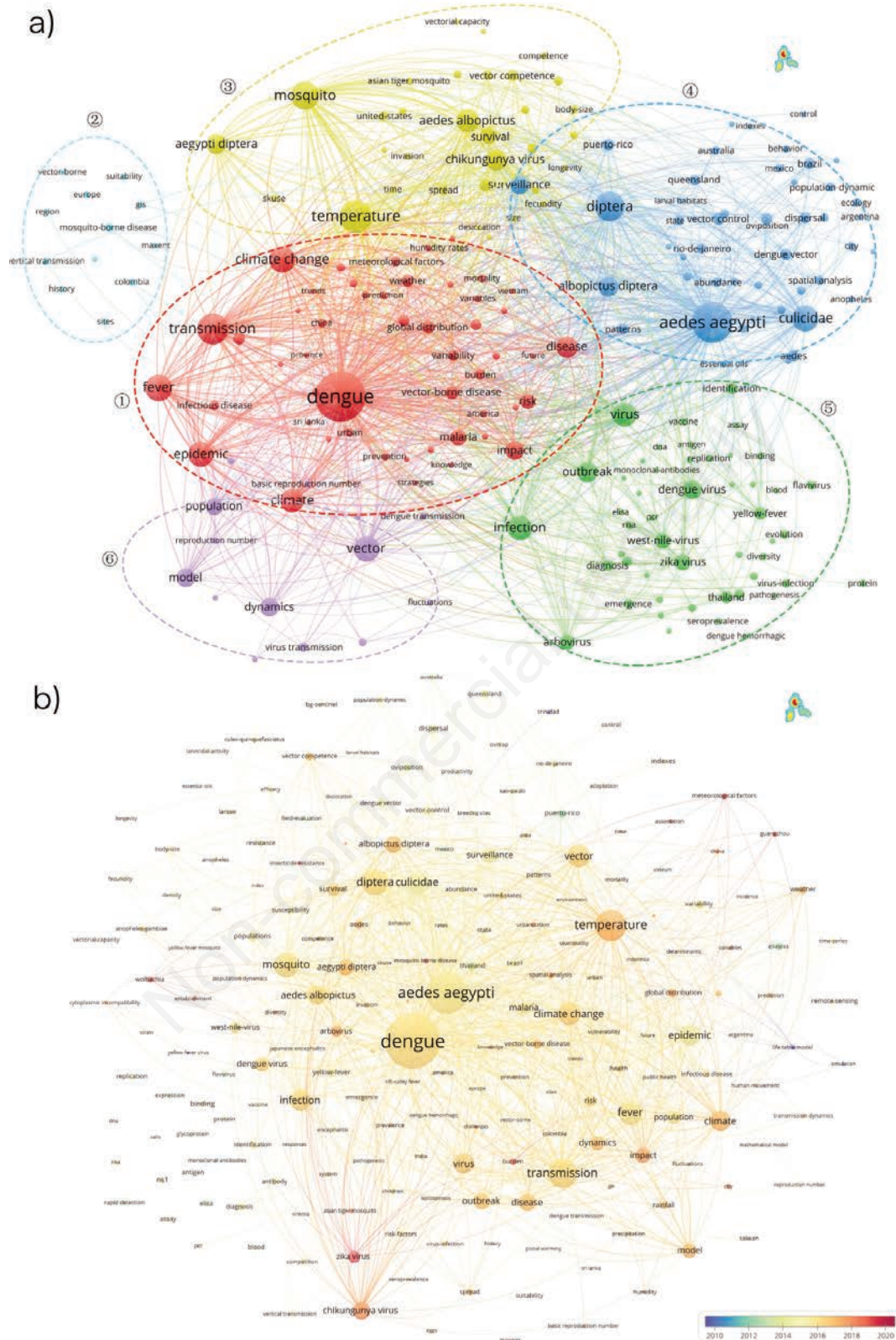


Figure 3. The keyword network. Keywords cited at least 15 times were considered and the node size represents the number of occurrences of a keyword and the links indicate the connections between keywords. **a)** with cluster colours (cluster 1 in red; cluster 2 in light blue; cluster 3 in yellow; cluster 4 in blue; cluster 5 in green; cluster 6 in purple); **b)** over time.

The remaining clusters, 4 (blue), 5 (green) and 6 (purple), mainly focused on spatial distribution characteristics, mosquito control, epidemic identification diagnosis and dynamic models.

The topics of interest in our study, such as temperature, climate change and meteorological factors, were mainly concentrated in the period 2015–2018 (Figure 3b). Topics such as yellow fever virus, life table models and El Niño, which were much used in earlier studies, gradually faded out of scholars' view in later years, while topics such as urbanisation, meteorological factors, zika virus and chikungunya virus have received increasing attention. We found some significant changes in the frequency of the 10 most-cited terms over a period of nearly 30 years (1990–2022) (Figure 4). The number of publications for the terms temperature and climate increased much more over time than that for the other terms in the last 10 years. The search terms were restricted to affiliations with Brunei, Cambodia, Indonesia, Laos, Malaysia,

Myanmar, Philippines, Singapore, Thailand and Vietnam. A comparison showed that both Southeast Asian countries and the rest of the world consider temperature to be one of the most important climatic factors affecting dengue fever (Figure 5).

Publication by country

Globally, 131 countries contributed to the research and collaboration on the impact of climate change on dengue fever. Network visualisation using VOSViewer showed a strong collaboration between these countries (Figure 6). Countries with the highest number of first-author signatures were USA (n=558), China (n=261), Brazil (n=228), the UK (n=217) and Australia (n=211). These papers accounted for 71.8% of the total research in this area. Studies from the USA accounted for approximately 27.2% of the total. Among the 449 papers published in Southeast Asia, Thailand had the highest number (n=123), accounting for approximately

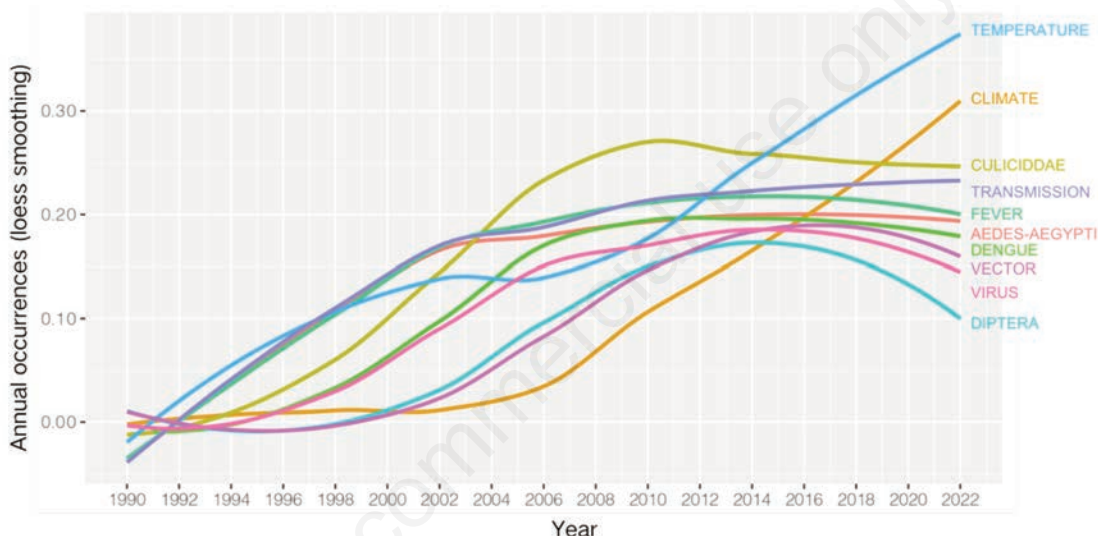


Figure 4. Frequency trends of the top 10 most frequently used keywords worldwide over the period 1990-2022.

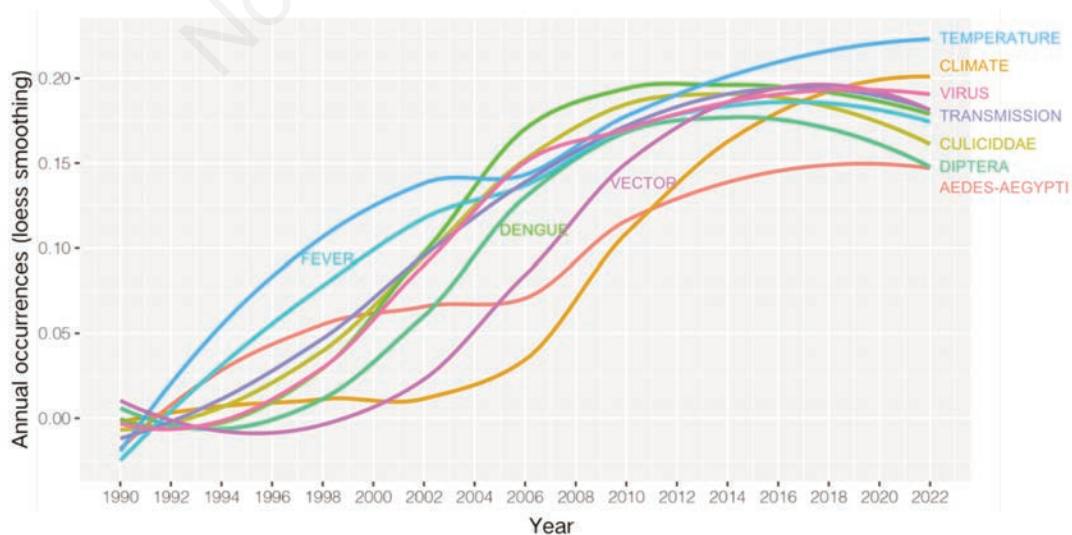


Figure 5. Frequency trends of the 10 most frequently used keywords in Southeast Asia over the period 1990-2022.

27.4% of the total, followed by Malaysia (n=81), Singapore (n=78), Vietnam (n=57), Indonesia (n=49), the Philippines (n=25), Laos (n=20) and Cambodia (n=11).

USA and the United Kingdom have the largest number of publications as well as the largest number of collaborative international collaborations. The former ranks first in international collaborations with 53 publications collaborating with other countries, while the latter collaborated with 51 countries. Despite having fewer publications, Southeast Asian countries have a high level of collaboration. For example, Thailand collaborated with 35 countries and published 205 collaborative articles, almost twice as many as those published domestically. Of these, 39 were published in collaboration with researchers in USA, while Singapore and Vietnam shared the second place, each with partnerships established with 27 countries. The correlation between the number of publications and dengue cases in each country ($r=0.013$; $p=0.928$) was far from statistically significant. However, a significant positive correlation was observed with the socioeconomic index (HDI, $r=0.441$, $p=0.002$) and GDP per capita, $r=0.491$, $p=0.000$).

Discussion

Over the past 30 years, the number of publications using temperature and climate as keywords has increased significantly (Haunschild, 2023), and climate change has become a focus of

global research. In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) jointly established the Intergovernmental Panel on Climate Change (IPCC). It specialises in assessing scientific facts, potential impacts, and mitigation and adaptation measures of anthropogenic climate change and provides relevant scientific and technical knowledge to national decision-makers. Published reports form an important basis for climate negotiations. When we examined trends in the number of annual publications, we observed a higher number of publications in 1991, 1995, 2001, 2009 and 2013. One reason for this may be that the IPCC has published five “Climate Change Assessment Reports” in coinciding years: 1990, 1995, 2001, 2007 and 2013. The terms temperature and *Ae. aegypti* were both prominent in the keyword word frequency trend graph. The vectorial capacity of this mosquito has also been investigated when studying the effects of temperature or climate change on dengue. Temperature is currently considered to be one of the most important meteorological factors affecting dengue fever. *Ae. aegypti* is a cold-blooded arthropod that is highly sensitive to temperature changes. Mosquito growth, development, activity and its viral transmission are all significantly influenced by temperature. Some research results show that daily fluctuations around low temperature (20°C) increase vector competence of *Ae. aegypti* for dengue viruses (Carrington *et al.*, 2013; Liu-Helmersson *et al.*, 2014). Even if a global climate agreement is signed, the capriciousness of some key countries on climate issues based on political and economic interests would lead to a more severe global climate and

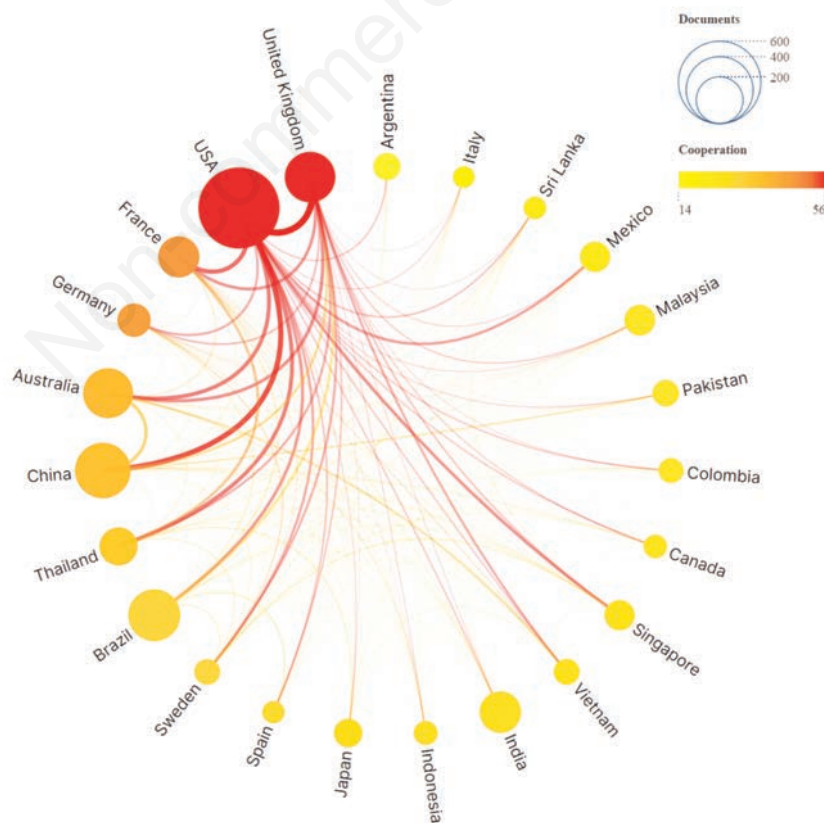


Figure 6. The collaboration network among countries regarding the impact of climate change on dengue research.



more difficult mosquito control (Lenton *et al.*, 2008). The results of these studies are extremely important for policymakers. Increasing attention to climate change, reducing greenhouse gas emissions, and controlling global temperatures can help reduce the breeding and transmission of *Ae. aegypti* and minimise mosquito invasion, thereby reducing the incidence of dengue fever (Bauch *et al.*, 2015; Santos & Almeida, 2018).

Keyword visualisation showed that keywords such as China and the Chinese city Guangzhou have appeared in recent years and appeared in the same clusters as mosquito-borne diseases, vertical transmission and GIS. Since the outbreak of dengue fever in Guangdong Province and other regions of southern China in 2014 (Luo *et al.*, 2017), the number of dengue fever publications in China has shown a rapid growth, focusing on epidemiology and insect vectors. According to the change of keywords with the year, it can be seen that the research hotspot of dengue fever has gradually changed from the analysis of epidemiological characteristics of the infection to the analysis of clinical treatment and social impact in the past 10 years (Luo *et al.*, 2017; Tripathi & Shrivastava, 2018). At the same time, owing to the influence of new infectious disease outbreaks, the research hotspot has changed to chikungunya fever, which has a certain time-sensitive characteristic. A combined analysis of the outbreak situation and keyword evolution can assist in exploring research frontier trends and hotspots.

By visualising international cooperation, we demonstrated the contributions of key countries to the impact of climate change on dengue fever, as well as their cooperation with other countries. Five countries (which contributed by approximately 70% of the research) led the research in this field: three developed countries (USA, UK and Australia) and two developing countries (Brazil and China). Among Southeast Asian countries, Thailand is the main contributor to research, accounting for 30% of the publications. In recent years, this country has carried out extensive international cooperation and established the Southeast Asian Tropical Medicine and Public Health Network, the Pediatric Dengue Vaccine Initiative, the Asian Centre of International Parasite Control and become a WHO Collaborating Centre for Vector Control. Thailand also partnered with the University of Oxford to establish the Mahidol–Oxford Tropical Medicine Research Unit, which has advanced research on the impact of climate change on dengue fever in Thailand.

These findings demonstrate the relationship between research in this field and socioeconomic indices. With the growing trend of globalisation, dengue fever epidemics have been increasing owing to multiple social, economic and environmental factors (Sirisena & Noordeen, 2014; Khetarpal & Khanna, 2016; Li *et al.*, 2018). However, there is limited published literature on this subject in other Southeast Asian countries with a high prevalence of dengue, such as The Philippines, Cambodia, Lao PDR and Myanmar. Interestingly, most of these countries had the lowest GDP per capita, HDI, and international cooperation. These socioeconomic factors may prevent countries from conducting dengue- and climate-related studies. Previous studies have demonstrated a significant correlation between global partnerships and scientific productivity. This emphasises the need to promote international collaboration to advance dengue- and climate-related research.

Conclusions

The impact of climate change on dengue fever has attracted widespread attention from the scientific community over the past 30 years, and the number of relevant publications has shown an overall increasing trend, with China and Brazil ranking among the top three developing countries. However, a significant gap exists between the publication volume in Southeast Asia and that in major countries worldwide, and various strategies should be employed to increase the quantity and quality of publications. Thailand can be considered an example of strengthening international collaboration with entities and providing academic resources and research platforms for researchers.

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