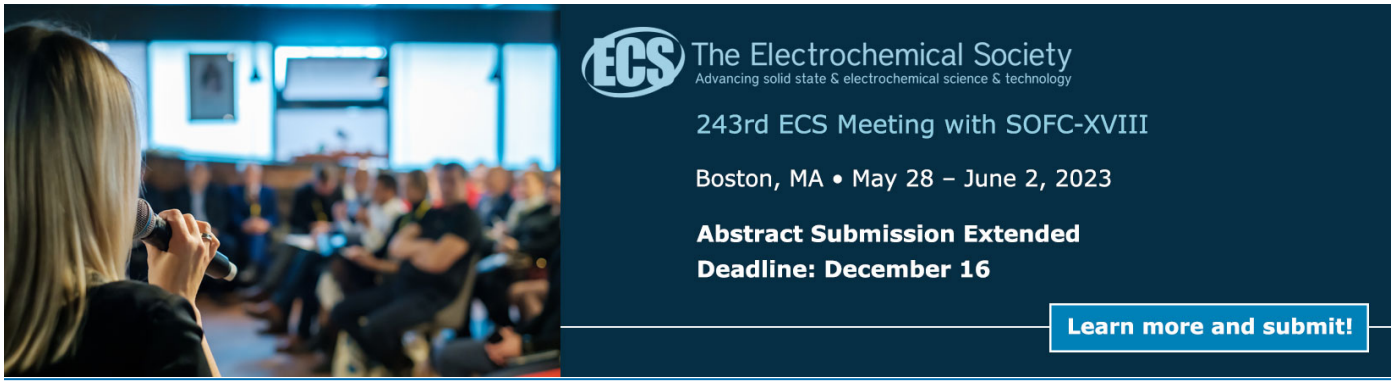
A Decade of Literature on Climate in Phytopathological Research: Visualising and Bibliometrics Analysis



A Decade of Literature on Climate in Phytopathological Research: Visualising and Bibliometrics Analysis

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Abstract: Climate change is a global concern which is predicted to dominate phytopathological research. Hence, we performed a bibliometric analysis of climate changes in relation to plant pathology research from 2012 to 2022, in order, to ascertain the publication trend in this study field. Consequently, Web of Science (WoS), a well-known database was chosen to obtain a total of 335 articles that matched the inclusion criteria. This research attempts to expand graphical mapping of the bibliographic information using VOSviewer software. The research conducted the performance and network mapping approaches: publication trends, subject area, most active journals and countries, citation metrics, highly cited papers, co-authorship, and co-occurrence of the keywords. Our analysis essentially concludes that the last decade of scientific papers shows a positive tendency of climatic influence on the plant pathology research field. Our work can be used by plant pathologists to consider the future direction of disease detection in light of global warming and soil status.

1. Introduction

Climate change is one of the most hotly debated problems in the world today, including tremendous implications for global agriculture. This is consistent with [1] who asserted that extreme conditions have significant impacts on crop yield and agricultural pests, where changes in climatic variations can have multiple effects on plant pathology studies. Consequently, climate changes and human population growth pose a significant threat to plant growth and a challenge for sustaining food security [2].

Previously, there is a study that performed bibliometric analysis on the prediction of plant disease based on meteorological conditions [3]. In addition, there are studies on more specialised sub-topics of plant pathology relating to climate or abiotic and biotic pressures, such as plant disease classification using artificial intelligence [4-6] and eco-climatic niche models for plant diseases and pests [7]. However, this article attempts to determine and generally provide a bibliographical summary of the

available literature on climate change and plant pathology. In this present study, scholars used bibliometric approaches to search related literature to the research topic using Web of Science database. This investigation employs the following objectives and methodologies: 1) to reveal the evolution and international research contribution via publication within a decade; 2) to identify the most active journals and countries in the field of climate change and plant pathology, including the most referenced works; 3) to evaluate the scientific mapping of climate change in phytopathological research using co-authorships and author keywords visualisation. At this stage, the bibliometric study might reignite interest in the research topics and stimulate young researchers to think critically about the research topic.

2. Materials and methods

2.1. Searching Strategy and Data Extraction

The systematic searching strategy was applied to peer-reviewed documents recorded by Web of Science database (Clarivate Analytics – Thomson ISI). To achieve the purpose of this study, a preliminary search was undertaken on April 7th, 2022; however, some of the publications in the downloaded database were unrelated to the topic of the study. Few downloaded papers were read before the development of the final search strings. Then, on 12th May 2022, an improved and systematic search strategy using an advanced search string was used to obtain relevant documents. The detailed information on the search strategy is explained in Table 1. The database was accessed through MyAthens provided by the Office of Library and Knowledge Management, Universiti Malaysia Kelantan (UMK). The entire record with cited references information was exported into the tab-delimited and Excel files for further analysis.

Table 1. The detailed information on searching strategy.

Date of preliminary searched	7th April 2022
Date of final searched	12th May 2022
Final search query	[TS= (("climate&chang*" OR "climat* chang*" OR "climat* variation*" OR "climat* variability" OR "global&warming*" OR " clima* warming" OR "atmospheric warming" OR "global heating" OR "temp* risk*") AND (“plant disease*” OR “plant patholog*”))]
Document type	Articles and review articles
Subject area	All field
Publication year	2012-2022
Language	English only
Total record identified	338 documents
Total record removed	3 documents; not related to plant pathology
Total record included	335 documents
Total citations count	6616

2.2. Bibliographical Data Analysis

Two methodologies were used to classify the bibliometric analysis tools: performance analysis and network visualisation and mapping [8]. In brief, the performance analysis is a descriptive and trend study that evaluates the influence and performance of the articles in a given area of research. Using the exported data, the following characteristics of publication were analysed: publication trend by year, most active journal, institution, and nations as well as highly cited papers. All input data is exported to an Excel file in order to create more informative figures and tables. While Publish or Perish (PoP) software was used to generate highly cited papers.

Furthermore, network visualising and mapping examine the relationship between research constituents. In this study, the methods of co-occurrence of the keywords and co-authorships were analysed using VOSviewer software. The output data from WoS were uploaded to the VOSviewer

software so that visuals could be generated to facilitate data understanding. Thesaurus files were used to merge synonym words ("biocontrol" and "biological control"), standardised spelling ("characterisation" and "characterization"), merged singular or plural terms ("plant disease" and "plant diseases"), merged abbreviations ("gis" and "geographic information system"), etc.

3. Results and discussion

3.1. Performance analysis

3.1.1. Global publication trend. Early publications in the database were carefully vetted to ensure that only pertinent documents were included in this study. Between 2012 and 2022, a total of 335 articles with 6616 citations and written in English were published. This survey included 257 original research articles (76.62%) and 78 review articles (23.28%). The current study was carried out to give a snapshot of the research on climates with an emphasis on plant diseases.

Over the past decade, although the number of published documents on climates and plant diseases has inconsistency, the overall trend is increasing. According to Figure 1, the growth pattern can be divided into two stages. In the first stage (2012 to 2014), a small number of research publications were published and therefore, contributed to the low level of knowledge contribution. In the second stage (2015 to 2020), the development of research on climates and plant diseases was slow and the number of annual publications was maintained in the years 2020 and 2021. Since 2019, scholars worldwide have been particularly aware of the climatic importance and plant diseases, and the number of published papers has sharply increased in 2020. Although the publication rates were good, a covid-19 outbreak that began in early 2020 has hindered and constrained research in all fields. In addition to that, only a few publications were found in the year 2022 due to ongoing works at the time of the search being conducted and it is anticipated that the number of publications for 2022 would increase to more than 58 documents.

Figure 1. The global publication trends from the year 2012 – 2022.

3.1.2. Most active journal. Table 2 lists the top ten most active journals linked to the topic of the study. Frontiers in Plant Science and European Journal of Plant Pathology had the largest percentage of articles published during the searched period, with 10 and 9 total publications, respectively. According to these findings, the top ten most active journals are all ranked in Q1 journals and referred by academicians. These indicate that Q1 publications are significantly superior to climate and plant disease publications compared to other quartile rankings (Q2, Q3, and Q4). Consideration of journal impact factor quartiles, particularly for Q1 journals, can assist new or experienced researchers in enhancing the impact of their research.

Table 2. Top ten most active journals reported by WoS.

Journal Titles	Total documents	Publisher	JCI
Frontiers in Plant Science	10	Springer	0.75
European Journal of Plant Pathology	9	Frontiers Media SA	1.39
Phytopathology	9	Amer Phytopathological Society	1.1
Plant Pathology	9	Wiley	0.96
Agronomy Basel	7	MDPI	0.94
Global Change Biology	7	Wiley	2.55
Journal of Plant Disease and Protection	7	Springer Heidelberg	0.57
Plant Basel	7	MDPI	0.95
Scientific Reports	7	Nature Portfolio	0.8
Agricultural and Forest Meteorology	6	Elsevier	2.03

Note: JCI is Journal Citation Indicator, which measures the average Category Normalised Citation Impact (CNCI) of citable items (articles & reviews) published in 2020.

3.1.3. International distribution and most active institution. Approximately 2000 authors from 79 countries have published at least one article in the research field. The geographical distribution of the chosen papers was determined by the affiliation of the authors. According to Table 3 and Figure 2, the majority of the research works that examine the substantial impacts of climates on plant diseases are located in the United States (85 records), where four institutions in the top ten list are from the US, followed by Italy (42 documents) and India (33 documents). In addition to that, according to the Funding agencies reported by WoS from 335 articles, 19 documents received funding from National Science Foundation based in the US, while 10 articles received funding from the United States Department of Agriculture (USDA). In the selection of the study, Malaysia had limited contribution to the literature on climate in plant pathology with 3 records.

Furthermore, the institution with the most publications is the League of European Research Universities (LERU) with 29 records, followed by the National Research Institute for Agriculture, Food, and the Environment (INRAE), which published 19 articles. LERU is a well-established consortium of Europe's leading 23 research-intensive universities. Collaboration between several institutions in conducting and publishing research articles enhances the visibility of the resulting publications. Table 3 displays the top ten active institutions of included articles.

Table 3. Top ten active institutions.

Affiliations	Total documents	Country
League of European Research Universities (LERU)	29	Belgium
National Research Institute for Agriculture, Food and the Environment (INRAE)	19	France
University of California (UC) System	18	United States
Consultative Group on International Agricultural Research (CGIAR)	17	France
United States Department of Agriculture (USDA)	15	United States
State University System of Florida	14	Unites States
University of Florida	14	Unites States
Swedish University of Agricultural Sciences	11	Sweden
University of Turin	11	Italy
UDICE French Research Universities	10	France

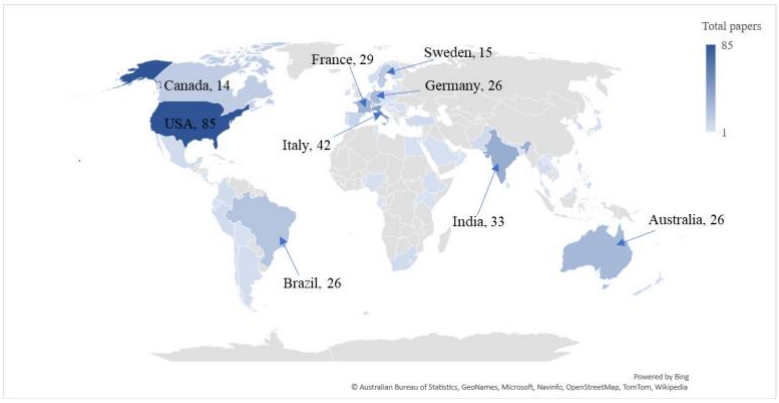


Figure 2. Map shows the distribution of the publication worldwide.

3.1.4. Highly cited papers. To identify highly cited papers, the researchers employed a criterion based on the total citations. According to Table 4, both old and new publications feature in the top ten most referenced papers, with "Deep neural networks-based recognition of plant diseases by leaf image classification" being the most cited. This paper was published by Hindawi Publishing Corporation and written by Sladojevic, S., Arsenovic. M., Andela, A., Culibrk, D., and Stefanovic, D. Additionally, most of the authors are from the Department of Industrial Engineering and Management, Faculty of Technical Science, University of Novi Sad, Serbia. The first author of this paper, Sladojevic, S. actively conducted research using deep learning for plant disease. Using leaf image classification and deep convolutional networks, this paper offered a new method for recognising and detecting plant diseases. In short, there is a need for early plant disease detection technology as a substitute diagnostic tool for the existence of plant diseases. As a result, it is worthwhile to provide early and simple methods for plant disease diagnosis, as they can mitigate yield loss.

Table 4. Highly cited papers from 2012 to 2022.

No.	Title	Year	TC	C/Y	Ref.
1	Deep neural networks based recognition of plant diseases by leaf image classification	2016	420	70.00	[9]
2	Crop pests and pathogens move polewards in a warming world	2013	396	44.00	[10]
3	Biogeographical patterns and determinants of invasion by forest pathogens in Europe	2013	325	36.11	[11]
4	Measuring ectomycorrhizal fungal dispersal: macroecological patterns driven by microscopic propagules	2012	246	24.60	[12]
5	Plant-pathogen warfare under changing climate conditions	2018	181	45.25	[13]
6	Impacts of climate change on plant diseases-opinions and trends	2012	158	15.80	[14]
7	Biological collections in an ever changing world: Herbaria as tools for biogeographical and environmental studies	2013	138	15.33	[15]
8	Climate change impacts on plant pathogens and plant diseases	2014	137	17.13	[16]

9	Modelling the impacts of pests and diseases on agricultural systems	2017	130	26.00	[17]
10	Current and projected global distribution of *Phytophthora cinnamomi*, one of the world's worst plant pathogens	2017	118	23.60	[18]

3.2. Network visualising and mapping

3.2.1. Co-authorship analysis. Co-authorship analysis is used to quantify the relationships of the authors, institutions, and nations with other researchers [8]. In this study, however, only co-authorship by authors was done. Out of 1390 authors with a minimum of a document, only 64 largest set connected items were included for the network visualisation map of the co-authorship. Thus, the international cooperation networks of climates and phytopathological research for different authors and research institutions are shown in Figure 3 (a). The more connections there are between nodes, the closer cooperation between the authors. The present study on authorship mapping has revealed a few prominent authors, including Savary, S., Willocquet, L., Rossi, V., Yuen, J. and Bregaglio, S. Most authors focused on plant disease and incorporated simulation and modelling techniques into their research. Due to similar affiliations (INRAE and Universite de Toulouse, France), Savary and Willocquet are strongly connected.

In brief, the number of contributors, whether a single author or numerous authors, depends on the research. Despite the effectiveness of certain research being conducted individually, scientific collaboration between two or more authors is a fantastic opportunity to discover new knowledge and address research difficulties promptly. This is consistent with [19] who noted that cooperation between researchers can expand the scope and quality of the research as the methodological and theoretical complexity of research increases.

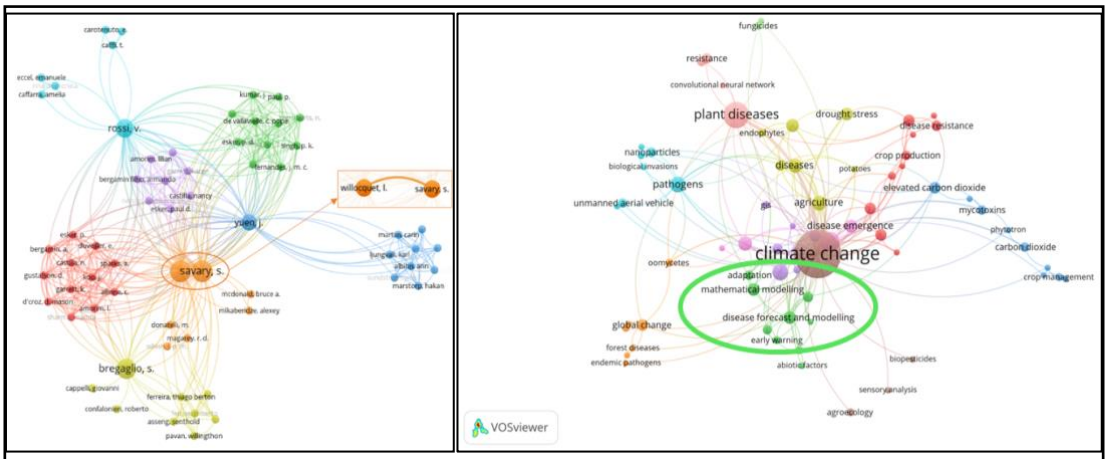
3.2.2. Co-occurrence of the keywords. The definition of keywords occurrence analysis is how two or more keywords are paired or occurred together in the selected documents. It assumes that words that commonly appear together have a thematic connection [8]. Based on the findings, there has been an impressive scientific output on the topic of climate change and plant disease studies. The present findings show that climate change has a significant impact on plant pathology in terms of developing management and diagnosis strategies.

Using Figure 3(b) as a reference, disease forecasting, modelling, and early warning are shown combined. Plant disease forecasting and modelling are one of the clusters formed by the co-occurrence of the terms. Plant disease forecasting is an excellent real-time management method that collects data to predict the occurrence of plant disease in a specific area, allowing control strategies to be implemented to prevent production losses. Despite various factors that can be forecasted, it is essential to measure climate change on a timely basis, as environmental factors play a crucial role in abiotic and biotic pressures [20]. To achieve the goal of plant disease prediction, it is necessary to develop a mathematical model or statistical tools that disclose the association between plant disease onset and weather parameters [21].

Previously, two publications relating to plant disease and modelling were included in the publication with the most citations over the time frame of the search. Computational forecasting utilising leaf image identification and deep neural networks allowed farmers to detect disease at the early stage of infestation, allowing for the consideration of effective management methods to limit plant disease distribution. In addition, the progress and impact of modelling work have a substantial influence on the impact of pests and diseases on agricultural production, where crop productivity is intimately linked to farmer incomes and food security [17]. To ensure adequate food is produced for human consumption despite climatic changes, the agriculture sector must have effective methods for forecasting and predicting plant disease outbreaks.

However, indirect effects and direct interactions among environments, plant hosts, and pathogens would complicate plant health prediction and management [22]. Thus, multidisciplinary studies [23]

involving standardised collection of long term-term data on plant diseases variables are essential to forecast the effects of climate change on progression and prediction of plant diseases [24].



(a) Co-authorship (b) Co-occurrence of author keywords

Figure 3. Network visualisation of the co-authorship and co-occurrence of author keywords.

4. Conclusion

Using bibliographical information retrieved from the WoS database, global publication trends, most contribution institutions and nations, highly cited papers, co-authorship, and author keywords co-occurrence analysis were used to address the questions regarding performance analysis and network mapping. One of the insights on the expansion of the research field using bibliometric methods may offer future directions for research in climates and plant pathology fields. Besides, the researchers may be able to explain the history of the subject of the study and the phases of its development based on the bibliographical data. Overall, it may be inferred that climate change has a substantial impact on plant pathology in terms of establishing management and diagnosis strategies. However, there is insufficient knowledge on how climates could affect plant disease diagnosis and management. To gain a deeper understanding of various climate effect variables on certain plant diseases and locations, additional research works are required, such as a systematic review of the literature, within the framework of climatic changes in phytopathology.

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