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**Original Research**

# Soil Salinity and Climate Change: A Bibliometric Analysis Based on the Scopus Database

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## ABSTRACT

***Purpose:*** *This study aims to identify knowledge gaps and research trends in soil salinity and climate change by conducting a bibliometric analysis of related publications from 1962 to 2023 in the Scopus database. Understanding these patterns is essential to guide future research and policy, given the growing global threat of salinisation to agriculture and food security.*

***Research Method:*** *This study used Scopus publications soil salinity due to climate change. This research was conducted between March and December 2023, with a Scopus search performed on July 30, 2023. Several programs are available to analyse bibliometric data; this research used Biblioshiny (R program-based software) and VOSviewer to extract all information completely from the abundant data gathered. These two programs have been used for data analysis in papers that were not commonly used in previous publications.*

***Findings and Values:*** *This bibliometric analysis identified several gaps in the literature on soil salinity and climate change research, including a lack of research on situation-based adaptation strategies for salinity reduction due to global climate change, no specifically designed draining system to control salinity in the soil, creating low-cost instruments for real-time tracking of soil moisture, fertiliser and salt levels, and agricultural stress, and sophisticated models that accurately simulate the complex relationships between physical, chemical, and biological processes in the soil-plant-atmosphere system. The article is the first study to analyse the published works in the field of soil salinity due to climate change since the first paper was published in 1962.*

**Keywords:** *Agricultural extension, Bibliometric analysis, Climate change, Global warming, Salinization*

## INTRODUCTION

Soil salinity is one of the most significant global challenges in the present age, impacting agricultural production and overall food security (Zaman 2018). The Central Soil Salinity Research Institute (CSSRI) of India predicted that soil salinity would increase by more than 50% of what it is at present by the year 2050 (Kumar & Sharma 2020). Soil salinity affects nearly one-fifth of cultivated land and one-third of irrigated land worldwide (Wang *et al.* 2022). For instance, the percentage of saline soils in Bangladesh increased from less than 1% in 1990 to 33% in 2015, primarily due to seawater intrusion in coastal areas (Corwin 2021). In addition, other anthropogenic activities, such as overusing groundwater and using synthetic fertilizers, increased industrialization, and high

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population pressures, are exacerbating the salt stress in soil (Minhas *et al.* 2017).

Around 800 million hectares of land are affected by soil salinity worldwide, predominantly in arid and semi-arid regions (Qadir *et al.* 2014). Furthermore, climate change and global warming aggravate the situation by altering precipitation patterns, increasing temperatures, and aggravating droughts (Eswar *et al.* 2021). Combining these factors causes significant changes in soil properties, increasing salinity.

Soil salinity creates extra ions in the ground, such as magnesium, calcium, sodium, chlorides, and sulfates, inhibiting plant development and function (Gul *et al.* 2022). In addition, the salinity of the soil disrupts the organic absorption of minerals and water, impairing vital metabolic processes needed for plant growth and development (Bhantana *et al.* 2021). Salinization thereby poses a severe danger to the health of the soil and contributes significantly to the deterioration of the land.

The degree of salinization around the world has effects on society and the economy. Soil salinity reduces agricultural output and farming profits. Globally, agrarian yield declines result in yearly losses of US$12 to $27.3 billion (Tropp 2015). However, it is expected that, especially in areas where salinity is already a problem, the harmful impacts of climate change on soil salinity will negatively influence food security.

Over the past few decades, the scholarly community has begun to pay more and more attention to two crucial issues: soil salt and climate change. Both problems significantly affect world agriculture, food security, ecosystem health and welfare, and human communities everywhere. Yet, even though there has been a lot of study on these subjects, soil salinity and climate change research patterns have not been thoroughly examined. Globally, soil salinity is a big problem likely to worsen due to climate change. Climate change changes how it rains, makes it hotter, and makes droughts worse, which leads to significant changes in soil properties and more salt in the soil (Okur & Örçen 2020).

Numerous studies have been conducted to comprehend the mechanisms of soil salinization due to climate change and to identify effective management strategies. Soil salinization due to climate change is anticipated to increase in salinity-affected regions (Munns & Tester, 2008), such as Australia, North Africa, and the Middle East. The study also showed that rising soil salinity would lower crop yields, worsen food insecurity, and have many other adverse environmental and social effects.

Salinity significantly impacts soil quality, plant growth, and crop yield (Safdar *et al.* 2019; Hailu & Mehari 2021). There are approximately 1060 million hectares of salt-affected soils in the world, and they are primarily located in North and Central Asia (around 211 Mha), Africa (210 Mha), and South America (130 Mha) (Eswar *et al.* 2021). In arid and semi-arid regions, irrigation-induced soil salinization has been discovered to be the leading cause of land degradation.

Among the many drivers of soil salinity, few of them are understood by scientists, e.g., sea-level rise and intrusion (Salehin *et al.* 2018), increase in surface temperature (Corwin 2021), poor drainage and irrigation quality (Zhang *et al.* 2022), changing rainfall patterns that decrease leaching resulting in amassing of salts in the plant root zone (Eswar *et al.* 2021), and cyclones or manmade flooding of seawater for aquaculture (Halder & Bandyopadhyay 2022) are contributing to salt accumulation in topsoil (Figure 1).

The two causes of salinity in the world are natural and anthropogenic (secondary salinization) (Williams 1999). The effects of secondary salinization are always negative, multifaceted, and practically irreversible. The diversion of incoming rivers primarily causes large lakes that are already salty. The impact of rising salinities in these lakes is contingent upon both their initial (natural) salinity and the magnitude of the increase. Low initial salinities have the most significant effects. As a result,

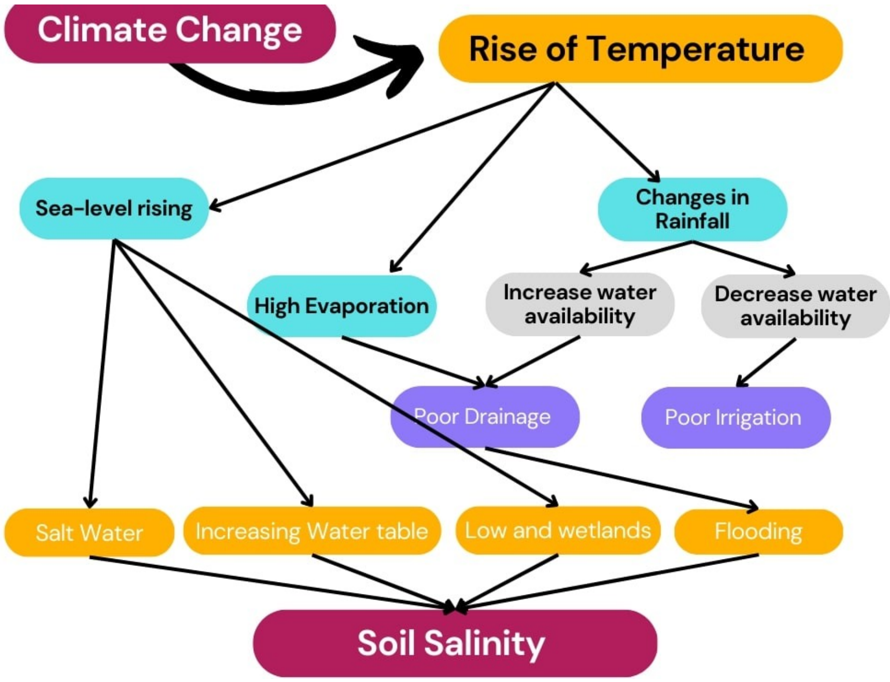


**Figure 1. Soil salinity due to climate change**
Source: Original materials of this research

most of the lake's economic, environmental, conservational, and ecological values decline. Over the past four decades, the mismanagement of water and land resources has increased soil salinity (Zewdu *et al.* 2016). Moreover, inadequate drainage conditions exacerbate secondary salinization.

By interfering with a plant's metabolic processes, salinity impairs its growth and development and decreases productivity. Salinity in the soil causes osmotic stress, leading to an imbalance of cellular ions and ion toxicity (Tuteja *et al.* 2012). High concentrations of certain salts, such as $Na^+$, $Cl^-$, and $HCO_3$, are deleterious to numerous plant species. The accumulation of NaCl salt causes the production of abscisic acid, resulting in stomatal closure and decreased photosynthesis in the plant (Xue *et al.* 2021). Stomatal closure reduces $CO_2$ availability, resulting in the production of highly toxic oxygen derivatives/reactive oxygen species (ROS), including superoxide radicals ($O_2^-$), singlet oxygen ($^1O_2$), hydrogen peroxide ($H_2O_2$), and hydroxyl radicals.

Furthermore, forming the most toxic hydroxyl radicals in plants causes cellular injury or cell mortality by interacting with macromolecules (lipid peroxidation, protein and nucleic acid oxidation), which reduces the productivity of crops.

Increased soil salinity, for instance, can induce substantial alterations in soil microbial communities, thereby diminishing soil fertility, ecosystem services, and ecological hazards (Haj-Amor *et al.* 2022, Qadir *et al.* 2014). The effects of climate change on soil salinity are not limited to agriculture but also have significant environmental and social consequences. Soil salinization can result in social and economic challenges, such as migration, community displacement, and decreased producer income (Chen & Mueller 2018).

Consequently, it is essential to identify effective measures for preventing and managing soil salinity caused by climate change. For instance, solar-powered trickle irrigation systems can reduce water losses and increase water use efficiency, thereby reducing the danger of soil salinity (Omuto *et al.* 2020). Remote sensing and geospatial tools have been used to monitor soil salinity and evaluate its impact on crop yield and ecosystem services. Hyperspectral and thermal imaging can identify areas affected by soil salinity and assess its effect on crop productivity (Hamzeh *et al.* 2016). Developing and implementing policies and regulations can significantly manage soil salinity caused by climate change. Integrating soil management and climate change policies can assist in mitigating the effects of soil salinization and enhancing soil health (Omuto *et al.* 2020). Promoting sustainable agricultural practices, such as conservation agriculture and agroforestry, can also improve soil health and lower the risk of soil salinization (Omuto *et al.* 2020). Bibliometric analysis can identify areas for future study and research voids. For instance, a study by Ma *et al.* (2022) found the need for additional research on how soil salinity affects relationships between plants and microbes and soil biodiversity. Similarly, bibliometric studies revealed a dearth of studies on how climate change affects soil salinity in Africa, emphasizing the need for more research in this area.

As a result, the primary goal of this study is to perform a bibliometric analysis of the research patterns in soil salinity and climate change. The study aims to summarize the knowledge gaps and research trends related to soil salinity and climate change, which can guide future studies and policy initiatives. However, the specific objectives are: (i) To analyze the top countries, organizations, writers, and publications and their linkage in soil salinity and climate change studies; (ii) Examine the number of research papers published and how often they have been cited over the previous years about soil salinity and climate change.(iii) Analyze the keywords based on centrality and density used in soil salinity and climate change research.(iv) To evaluate the co-authorship trends and institutional partnerships in this field.(v) Analyze the knowledge gaps that can direct soil salinity and climate change-related future research.

## MATERIALS AND METHODS

A limitation of the current bibliometric analysis may be attributed to using a single database (i.e., Scopus) for data collection, which could affect the comprehensiveness and generalizability of the results. Despite Scopus being recognized as a comprehensive database, the utilization of more databases like Web of Science, Google Scholar, and Dimensions may increase the strength of the findings. Including multiple databases would, therefore, allow for a more comprehensive coverage of pertinent literature, including non-Scopus-indexed journals, regional journals, and publications in non-English languages, which may be underrepresented in Scopus.

As a result, there might be differences in bibliometric trends, such as changes in top authors, institutions, and countries and in citation patterns. Moreover, extending to multiple databases facilitates a more nuanced understanding of keyword analysis, co-authorship dynamics, and institutional collaborations, providing the potential for more accurate insights into these metrics. By recognizing this limitation, future studies can use multiple databases to corroborate and elaborate on the bibliometric trends identified in the present study.

Bibliometric analysis is a quantitative descriptive research method that uses library data to perceive the different patterns in research production, citation networks, and scientific collaboration (Velez-Estevez *et al.* 2022). It gives insights into main publications, key authors, research themes and international collaboration (Donthu *et al.* 2021). Furthermore, bibliometric analysis contributes to evaluating research productivity, bypassing gaps, and informing funding and policy responses (Kabir *et al.* 2024).

### *Data collection*

We first checked the Scopus database (https://www.scopus.com/home.uri) to see how many papers were about this topic. Although there are more databases, such as PubMed, Web of Science, and Google Scholar, Scopus is more powerful and convenient (Pranckutė 2021). The terms "soil salinity AND climate change" were searched. "Soil Salinity AND Climate Change" were the keywords interrelated to soil salinity research.

The search criteria looked to see if the words were in the articles’ titles, keywords, or

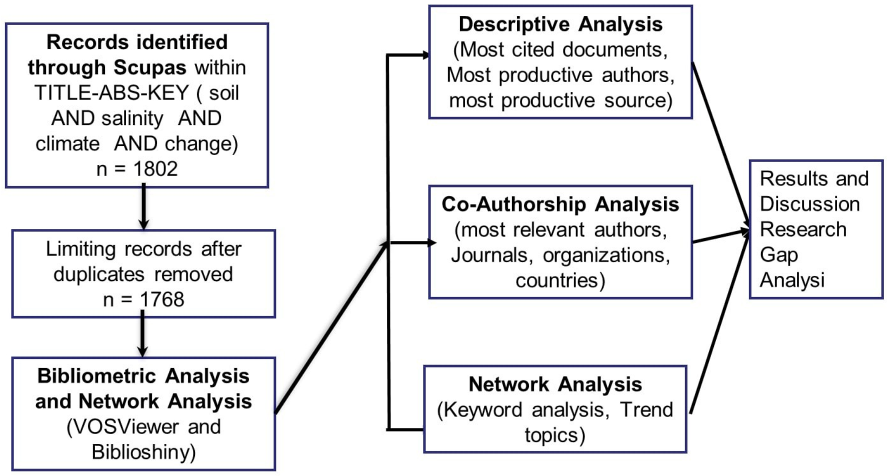


**Figure 2. Research design for this study**
Source: Original materials of this research

abstracts. This research included articles, book chapters, and conference papers. We excluded articles written in other languages besides English. We included the first paper published related to soil salinity in 1962 to date. The study spanned 1962 (when the first paper in this field was published) to 2023. A list of 1802 papers was found after this search. After that, a two-step process was used to choose the articles. First, the names of each article were looked at to see if they were relevant to the study. Secondly, the duplicated records were removed. The research methodology is presented in figure 2.

### *Data analysis*

Several programs are available to analyze bibliometric data; this research used Biblioshiny and VOSviewer to extract all information completely from the abundant data gathered. These two programs have been used for data analysis in papers, but combining them is uncommon. While VOSviewer was used to create the visualization (Van Eck & Waltman 2017), Biblioshiny was mainly used for the detailed analysis. Bibliometrix is a package for R, and Biblioshiny is its variant, a user-friendly, web-based application for non-coders (Aria & Cuccurullo 2017).

It is run in R Studio and is based on the Bibliometrix package (Ahmi 2022). It is compatible with Dimensions, Pubmed, Scopus, Web of Science, and the Cochrane Library. It is known that the images are generated through Biblioshiny. Bibliometrics is based on two main network components: items and their links that create connections between items. VOSviewer has been extensively used for bibliometric research on climate change; e.g., Luckyardi et al. (2022) used it for a study of climate-smart agriculture, and Einecker & Kirby (2020) used it to review studies of climate change adaptation and resilience.

## RESULTS AND DISCUSSION

### *Description of the data*

The articles come from 814 journals and 1768 articles from 1962 through 2023 (shown in Table 1). The yearly growth rate of publications is 4.85%, which indicates that the number of articles has gradually risen. In addition, the papers have an average age of 6.82 years, which suggests that the articles they include were published recently.

Each document in the collection has an average of 25.34 citations, which shows a comparatively high degree of influence. The group has 128 single-authored papers and 6814 overall writers. There are 4.9 co-authors on average per document, and 35.18% of co-authorships are foreign, demonstrating a high degree of cross-national cooperation.

The 1237 research articles comprise most of the journal's article categories. Other sources, e.g., book chapters, conference papers, reviews, and other documents.

**Table 1. Descriptive Statistics of the Data**

| Description | Results |
|---|---|
| Main Information About Data | |
| Timespan | 1962:2023 |
| Sources (Journals, Books, Etc) | 814 |
| Documents | 1768 |
| Annual Growth Rate (%) | 4.85 |
| Document Average Age | 6.82 |
| Average Citations Per Document | 25.34 |
| References | 125,969 |
| Document Contents | |
| Keywords Plus (ID) | 8943 |
| Author's Keywords (DE) | 4900 |
| Authors | |
| Total Authors | 6814 |
| Authors of Single-Authored Documents | 128 |
| Authors Collaboration | |
| Single-Authored Documents | 140 |
| Co-Authors Per Document | 4.9 |
| International Co-Authorships (%) | 35.18 |
| Document Types | |
| Article | 1237 |
| Book | 13 |
| Book Chapter | 191 |
| Conference Paper | 122 |
| Conference Review | 5 |
| Data Paper | 1 |
| Editorial | 1 |
| Letter | 3 |
| Note | 1 |
| Retracted | 1 |
| Review | 191 |
| Short Survey | 2 |

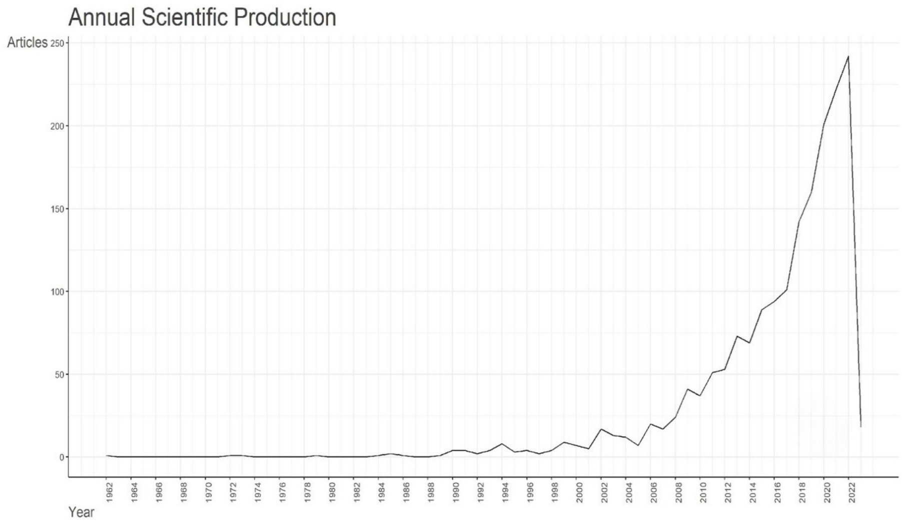


**Figure 3. Annual scientific production over time (1962-2023)**
Source: Developed by authors using Biblioshiny software

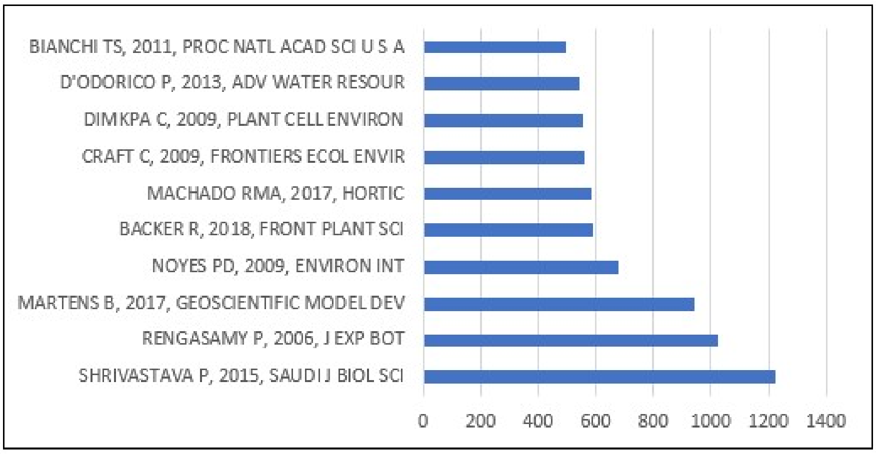


**Figure 4. Most influential publications in the area of ("soil salinity and climate change")**
Source: Developed by authors using Biblioshiny software

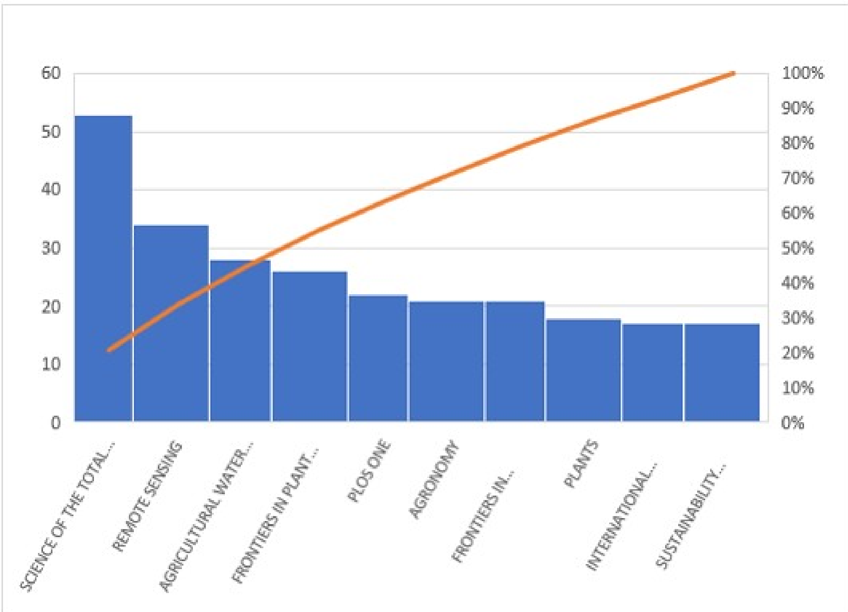


**Figure 5. Most influential journals in this area**
Source: Developed by authors using Biblioshiny software

***Publication progression***

The first article published in 'Soil Salinity AND Climate Change' was in 1962, and there were no publications in the years after that until one article was published in 1972. One article in 1973 and 1979, two in 1985 and 1992, and four in 1990 and 1993 marked a steady rise in releases. After that, there was a sharp rise in the number of publications, with nine papers appearing in 1999, 17 in 2002, and 41 in 2009. With 142 articles released in 2018, 160 articles published in 2019, and 201 articles published in 2020, the number of writings has continued to rise. There were 222 papers released in 2021 and 242 stories published in 2022. There have been 18 stories released so far in 2023.

***Influential publications***

The normalized TC (total citations) is calculated by dividing the TC per year by the average TC per year of all publications in the discipline. The TC per year is the average number of citations received annually since the publication's release. The article with the greatest TC is "Shrivastava P, 2015, Saudi J Biol Sci," which has 1223 citations. "Rengasamy P, 2006, J Exp Bot," with 1023 citations, is the second-highest.The normalized TC varies from 7.63 for "Mulholland PJ, 1997, Hydrol Processes" to 135.89 for "Shrivastava P, 2015, Saudi J Biol Sci." For "Shrivastava P, 2015, Saudi J Biol Sci," the normalized TC values vary from 26.98 to 1.80. For "Mulholland PJ, 1997, Hydrol Processes," they are 1.80 to 26.98.

***Influential journals***

"Science of the Total Environment" has published 53 articles. Other prominent sources include "Agricultural Water Management," which has 28 papers, "Remote Sensing," which has 34 articles; and "Frontiers in Plant Science," which has 26 articles.

***Bradford's law***

Bradford's law explains how scholarly material on a subject is dispersed among various periodicals or papers (Venable et al. 2016). Samuel C. Bradford first put forth the rule in 1934. It is based on the observation that the distribution of papers released on a given subject across various periodicals or magazines tends to follow a particular pattern (Alvarado 2016). Bradford's law states three distinct areas of a topic's scholarly writings. The first zone is a central zone comprising a few select periodicals that disseminate the most significant and pertinent articles on the subject. A greater number of journals that print papers of middling significance and value can be found in the second zone, a middle dispersion zone. Finally, the third zone, known as a zone of periphery dispersion, comprises numerous periodicals that print scantly connected pieces on the subject. A total of 44 journals come under Zone 1, showing that they have made significant attention in the mentioned research area, 100 journals in Zone 2, and 671 journals in Zone 3.

**Table 2. Most Cited Documents in Soil Salinity and Climate Change Research**

| Paper | Total Citations | TC per Year | Normalised TC |
|---|---|---|---|
| Shrivastava P, 2015, Saudi J Biol Sci | 1223 | 135.89 | 26.98 |
| Rengasamy P, 2006, J Exp Bot | 1023 | 56.83 | 10.43 |
| Martens B, 2017, Geoscientific Model Dev | 940 | 134.29 | 25.65 |
| Noyes Pd, 2009, Environ Int | 679 | 45.27 | 9.78 |
| Backer R, 2018, Front Plant Sci | 590 | 98.33 | 24.21 |
| Machado Rma, 2017, Hortic | 586 | 83.71 | 15.99 |
| Craft C, 2009, Frontiers Ecol Envir | 564 | 37.60 | 8.13 |
| Dimkpa C, 2009, Plant Cell Environ | 554 | 36.93 | 7.98 |

**Table 2. Most cited document in soil salinity and climate change research**

| Paper | Total Citations | TC per Year | Normalised TC |
|---|---|---|---|
| D'odorico P, 2013, Adv Water Resour | 541 | 49.18 | 14.35 |
| Bianchi Ts, 2011, Proc Natl Acad Sci U S A | 495 | 38.08 | 10.10 |
| Dalal Rc, 2003, Aust J Soil Res | 467 | 22.24 | 5.24 |
| Pereira Ls, 2015, Agric Water Manage | 402 | 44.67 | 8.87 |
| Grover M, 2011, World J Microbiol Biotechnol | 386 | 29.69 | 7.87 |
| Gilliam Jw, 1994, Crit Rev Environ Sci Technol | 353 | 11.77 | 4.13 |
| Lareen A, 2016, Plant Mol Biol | 342 | 42.75 | 13.80 |
| Daliakopoulos In, 2016, Sci Total Environ | 341 | 42.63 | 13.76 |
| Jiang H, 2006, Appl Environ Microbiol | 330 | 18.33 | 3.36 |
| Redman Rs, 2011, Plos One | 293 | 22.54 | 5.98 |
| Morrissey Em, 2014, Global Change Biol | 245 | 24.50 | 7.20 |
| Al Bitar A, 2012, IEEE Trans Geosci Remote Sens | 215 | 17.92 | 5.59 |
| Deil U, 2005, Phytocoenologia | 210 | 11.05 | 3.75 |
| Hanjra Ma, 2012, Int J Hyg Environ Health | 207 | 17.25 | 5.39 |
| Mulholland Pj, 1997, Hydrol Processes | 206 | 7.63 | 1.80 |
| Anderson Nj, 2000, Eur J Phycol | 204 | 8.50 | 3.31 |
| Witcombe Jr, 2008, Philos Trans R Soc B Biol Sci | 203 | 12.69 | 6.05 |
| Fita A, 2015, Front Plant Sci | 202 | 22.44 | 4.46 |
| Ruiz Kb, 2014, Agron Sustainable Dev | 198 | 19.80 | 5.82 |
| Xie J, 2009, Environ Geol | 196 | 13.07 | 2.82 |
| Bordeleau Lm, 1994, Plant Soil | 196 | 6.53 | 2.30 |
| Adame Mf, 2013, Plos One | 193 | 17.55 | 5.12 |
| Etesami H, 2018, Front Microbiol | 191 | 31.83 | 7.84 |
| Bertness Md, 2002, Oecologia | 184 | 8.36 | 2.77 |
| Jobbágy Eg, 2004, Global Change Biol | 179 | 8.95 | 2.58 |
| Mckee Kl, 2004, Global Ecol Biogeogr | 178 | 8.90 | 2.57 |
| Lashari Ms, 2013, Field Crops Res | 174 | 15.82 | 4.62 |
| Merlin O, 2012, IEEE Trans Geosci Remote Sens | 173 | 14.42 | 4.50 |
| Vimal Sr, 2017, Pedosphere | 172 | 24.57 | 4.69 |
| Vanuytrecht E, 2014, Environ Model Softw | 172 | 17.20 | 5.06 |
| Tjiputra Jf, 2013, Geoscientific Model Dev | 171 | 15.55 | 4.54 |
| Neubauer Sc, 2013, Estuar Coasts | 169 | 15.36 | 4.48 |

**Table 2. Most cited document in soil salinity and climate change research**

| Paper | Total Citations | TC per Year | Normalised TC |
|---|---|---|---|
| Egamberdieva D, 2019, Front Microbiol | 168 | 33.60 | 9.36 |
| Salama Rb, 1999, Hydrogeol J | 157 | 6.28 | 4.28 |
| Leigh Eg, 2014, Biol Rev | 152 | 15.20 | 4.47 |
| Douville H, 2002, Clim Dyn | 152 | 6.91 | 2.29 |
| Lashari Ms, 2015, J Sci Food Agric | 146 | 16.22 | 3.22 |
| Comeaux Rs, 2012, Estuar Coast Shelf Sci | 145 | 12.08 | 3.77 |
| Kang S, 2004, Hydrol Sci J | 141 | 7.05 | 2.03 |
| Lu T, 2018, Microbiome | 140 | 23.33 | 5.74 |
| Cowan Da, 2004, Annu Rev Microbiol | 140 | 7.00 | 2.02 |
| Bezborodov Ga, 2010, Agric Ecosyst Environ | 139 | 9.93 | 4.58 |

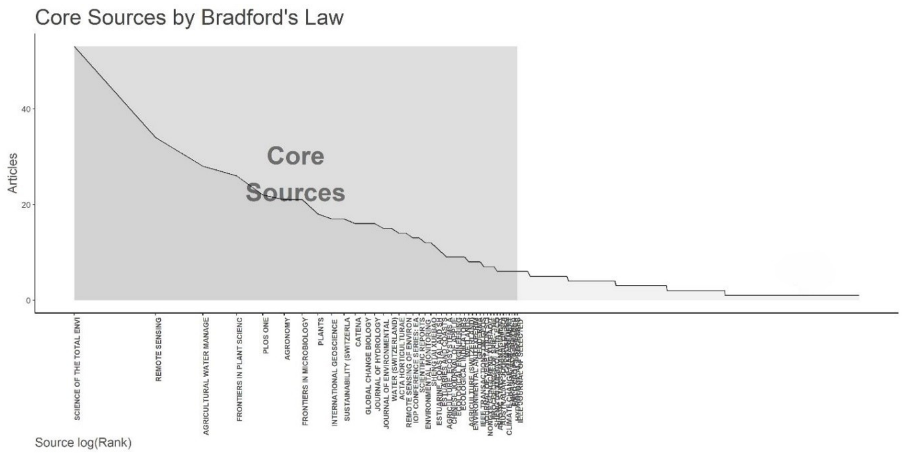


**Figure 6. Core sources by Bradford's Law**
Source: Developed by authors using Biblioshiny software

***Author's outputs***

With 20 papers each, Li X and Wang J contributed the highest in soil salinity and climate change research. Wang X and Li Y Both authors have written 15, and Wang Y and Liu J have authored 14 papers.

***Author Productivity through Lotka's Law***

An actual finding in the study of bibliometrics, or evaluating scholarly literature, is known as Lotka's Law. The rule was initially suggested in 1926 and is called after the American researcher and scientist Alfred J. Lotka. It outlines the author's frequent distribution of scholarly writings in a particular study area. (Lotka 1926). Lotka's law states that the number of authors (Y) who published a given number of papers (X) is inversely proportionate to X. The connection can be modelled mathematically as follows:

$$Y = \frac{C}{X^a}$$

Where C and an are factors that vary depending on the particular study area, the value of an is typically around 2, which indicates that the proportion of writers who have written twice as many papers as those who have only published one is roughly one-fourth (Pritchard

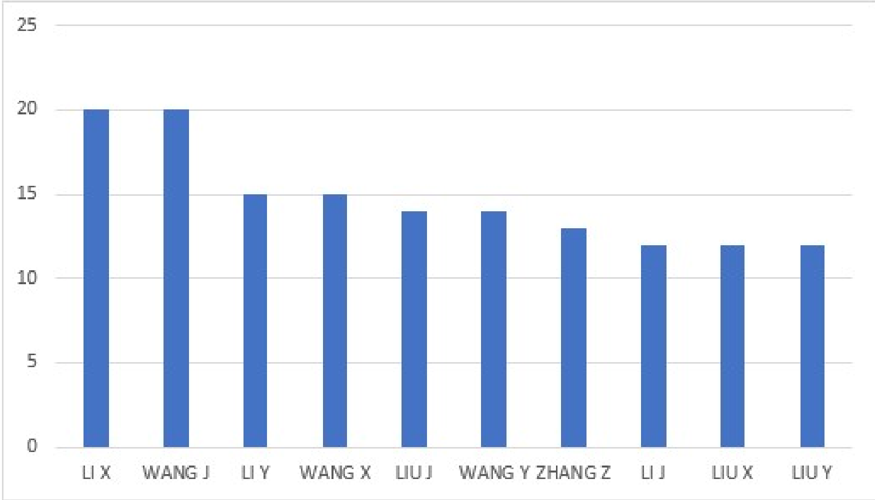


**Figure 7. The most contributing authors in 'soil salinity and climate change research domain**
Source: Developed by authors using Biblioshiny software

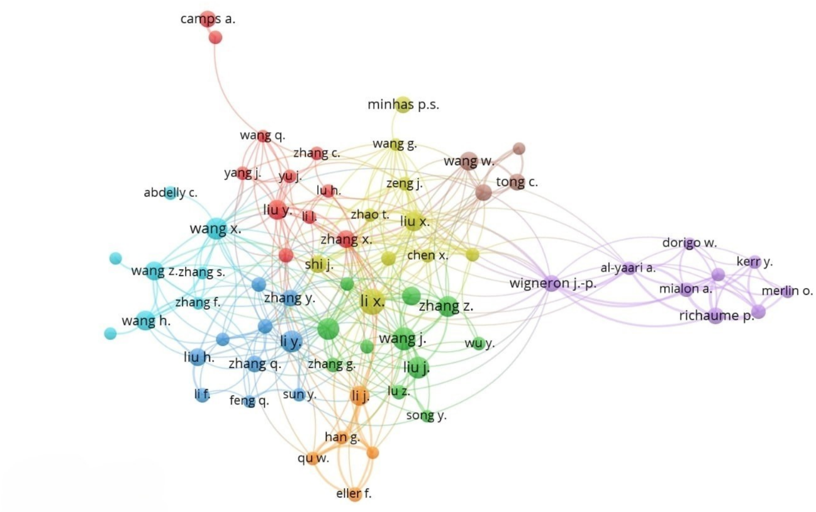


**Figure 8. Authors in 'soil salinity and climate change' research and their co-authorship patterns**
Source: Developed by authors using VOSviewer software

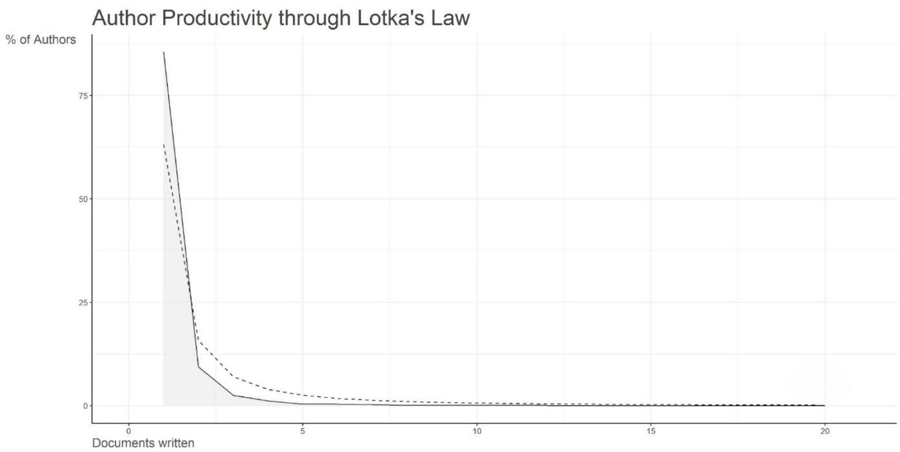


**Figure 9. The author's productivity in Soil salinity and climate change research through Lotka's law**

Source: Developed by authors using Biblioshiny software

1969).

Scholars' output across subjects has been extensively studied using bibliometrics, and Lotka's Law has been found to be generally constant (Cole 1954). However, arguments have been over whether the law is always accurate because some studies have discovered variations from the expected distribution in particular study fields. (Cole 1954).

A total of 5827 authors (85.5%) have produced just one work on the subject. As the number of written papers rises, the percentage of writers falls, suggesting that fewer authors add to numerous writings. 640 authors (9.4%) and 170 authors (2.5%) wrote three and two papers, respectively. The percentage of writers in each group gradually decreases as an author's number of articles rises. For instance, only four writers (0.1%) and 27 authors (0.4%) have each written eight and nine papers, respectively.

***Corresponding author's countries***

China, the United States, and the countries with the most scholarly papers released.

However, Japan has the most significant percentage when comparing the MCP (Multiple Country Production) to the SCP (Single Country Production), followed by Italy and the United Kingdom.

***Scientific production by countries***

China (1538), the United States (1074), and India (672) are the three countries with the most significant number of publications.

***Most cited countries***

The USA has the most significant overall citations, with 8,986 total citations and an average of 45.16 per article. China comes second with 4,215 total citations and an average of 17.06 per paper. However, according to their available sources and specific paper citations, other nations like Australia, India, and Germany have also made sizable advances to the subject.

***Country collaboration***

There were 20 partnerships between the USA and Australia and 20 collaborations between China and the USA in this area of research. There were also 24 collaborations between China and Australia. In comparison, there were 20 collaborations between the United States and Germany, Spain, and India.

There were also 15 collaborations between China and Spain, 17 collaborations between Spain and Italy, and 16 partnerships between the United States and the Netherlands in research on soil salinity and climate change.

***Network analysis and trend word analysis***

***Co-occurance network***

The figure displays two influential groups, Cluster 1 (red colour) and Cluster 2 (green colour), each containing various study components.

Cluster 1: Environmental, agricultural, water resource, and remote sensing study subjects are included in Cluster 1. Climate change, soil wetness, farmland, groundwater, remote sensing, and irrigation are a few of the notable nodes in this cluster. These subjects typically involve administrating and observing habitats, natural resources, and land use, concentrating on their interconnectedness.

Cluster 2: Research on soil characteristics, chemistry, carbon storage, and marsh habitats are some subjects covered in Cluster 2. Salt, earth, sodium chloride, and habitat nodes are some of its essential nodes. The main topics of discussion in these fields are biological processes, ecological characteristics, and environmental interactions.

***Keywords***

The word "climate change" appears 946 times, making it the most frequently used in the study area. "Salinity," which appears 747 times, comes in second, followed by "soil," which appears 360 times, and "soil moisture," which appears

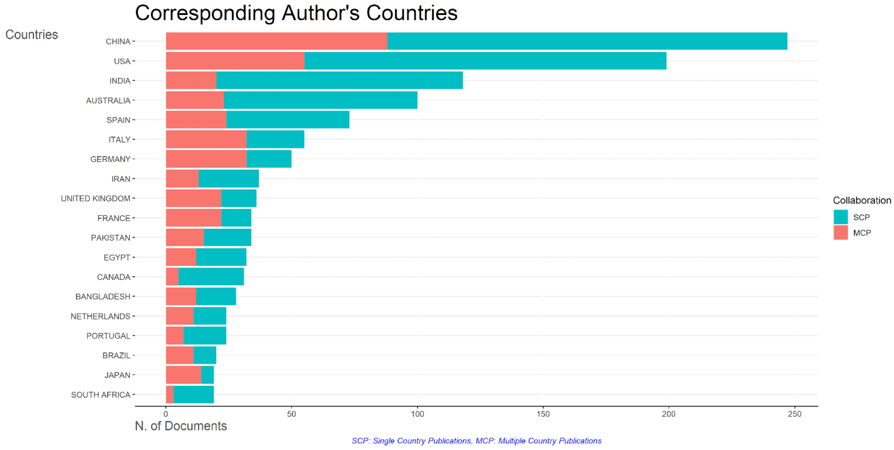


**Figure 10. Corresponding authors' country**
Source: Developed by authors using Biblioshiny software

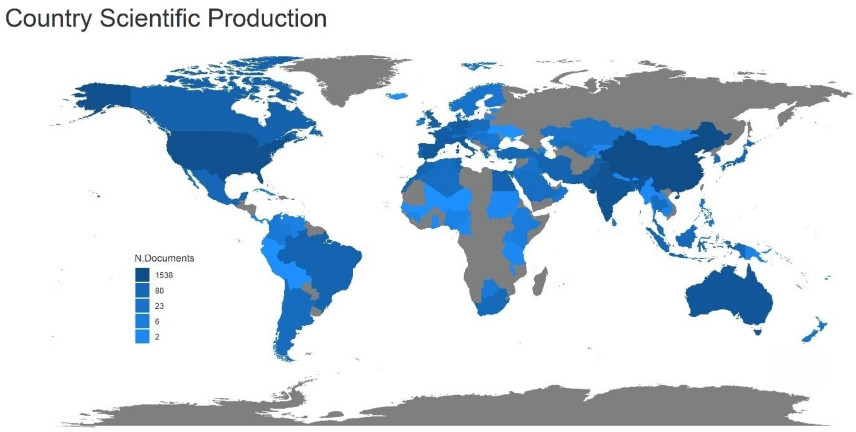


**Figure 11. Country-specific production**
Source: Developed by authors using Biblioshiny software

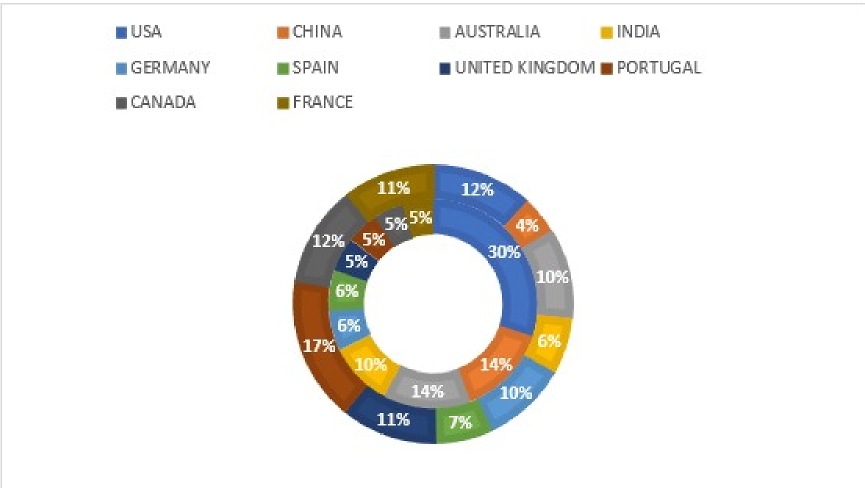


**Figure 12. Most cited countries in the mentioned research domain**
Source: Developed by authors using Biblioshiny software

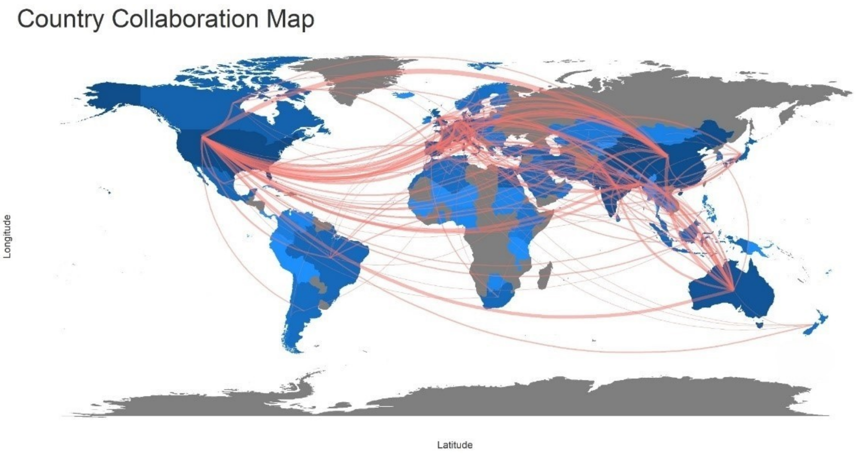


**Figure 13. Country collaboration map**
Source: Developed by authors using Biblioshiny software

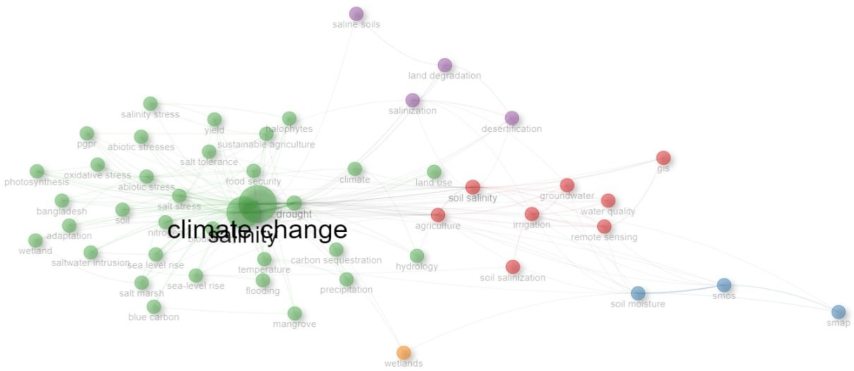


**Figure 14. Co-occurrence network of the author's keywords**
Source: Developed by authors using Biblioshiny software

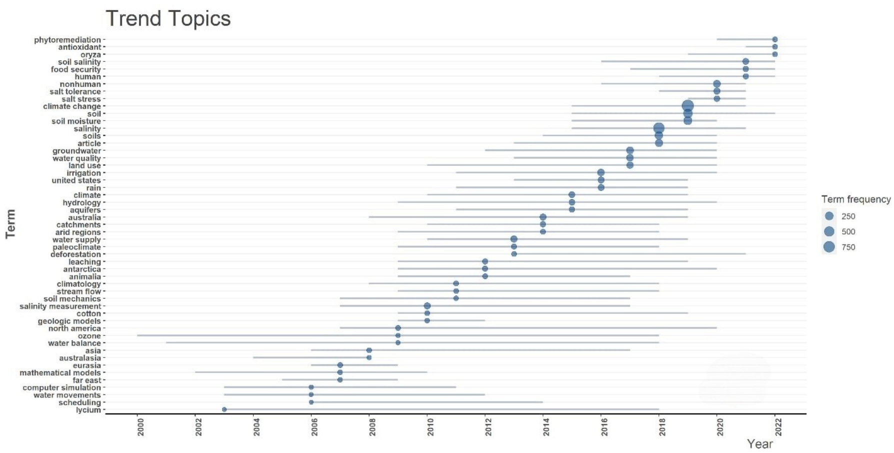


**Figure 15. Trend topics related to soil salinity and climate change**
Source: Developed by authors using Biblioshiny software

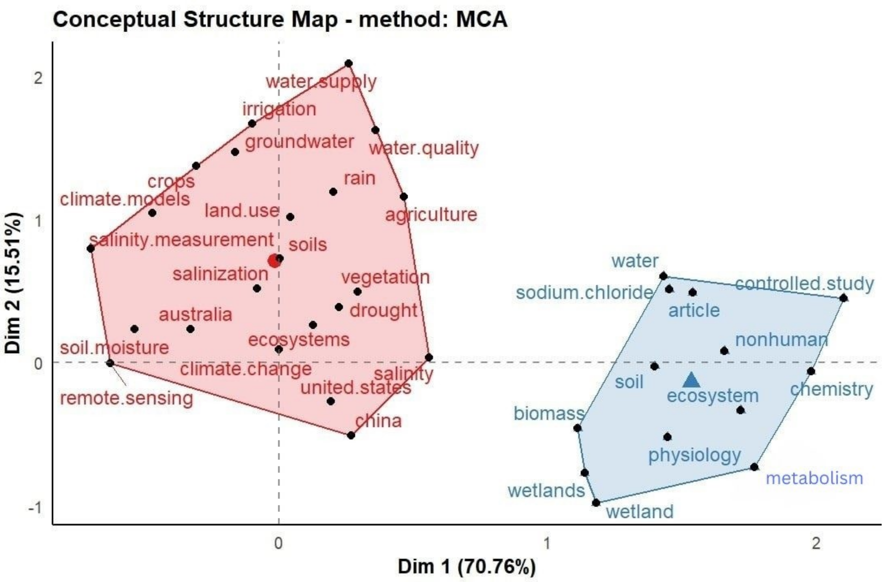


**Figure 16. Conceptual Structure Map Multiple Correspondence Analysis (MCA)**
Source: Developed by authors using Biblioshiny software

287 times.

The predominance of these words in studies performed within environmental, farming, and climate studies indicates their respective significance. High-frequency words like "climate change," "salinity," and "soil" show where study efforts are concentrated to comprehend and resolve the problems these issues present. The figure summarizes the main subjects covered in the study papers in this area and provides information on patterns and areas of interest.

***Trending topics***

The chart gives a summary of keywords, their prevalence, and the first quartile (Q1), median (Med), and third quartile (Q3) of the years in which these keywords appeared in study papers. These terms have different connections to ecology, agriculture, and temperature studies.

The term "climate change" has a high frequency of 946 papers distributed across the years 2015 (Q1) to 2021 (Q3), indicating that it has recently become a hot topic for study. "Soil mechanics," "climate," and "hydrology," as well as regional areas like "Eurasia," "Asia," "Australasia," and "North America," are included in the chart.

We can track interest changes over time and study emphasis patterns by looking at the years connected to each term. For instance, research was concentrated around the early 2000s for keywords like "computer simulation" and "mathematical models." In contrast, more recent keywords like "food security" and "antioxidant" indicate a preponderance of research papers in the late 2010s and early 2020s.

***Conceptual structure map Multiple Correspondence Analysis (MCA)***

The findings are analyzed based on the relative locations of the spots and their distribution along the dimensions; the closer the words are depicted in the image, the closer their distribution is (Aria & Cuccurullo 2017). For example, papers relating to water supply, irrigation, soil moisture, climate change, agriculture, water quality, and groundwater are in Cluster 1 (red colour).

Papers relating to sodium chloride, soil, biomass, wetlands, chemistry, nonhumans, and controlled studies are in Cluster 2 (blue colour).

## CONCLUSION

To sum up, this bibliometric analysis identifies significant research gaps in the field of soil salinity and climate change and encourages investigation into on-site adaptation approaches, use of novel drain designs to reclaim and/or integrate salinity into agricultural management, and low-cost, real-time soil health monitoring tools. In this regard, advanced models and hydro-salinity modeling methods are required to anticipate definite aspects of soil-plant-atmosphere interaction and respond to the climate change impact on certain soil characteristics. It requires subsurface runoff in saline farming, halophyte-based crop improvement, and natural alternatives to gypsum for sustainable management of salt-affected soils. Potential of functionalized biochar and cyanobacterial treatments in ameliorating sodic soils and advancing salt tolerance in plants. Climate change and increasing soil salinity are major challenges in the agricultural and food security domain, more pronounced in arid zones, and mitigation technologies involving amendments, salt-tolerant genotypes, micro-irrigation, and agroforestry remain the only feasible options. Such approaches can enhance soil health, increase agricultural yields, and contribute to food security. Further research on these practices, as well as their widespread adoption, is needed, adjusted to the ecological and socioeconomic context of the respective regions, because salt-affected areas exist in all the regions of the world and resilient sustainable farming in them is essential.

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