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Climate Change and its Effects on Agricultural Factors: A Bibliometric Analysis and Review

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Regarding food, agricultural productivity, and crop output, climate change is an unavoidable problem and concern that affects the entire planet. In the past ten years, climate change has profoundly affected various abiotic and biotic aspects linked to plants. In light of this, the current study provides a bibliometric and thematic overview of research in this field. WoS is used to search for the current study, and 29 publications published between 2013 and 2021 were utilized to complete the review. Most research in this field has been undertaken during the previous three years, focuses equally on all three themes (biotic, abiotic, and food security), and employs both qualitative and review methodologies. To boost the sustainability and sustenance of food crops and the agricultural sector, more quantitative and experimental research is needed to mitigate the effects of climate change.

Key words: Climate Change, Agriculture, Plants, Bibliometric Analysis.

1. INTRODUCTION

The magnitude of climate change is intensifying. A disparity between incoming and outgoing rays in the environment causes climate change. Climate change affects every region of the world we live. However, the effects of climate change are not consistent across the country and the globe. Various communities or individuals within a city may suffer different effects (Administration, 2021). Global warming is currently affecting public health. When meteorological and climatic trends shift, human life is at risk. Temperature ranks among the most lethal climatic situations (Service, 2022). Climate change influences the way of life throughout the world. It impacts plants and animals and has ramifications for the extinction of some species. In a variety of harmful ways, global warming affects people. Climate change causes community displacement, an increase in disease and mortality, and water and food insecurity (Heshmati, 2022). Global warming significantly impacts ecology, habitat, and quality of life. It has a global influence and is linked to changes in the planet's natural environment (Ahima, 2020; Hsiang et al., 2018; Raza et al., 2019). Adapting to the effects of global warming and limiting its escalation are the general society's principal challenges. Particularly with underrepresented communities, the government must employ tailored techniques (Ahima, 2020).

Throughout history, climate change has impacted the surface of the globe. The planet's environment is badly influenced by global warming in several ways. It affects the magnitude of extreme occurrences and the intensity of catastrophes (Brando et al., 2020; Sobrino et al., 2020). Effects of climate change on human health and well-being include more frequent and intense tropical storms, wildfires, deteriorating air circulation, and diseases transmitted by insects, foods, and water. It is anticipated that climatic disturbances to agricultural production will worsen throughout this century, a trend that could weaken the stability of food production. It is becoming increasingly challenging for habitats such as forests, coastlines, and marshes to buffer the consequences of natural disasters such as wildfires, flooding, and intense storms. In addition to other pressures, such as overfishing and pollution, changes in the sea's composition and global temperatures are affecting oceanic food security and damaging fish populations (Change.Gov). The effects of climate change on the agriculture system are depicted in Figure 1.

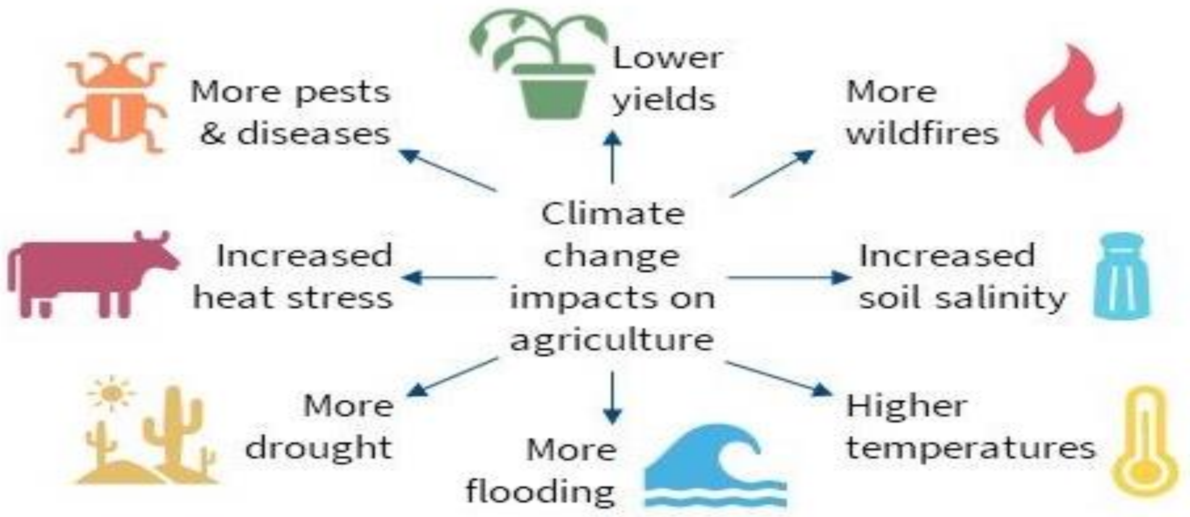

Figure 1. Changing climate impacts on Agriculture

Among the most critical challenges of our day is climate change, which has dramatically impacted or is still affecting the habitats of the globe. Even while the planet has always suffered some degree of climate change, the rate of this variability has accelerated during the past century (Arora, 2019). Due to the ever-increasing need for food resulting from the nation's population expansion, effective agricultural practices have been developed, such as the excessive use of pesticides, the production of animals (for meat and other types of revenue), and the manipulation of water. Changes in precipitation, temperature, atmospheric carbon fertilization, and weather patterns are anticipated to have a considerable impact on agricultural operations due to climate change. In addition, the agricultural sector is under additional strain due to the rapid growth of the population, the depletion of productive land, and inadequate water supplies. Thus, it is alarming that global warming may threaten farmers' incomes and prevent the nation from achieving long-term sustainability (Vahid et al., 2018). A notably high level of land deterioration brought on by global warming accelerates soil dehydration and nutrient deficiency. The problem of habitat destruction is claimed to be an enormous global threat worsening by the minute. Any weather patterns that interrupt agricultural production and transportation, whether locally or globally, can have a significant impact on food availability, quality, and safety (Agency). Due to changing cuisines and a growing global population, the hunger for food is growing. As global grain yields decline, marine quality deteriorates, and environmental ecosystems such as lands, waters, and wildlife are severely reduced, it is difficult for production to keep up (Bank, 2021). Climate change will likely impact agricultural productivity in various locations throughout the coming decades.

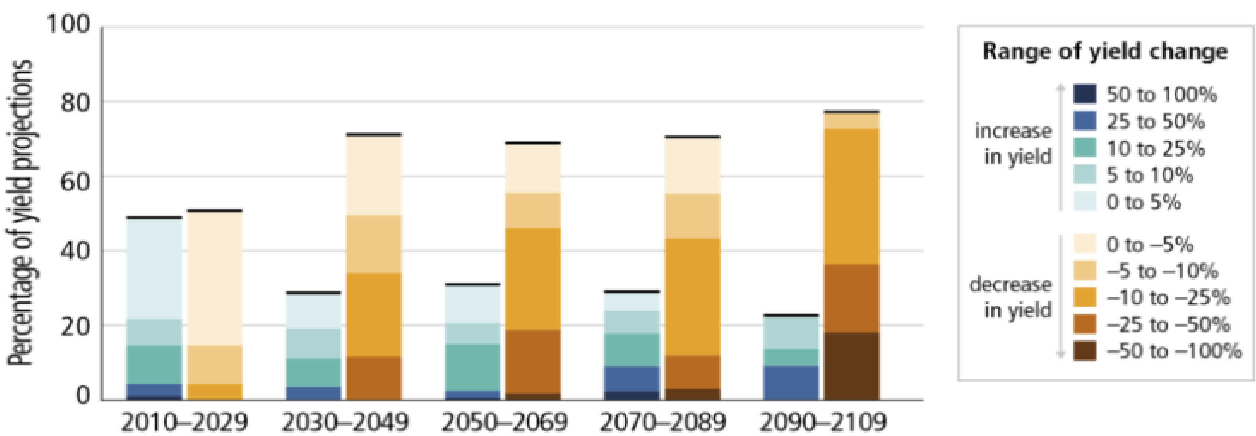

Figure 2. Predicted modifications to crop yields over the 21st century

Future food insecurity is anticipated to be substantially aggravated by climate change, rising inflationary pressure, and declining food production. Food may become more unaffordable due to rising resource inflation caused by efforts to counteract global climate change. Due to increased agricultural water demand and droughts, the water required for agricultural output may become more constrained. Agricultural biotechnology may be an essential tool for addressing the causes and effects of climate change and achieving significant socioeconomic goals, such as reducing hunger, boosting international food security, and decreasing agriculture's ecological impacts (Agriculture). Products created with Argo technology, including vegetative propagation that creates renewable bioenergy, vegetables and fruits with extended shelf life, and goods that prevent food waste, may help lower carbon dioxide emissions. Using agricultural engineering, farmers of livestock and plants could produce livestock and plants resistant to natural pressures, such as drought, heatwaves, new diseases, and other obstacles. The bulk of firms and an entire stage of industrial prosperity are impacted by a techno-economic framework, which comprises massive constellations of interwoven technology and economic developments (Andrew, 2019). Biotechnology has provided manufacturers with a variety of cost-cutting and efficiency-enhancing solutions. Some biotechnology cultivars, for instance, can be modified to resist specific insecticides, simplifying and improving integrated pest management's efficacy. Biotechnology developments may provide humans with foods that are more nutritious, more resistant to spoilage or include trace amounts of naturally occurring toxins in some fruits and vegetables (Agriculture).

In addition to global temperature and weather events, substantial changes in precipitation patterns are projected due to predicted climatic transitions. Upcoming shortages are likely to affect some regions more regularly. In contrast, severe rainstorms and more intense flash floods are forecast for some regions. To boost the agriculture sector's capacity to adapt to a changing environment, policymakers must employ many flexible policies. Additionally, producers must select improved designs and approaches. Assume the administration and farmers can effectively adapt. In this instance, the agricultural industry may be able to survive temperature and precipitation changes and may even gain from climate change. Using existing technologies and strategies, such as altering crop patterns, might not necessitate substantial additional investments. Costlier adaptation strategies will typically provide more significant benefits (Karimi et al., 2018). Suppose producers have access to biotechnology solutions that mitigate the negative effects of climate change. In that case, there is great potential for conserving agricultural and food products from potential detrimental effects and expanding agriculturally productive areas into currently unsuitable locations. Farmers are likely to rapidly embrace these production-sustaining or increasing technology, especially in places where temperature, dryness, or saltwater have been acting against them over several years. Implementing agricultural biotechnology can significantly increase food chains' resilience while aiding in climate change mitigation and adaptation. The United States is a leader in agricultural research and development to improve efficiency and stimulate the use of environmental assets in agribusiness. Farmers confront a severe economic challenge due to a decline in output. They currently struggle to compete with industrialized countries where subsidies have unfairly cut the cost of agricultural products (Forum, 2019).

1.1 Problem statement and Rationale

The sustainability of the environment is increasingly threatened by climate change. The predicted effects of climate change could threaten agriculture's ability to feed the world and significantly delay attempts to alleviate hunger, malnutrition, and poverty. Immediate action is essential for agricultural production to be prepared for constantly fluctuating environmental circumstances (Nations). Any weather patterns that interrupt food supply and transit, whether locally or globally, may have a significant impact on food availability, quality, and safety. In rising economies, there are minimal opportunities for flexibility, such as altering livestock or agricultural practices or enhancing irrigation. Agriculture is a prominent business for climate change impacts due to the direct influence of global warming on agriculture and the enormous ramifications for societal well-being and food production. Due to population growth and economic expansion across the bulk of the emerging world, the demand for agricultural commodities and food has reached unimaginable heights. Despite more significant efforts to eliminate hunger and raise agricultural production, several low-income nations, particularly those in sub-Saharan Africa and South Asia, will struggle to ensure that everyone has access to sufficient food. These regions practice agriculture and are not technologically or economically developed enough to minimize the negative effects of climate change.

Additionally, there is little room for personalization. Their reliance on agriculture for a living is detrimental to the inhabitants of these nations. Climate change is a phenomenon that has negative effects on abiotic and biotic components as well as food security. No comprehensive bibliometric study has been performed on it. This study is a bibliometric analysis of the previous ten years.

Although climate change is acknowledged as a global phenomenon, its consequences are felt most strongly in developed markets due to their higher vulnerability and limited ability to mitigate its effects (Ali et al., 2017). The agricultural productivity in food-insecure regions is threatened by climate change, notably in Asian nations. Various weather patterns, including drought, rising temperatures, unpredictable and intense precipitation patterns, thunderstorms, flooding, and an increase in predatory insects, have significantly impacted farmers' way of life (Habib-ur-Rahman et al., 2022). Climate change harms the evaluation criteria of wheat plants, specifically their total protein, sugar, and carbohydrate contents. Wheat grains express less protein due to increased temperature and carbon dioxide levels, which stimulate the expression of development characteristics but inhibit protein expression.

This study examines the relationship between climate change and numerous agricultural aspects, given the preceding characteristics. To address the interrelated concerns of sustainable construction, ensuring agricultural production, and combatting climate change, agriculture production infrastructures and food networks must be modified as described below. Increased capacity utilization is required to improve and safeguard food production throughout time and significantly contribute to avoiding global warming. Finding effective methods to encourage individuals to utilize weather pattern substitutes is a fundamental objective. In many nations, agricultural legislation and financial aid for local livelihoods are tightly intertwined. There are many chances for low-income nations to direct output in more effective and long-lasting ways. Focusing on a detailed meta-analysis, this study began with a comprehensive review of the agricultural literature on the effects of climate change on agricultural production. Using bibliometric analysis of the dataset, the current study findings are aggregated to a global level.

1.2 AIMS AND OBJECTIVES

This review's primary objective is to provide a bibliometric analysis of research conducted over the previous decade on the effects of climate change on plants. For this reason, teams specializing in biotic, abiotic, agricultural, and food security have focused on the review. In addition to offering a bibliometric summary, an overview of the publications' conclusions is also provided.

1.3 RESEARCH SIGNIFICANCE

Agriculture farmers in emerging nations who are vulnerable to food insecurity due to global warming and who have little finances, few government initiatives, and few institutional resources can be assisted by the current study in adapting to change. It is necessary to intervene to assist those farmers who have contributed the least to climate change but are the most hit by it and to allow rising economies to improve agricultural productivity and stimulate their economies. Climate-smart agribusiness provides a model for efficiently applying rules, sufficient organizations, and government performance to execute climate-sensitive planning applications. In addition, the approach can focus new money on research organizations' capital investments and assist farmers in overcoming challenges such as up-front costs and temporary revenue losses that prohibit them from implementing climate-smart farming practices. All of these climate disturbances could substantially impact the geographical distribution of food, as well as its availability and quality. In addition, this would raise ethical concerns due to the direct relationship between food supply and world health, resulting in a downward spiral of poverty, disease, and crime. This study focuses on upcoming challenges and mitigating strategies to alleviate the consequences of climate change and ensure agricultural output for humans and other life forms.

Agriculture and climate science are intricately related. The high rate of climate change will have a considerable impact on agribusiness and its output. The increasing annual temperature may impair crop productivity. In conjunction with meteorological and economic systems, crop development projections are useful for projecting the effects of global warming and building policy frameworks. In response to the negative impacts of climate change, it may achieve sustained output within weather patterns and vital agriculture by using mitigation and adaptation methods. Due to its complex structure and interconnections, agribusiness will remain obscure in a global period where the state's agricultural production faces considerable danger. In light of this, the current study will assess the negative consequences of climate change on the agriculture industry and develop mitigation and adaptation strategies.

1.4 STRUCTURE OF REVIEW

This research will be organized with an introduction, an abstract of the thesis, and seven primary sections for the paper's body

1.5 RESEARCH METHOD

This study's primary objective was to examine prior literature discussing climate change and its effect on enzymatic and microbiological activity. In addition, it examines the impact of climate change on agricultural aspects. Bibliometric analysis was undertaken for this aim, followed by research by Malhi et al. (2021) and Kogo et al. (2001). According to Donthu et al. (2021), bibliometric analysis is a scientific and sophisticated way to understand information science and library disciplines comprehensively. Bibliometrics combines the statistical methods used to assess articles, books, and other publications within the framework of scientific content. It is a quantitative way of analyzing and citing content. This method is beneficial for predicting the future trends of fields. A bibliometric evaluation was conducted for this study in the context of climate change and its impact on agricultural aspects. To achieve this, VOSviewer software was utilized. This evaluation consisted of four significant steps (figure 1), which included:

- Step 1: Data collection
- Step 2: Data analysis
- Step 3: Data visualization
- Step 4: Interpretation

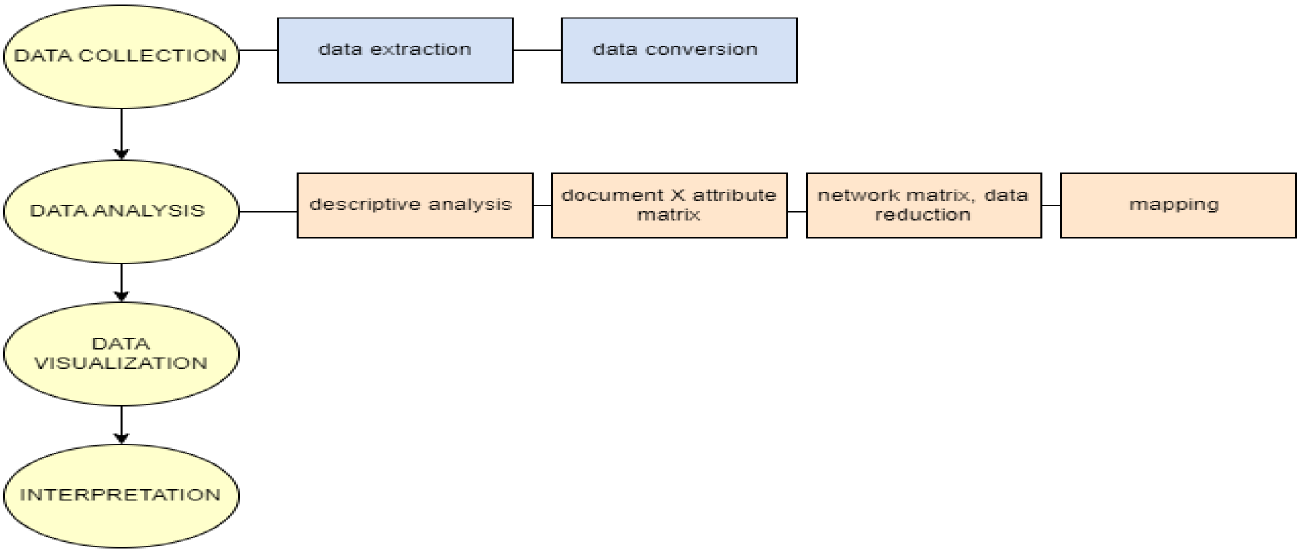

Figure 3. Research Methodology

This study's primary objective was searching online for reputable journals. The primary focus of these publications is on climate change and agriculture. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria were used to review the prior literature. According to the PRISMA standards, no meta-analysis strategies were considered. The journals linked with climate change and agriculture were searched on Google Scholar. This investigation was done between 2013 and 2022. investigation, a final sample of 29 journal articles was chosen. Four essential steps were included in this process: (a) identification (in this step, online databases were

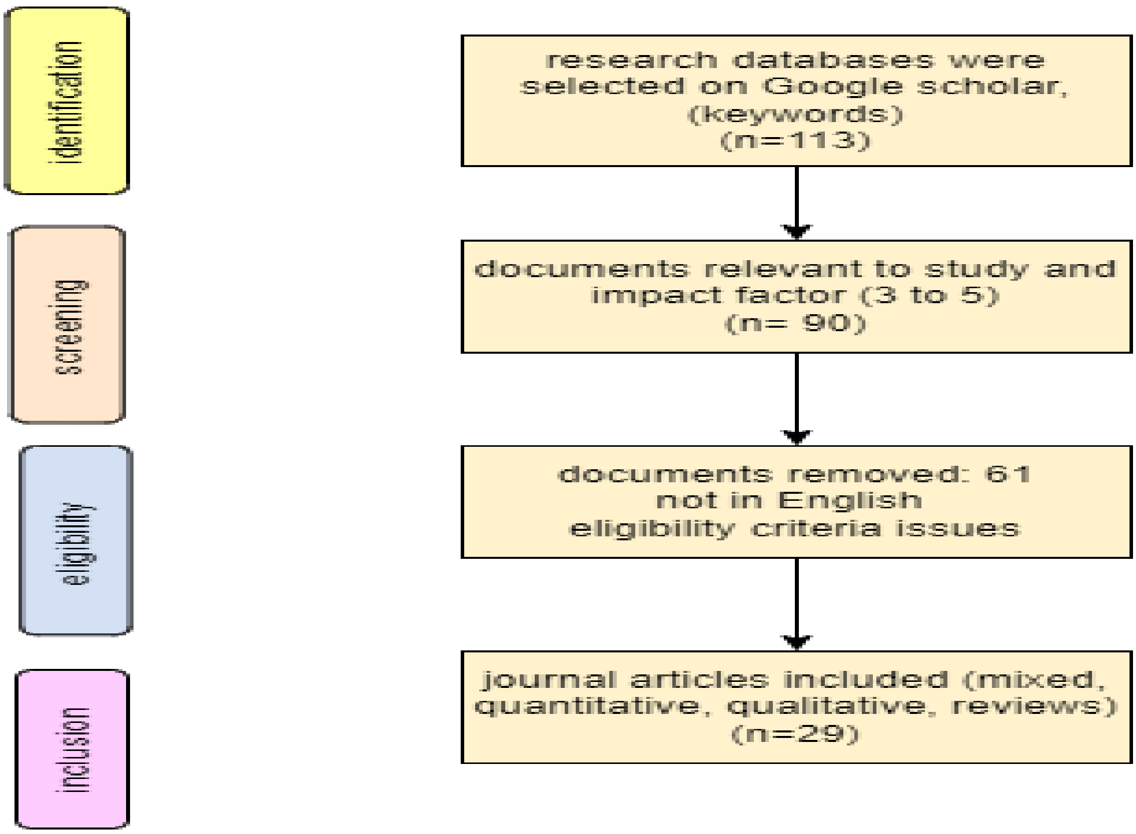

Figure 4. PRISMA Diagram

The acquired data was appropriately examined according to the suggested selection criteria based on the proposed keyword list and other relevant parameters. For this searched on Google Scholar using the formulated keyword list); (b) screening (in this step, the documents from journals with an impact factor of 3 to 5 that focused on agriculture and climate change were separated from the rest of the irrelevant documents); and (c) eligibility (in this step, the irrelevant documents and documents that were not in English were eliminated) (in this step, the final list of included journal articles for the present study were presented for further analysis). Consequently, the PRISMA diagram for this study is shown in Figure 2.

1.6 Keywords

An adequate and effective search criterion was established for the present study to collect the required data. The results from prior studies, such as (Parajuli et al., 2019) and (Tang, 2019), conducted in the context of climate change and agriculture, were focused on formulating effective search criteria for the current study. For this purpose, a list of keywords focusing on climate change and agriculture was formulated. These keywords included: "Agriculture;" "Climate Change;" "Mitigation Strategies;" "Climate-Smart Agriculture Technologies;" "Economic Impact;" "Causes;" "Social Impact;" "Diseases;" "Pests;" "Weeds;" "Global Warming;" "Carbon Dioxide Emissions;" "Green Gases;" "Health-related Issues;" "Enzymatic Activities;" "Microbial Population" and other related keywords.

1.7 Selection of Online Databases

In the context of bibliometric analysis, selecting online resources is vital for gathering the necessary data. The bibliometric dataset is typically extensive, highlighting the importance of utilizing excellent and suitable online database sources. Based on earlier research undertaken in agriculture and climate change, two critical online databases were chosen for the present study. Scopus and WoS were these online resources. According to the issue under discussion, only a small number of documents were gathered from these databases, stressing the selection of additional online databases for this purpose. Thus, Google Scholar was the primary source for identifying other online databases to obtain the necessary data on climate change, agriculture, and other related topics. Thus, IEEE, Wiley Online, Science Direct, Francis and Taylor, Springer, Mdpi, Elsevier, and Frontiers were selected as additional online databases for this investigation.

1.8 Data Collection Route

An efficient data collection approach was adopted to acquire the necessary bibliometric data for this investigation. The recommended search criteria for this study were rigorously evaluated for this aim. The following actions were taken to acquire the essential data:

• Initially, the selected keywords for the present study were entered into the Google Scholar search engine, and approximately 113 relevant documents were retrieved. We organized the collected documents according to their sources and chose the materials published in the selected internet databases for this study. We acquired 90 documents as a result of this procedure. These materials comprised journal articles, conference papers, book chapters, and other publications.

• For this analysis, we collected only journal publications from 2013 to 2022 that focused on climate change and agricultural aspects. Therefore, we compiled all papers into an Excel spreadsheet and divided the journal articles pertinent to the designated period. There were 60 selected articles in all.

• We then concentrated on the language of the chosen Journal articles. According to the selection criteria for the present study, all selected papers and publications must be written in English. In the framework of the present research project, a final sample of 29 journal articles was chosen for bibliometric analysis following rigorous evaluation. There were no journal papers published before 2013 in this sample.

1.9 Data Analysis

There has been a steady increase in technological advancement over the years, which has led to the creation of numerous sophisticated and efficient bibliometric analysis software programs. "VOSvewer" and "Bibliometrix package of R software" are two of the most prevalent bibliometric analytic tools and approaches (Moral-Muoz et al., 2020). Inspired by previous research (Malhi et al., 2021), we employed VOSviewer to conduct bibliometric analysis within the framework of the present research study. VOSviewer efficiently manages more extensive networks and provides adequate text-mining functionality. VOSviewer is utilized in various study fields, including business, construction, library, and agriculture. This explains its usefulness for the current bibliometric study. Therefore, VOSviewer was employed to conduct a bibliometric analysis for this study. However, five significant characteristics were considered when analyzing this study's collected publications and papers. Countries, keywords, scientific journals, citations, and authors were among these criteria. These criteria facilitate a better grasp of the current situation of the connected topic. According to Donthu et al. (2021), the most critical bibliometric metrics are average citations, documents, average normalized citations, citations, and publication year on average. In this aspect, the more significant the score, the greater the influence.

Table 1: Main Information about the Data

Time horizon	2013-2022
Total documents	29
Authors	143
Total Keywords	103
Keywords Focused	Climate Change, Agriculture, Plants, Microbes, Pests, Floods, Drought, etc.

2. RESULTS

This review spans the years 2013 to 2022 and contains twenty-nine articles. According to an analysis of these documents, 143 authors and 103 keywords were included in this data collection. The VosViewer word frequency analysis indicated that the six most often used terms were food security, drought, climate change, impact, weight, and agriculture. According to the review team, climate change was the most frequent term in the keywords and titles of the reviewed papers. The table below displays the number of occurrences and related VosViewer ratings for each of the terms, whereas figure five depicts a network diagram for these terms.

Table 2: Key Word Frequency (VosViewer)

Terms	Occurrence	Relevance Score (VosViewer)
Drought	4	2.74
Food Security	3	1.07
Climate Change	22	1.04
Impact	8	0.54
Weed	5	0.46
Agriculture	3	0.15

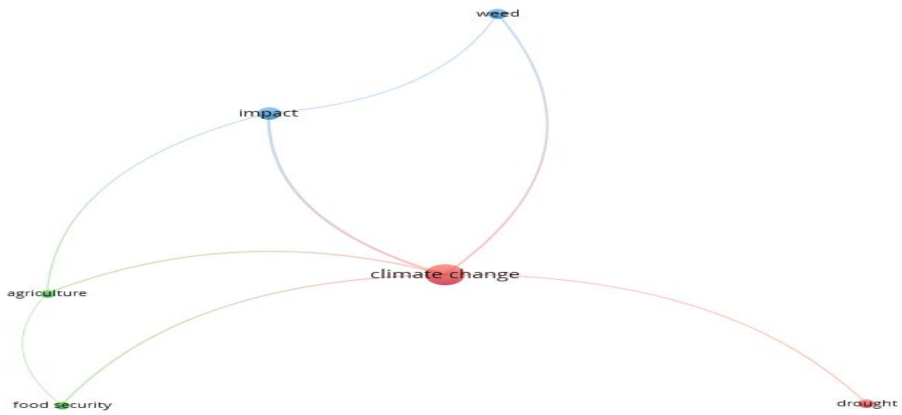

Figure 5: Network Diagram of Keywords

The following analysis performed on the sampled papers was of authorship. The smallest number of authors in the sampled publications was one, and the maximum was ten, as shown in Table 3. Only one paper had one author, five papers had two authors, six papers had three, four papers had four authors, three papers had five authors, one paper had six writers, and three papers each had seven, eight, and ten authors.

Table 3: Number of Authors Per Paper

Number of Authors	Number of Papers	Percentage
1 Author	1	3.5
2 Authors	5	17.3
3 Authors	6	20.7
4 Authors	4	13.8
5 Authors	3	10.3
6 Authors	1	3.5
7 Authors	3	10.3
8 Authors	3	10.3
9 Authors	0	0
10 Authors	3	10.3
Total	29	100

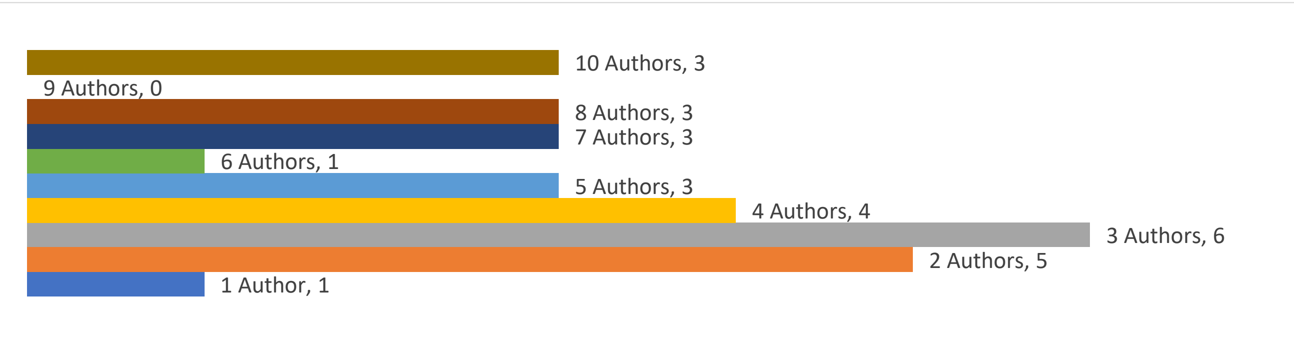

Figure 6: Author Frequency

Additionally, VosVeiwer was utilized to examine the co-occurrence of authors. 18 authors were discovered to be associated; nevertheless, they did not form a single cluster but rather three clusters. These clusters are exhibited in Figures 7/8 and 9. The first cluster is the largest, containing ten interconnected writers through the publications sampled for this review. Similarly, the other two clusters had three and five authors, respectively.

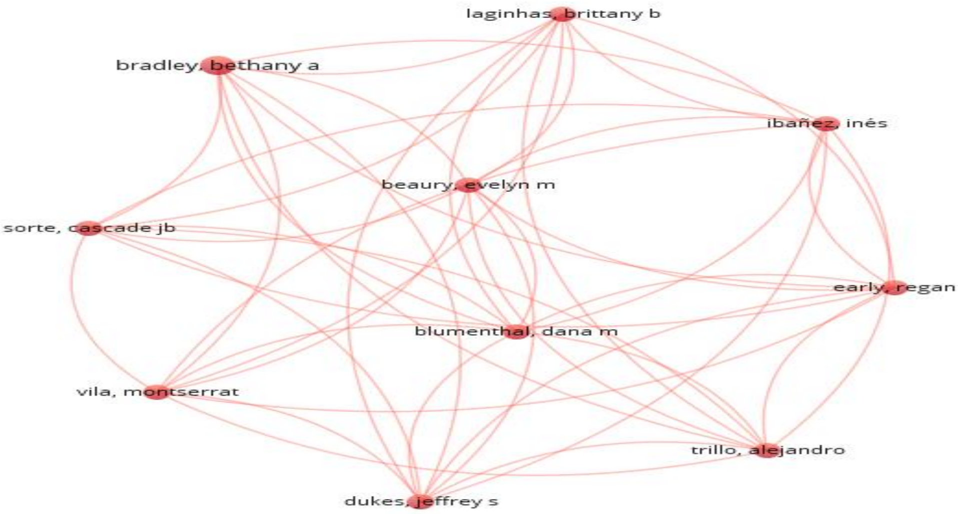

Figure 7: Author Cluster 1

Figure 8: Author Cluster 2

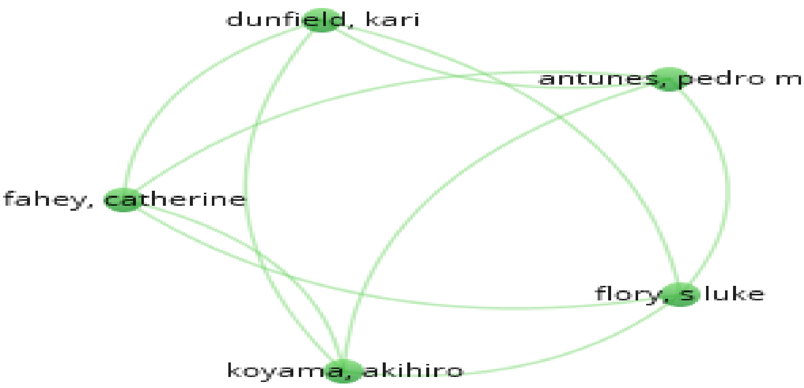

Figure 9: Author Cluster 3

In this review, a range of articles from various periodicals was analyzed. However, all journals were peer-reviewed and indexed on the Web of Science. Table 4 displays the list of included periodicals and the number of publications extracted from each journal.

Table 4: Journal Distribution

Journal	# of Papers
Current opinion in insect science	1
Current Opinion in Plant Biology	1
Ecosphere	1
Environmental Research Letters	1
Environmental Sustainability	1
Environments	1
Frontiers in plant science	1
Insects	1
International Journal of Climate Change Strategies and Management	1
International Journal of Clinical and Biological Sciences	1
Journal of Ecology	1
Journal of Experimental Botany	1
Microbiology and Molecular Biology Reviews	1
Perspectives in Ecology and Conservation	1
PLoS One	1
Scientific reports	1
Soil & Plant Science	1
Sustainability	1
The ISME journal	1
Advances in agronomy	2
Agronomy	2
Current Climate Change Reports	2
Nature	2
Regional Environmental Change	2

The distribution by year was also investigated. The majority of the 29 publications included in this study were published in 2020 (7) and 2021, according to this analysis (5). This demonstrates that contemporary research is concentrating more and more on how climate change has affected the local plant biodiversity. Figure 10 also illustrates the year-by-year distribution of the publications included in the review.

Table 5: Year-Wise Distribution of Papers

Year	Number of Papers	Percentage of Papers
2013	1	3.5
2014	0	0
2015	2	6.9
2016	4	13.8
2017	3	10.3
2018	3	10.3
2019	4	13.8
2020	7	24.1
2021	5	17.3
2022	0	0
Total	29	100

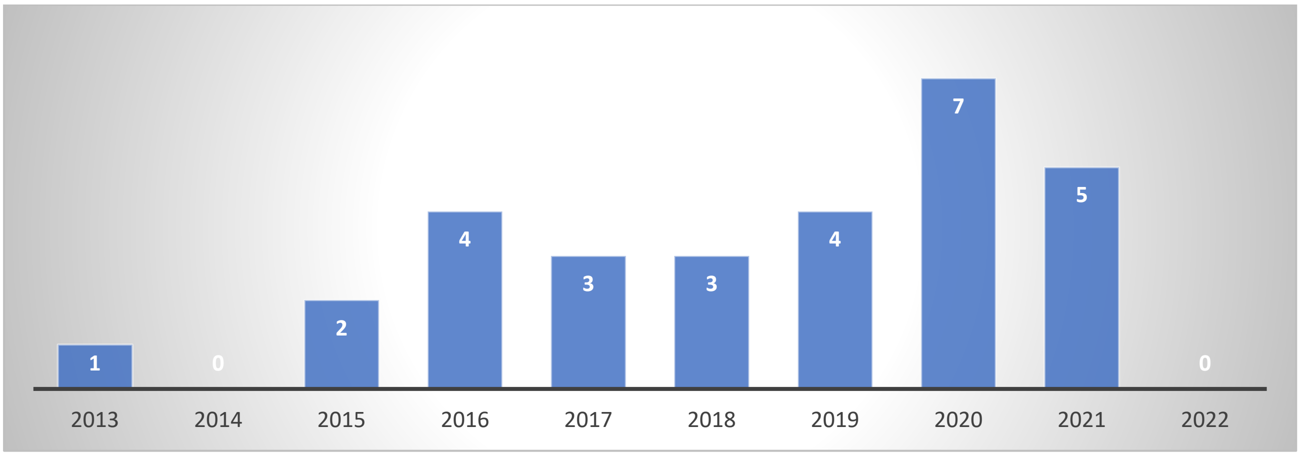

Figure 10: Yearly Distribution

The researcher has also studied journal distribution by year to enhance the results. Only one journal from 2013 was included. Two journals from 2015, four from 2016, three from 2017, two from 2018, four from 2019, six from 2020, and five from 2021 were included. The journals listed in Table 6 are as follows.

Table 6: Year-Wise Journal Distribution

Year	Journals	Total
2013	Journal of Ecology	1
2015	Ecosphere Nature	2
2016	Advances in agronomy Regional Environmental Change International Journal of Clinical and Biological Sciences Current Opinion in Plant Biology	4
2017	Microbiology and Molecular Biology Reviews PLoS One Frontiers in plant science	3
2018	Current Climate Change Reports Agronomy	2
2019	Environments Scientific reports Soil & Plant Science Environmental Sustainability	4
2020	Current opinion in insect science Regional Environmental Change, Agronomy Journal of Experimental Botany The ISME journal International Journal of Climate Change Strategies and Management Nature	6
2021	Perspectives in Ecology and Conservation Insects Sustainability Agronomy Environmental Research Letters	5

The papers included in this review were also evaluated based on their approach. Most of the included publications were either qualitative reviews or idea papers. 18 studies were qualitative reviews, 2 were concept papers, and 2 were reviews based on a meta-analysis. In addition, five of the included studies employed experimental tactics leading to quantitative statistical analysis, one used a practical strategy leading to an analysis based on structural equation modeling, and one used a quantitative technique based on statistical analysis and regression.

Table 7: Methodological Distribution

Methodology Type	Number of Papers	Percentage
Concept Paper	2	6.9
Review (Qualitative)	18	62.1
Quantitative (Experimental and Statistical Analysis)	5	17.2
Quantitative (Statistical and Regression)	1	3.5
Quantitative (Experimental and SEM)	1	3.5
Meta-analysis Review	2	6.8

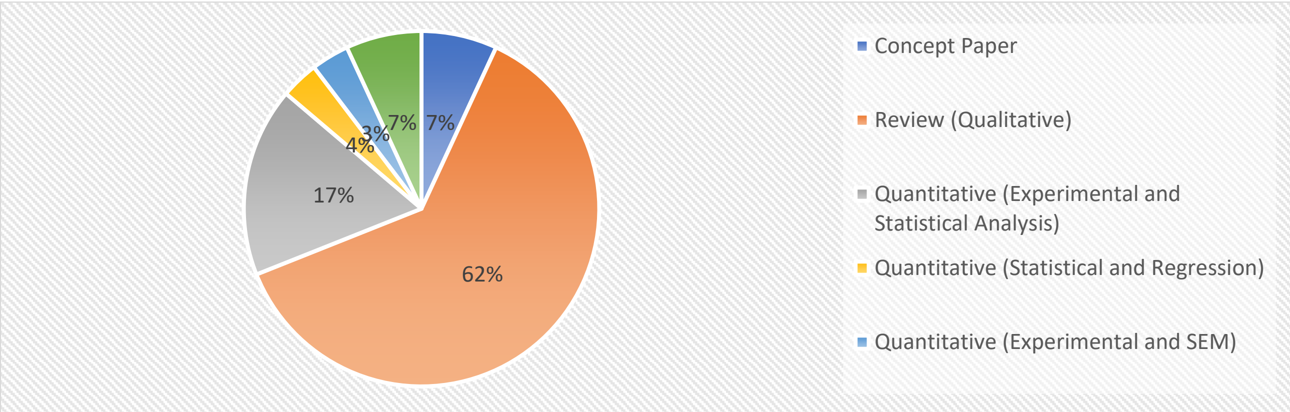

Figure 11: Method-Type Percentage

As for the topics mentioned in the articles, the examined research was divided into three sections: abiotic factors influencing plants due to climate change, biotic factors impacting plants due to climate change, and publications pertaining to agriculture and food security. The biotic aspects were subdivided into pollinators, soil interaction and microorganisms, pests, and weed control. In addition, the evaluated abiotic stressors included drought, flooding, and heat stress. Table 8 displays the categorization of the reviewed studies.

Table 8: Thematic Classification

Biotic Factors	Pollinators	(Giannini et al., 2020) (Giannini et al., 2017) (Gómez-Ruiz & Lacher Jr, 2019) (Gonzalez et al., 2021) (Marshman et al., 2019)
	Soil interactions and Microbes	(Classen et al., 2015) (Lladó et al., 2017) (Jansson et al., 2020) (Bardgett et al., 2013) (Fahey et al., 2020)
	Pests	(Skendžić et al., 2021) (War, Taggar, War, & Hussain, 2016) (Ziska et al., 2018)
	Weeds Management	(Clements & Jones, 2021) (Ramesh et al., 2017; Sun et al., 2020; Vila et al., 2021)
Abiotic Factor	Drought	(Berg et al., 2018; Fahey et al., 2020; Mukherjee et al., 2018)
	Heat Stress	(Ihsan et al., 2019; Janni et al., 2020)
	Floods and Salinity	(Kaur et al., 2020; Loreti, van Veen, & Perata, 2016; Wright et al., 2015)
Agriculture and Food Security		(Arora, 2019; Chandio et al., 2020; Connolly-Boutin et al., 2016; Jat et al., 2016; Malhi et al., 2021)

3. FINDINGS

In recent years, the constant rise in global warming has significantly impacted agriculture, resulting in food insecurity. This has prompted numerous previous research to examine the effects of climate change on agricultural sustainability and food security. This study examines previous research to understand the relationship between the agriculture sector and climate change. Therefore, thirty articles and papers published between 2013 and 2022 in the context of climate change and the agriculture sector were included in the bibliometric analysis of the current research study. As a result of this analysis, three critical themes were formulated for the present study: (a) climate change impacts on biotic factors relating to plants (it is further classified into different sub-themes including drought, flooding, and heat stress); (b) climate change impacts on abiotic factors relating to plants (it is further classified into different sub-themes including pollinators, soil beneficial plant microbes, and climate change effects on insects); and (c) climate change impacts on biotic factors relating to plants

3.1 Climate Change Impacts Biotic Factors Relating to Plants

This research demonstrated that climate change affects biotic elements in agriculture, including plants, bacteria, fungi, and animals. This theme is subdivided into four subthemes: pollinators, soil-beneficial plant microorganisms, and the effects of climate change on insect pests and weeds. According to Giannini et al. (2020) and Gómez-Ruizet al. (2019), natural crop pollinators include small insects such as bees, butterflies, etc. These insects have been vital to the pollination process for centuries. However, climate change has disrupted the equilibrium between these insects' native habitats and their performance (Giannini et al., 2017). Due to accelerated climate change, it has become increasingly difficult for these insects to withstand the environmental stress that negatively affects their overall effectiveness (Gonzalez et al., 2021). In recent years, as a result, synthetic pollinators have replaced these natural pollinators, also contributing to excessive climate change (Marshman et al., 2019).

Both Classen et al. (2015) and Lladó et al. (2017) emphasized the importance of beneficial soil bacteria to the ecosystem. It has been discovered that many forest-soil microorganisms, including specific bacteria and fungi, have always been effective in boosting micronutrients necessary for many agricultural results. Numerous academics and researchers have also pushed for the importance of beneficial soil bacteria in soil fertility. Nonetheless, Jansson et al. (2020) and Bardgett et al. (2013) found that climate change harms these bacteria, reducing the overall fertility of the soil and resulting in bad agricultural outcomes. Therefore, many sustainable measures are required to ensure the contribution of soil microorganisms to soil fertility (Fahey et al., 2020). According to Skendi et al. (2021), in addition to drought, floods, and other natural hazards, climate change has resulted in insect pests that have harmed the overall performance of the ecosystem, leading to unfavorable agricultural outcomes. War et al. (2016) and Ziska et al. (2018) found that climate change has harmed plant pest interactions, chemical ecology, and phytophagous insects, resulting in food insecurity. Therefore, climate change has contributed to national and worldwide food insecurity, prompting numerous governments and politicians to take significant action. According to Clements et al. (2021) and Ramesh et al. (2017), the emission of carbon dioxide and methane has affected the ecology and biology of weeds, influencing their total growth and development. Changes in the climate have affected not only the health results of living things, but also the general functioning of the agricultural system (Vila et al., 2021). However, previous work has also proposed using various mitigation and adaptation techniques in the context of complex weed interactions resulting from climate change (Sun et al., 2020).

Author and Year	Theme	Main findings
(Bardgett et al., 2013)	Biotic (Soil Microbes)	A framework is presented that highlights a need for approaching plant and soil interaction and carbon cycling strategies in response to climate change to mitigate the negative impacts of climate change.
(Classen et al., 2015)	Biotic (Soil Microbes)	This review discussed the impact of soil microbe and plant interactions of climate change on these interactions and the future research directions that can be adopted in this domain.
(Wright et al., 2015)	Abiotic (Flooding and Salinity)	Climate change-induced flooding activities were found to be associated with increased productivity of crops and decreased stability of plants.
(Connolly-Boutin & Smit, 2016)	Agriculture and Food Security	The framework presented in this paper discusses how food security and climate change can be researched in the future to make effective policies and programs for food and agricultural sustainability.
(Jat et al., 2016)	Agriculture and Food Security	This review revealed the need for short- and long-term policies for increasing the sustenance and protection of natural resources like plants and food crops to enhance overall food security and agricultural sustainability.
(Loreti et al., 2016)	Abiotic (Flooding and Salinity)	Different plants have varying salinity and flood resistance levels. Overall, there is a need to enhance the research in this domain to develop better mitigation and survival strategies.
(War et al., 2016)	Biotic (Pests)	The possible impact of climate change on various pests, chemical ecology, and interactions between plants and pests are studied in this review, which can create food insecurity.
(Giannini et al., 2017)	Biotic (Pollinators)	This study reveals municipalities where crops are economically essential and climate change can have the worst impact on pollinators. However, the study also discusses several policy decisions that can be adapted to overcome the loss of pollinator species due to climate change
(Lladó et al., 2017)	Biotic (Soil Microbes)	Bacterial ecology in forest soils is not fully understood. It needs to be evaluated in the future to understand how soil microbes can combat climate change.
(Ramesh et al., 2017)	Biotic (Weeds)	Climate change has impacted weed management and ecosystems, leading to the need for further research in the domain to understand how weeds can be managed better to preserve plants.
(Berg & Sheffield, 2018)	Abiotic (Drought)	Droughts can drastically impact the level of soil moisture levels. They can play to impacting the vegetation sustainability in a region.
(Mukherjee et al., 2018)	Abiotic (Drought)	This review indicates that the performance of drought indicators can be improved by incorporating reliable soil moisture estimations.
(Ziska et al., 2018)	Biotic (Pests)	This review presented an overview of pest biology and climate interactions.
(Arora, 2019)	Agriculture and Food Security	Climate change has led to increasing land degradation and has caused growing in desertification and the production of nutrient deficient soil.
(Gómez-Ruiz & Lacher Jr, 2019)	Biotic (Pollinators)	Pollinators are impacted by environmental changes leading to the increasing vulnerability of agave plants.
(Ihsan et al., 2019)	Abiotic (Heat Stress)	Sulpher-induced heat stress reduction strategies are increasingly used and must be further researched.
(Marshman et al., 2019)	Biotic (Pollinators)	It is found that pollinator health is an important domain to be addressed in future research, and the Bee City movement strategy is proposed
(Chandio et al., 2020)	Agriculture and Food Security	The study reveals that it is essential for policymakers to understand the impact of climate change on overall food production and food security to develop strategies.
(Fahey et al., 2020)	Biotic (Soil Microbes) Abiotic (Drought)	The study revealed that plant communities could mediate the impact of global change drivers on the community structure of soil microbes; this leads to indicate that the potential consequences of climate change on community dynamics and ecosystem functions can be mitigated through management strategies
(Giannini et al., 2020)	Biotic (Pollinators)	Climate change has impacted all the analyzed traits of pollinating bees leading to indicating that biodiversity and plant diversity is negatively affected by climate change
(Janni et al., 2020)	Abiotic (Heat Stress)	It is essential to ensure that heat stress induced by climate change is managed effectively to ensure that future generations have sustainable food chains and food security.
(Jansson & Hofmockel, 2020)	Biotic (Soil Microbes)	Climate change impacts soil microorganisms significantly, and there is a need to research strategies to mitigate these negative consequences.
(Kaur et al., 2020)	Abiotic (Flooding and Salinity)	There is a need to develop flood management and waterlogging management strategies that can help in the sustenance of crops
(Sun et al., 2020)	Biotic (Weeds)	The review discusses potential ecological and evolutionary responses to weeds to increase plant sustenance under climate change.
(Clements & Jones, 2021)	Biotic Factors (Weeds)	Invasive plant species, such as weeds, have better resistance to climate change in comparison to native plants, leading to creating a disbalance in the sustenance of weeds compared to plants.
(Gonzalez et al., 2021)	Biotic (Pollinators)	New conservation and climate adaptation strategies must be developed to help beekeepers increase bee pollinators' sustenance and enhance food sustainability through pollination activities.
(Malhi et al., 2021)	Agriculture and Food Security	It is reported in this review that various outcomes of climate change in the agricultural sector can impact the physiological and metabolic activities of plants leading to impacting the plant productivity and sustenance.
(Skendžić et al., 2021)	Biotic (Pests)	Pest management tactics and monitoring strategies must be enhanced in response to climate change as pests have become more resistant.
(Vila et al., 2021)	Biotic (Weeds)	The combined impact of climate change and weeds has negatively impacted crops' productivity regarding yield and sustenance.

3.2 Climate Change Impacts Abiotic Factors Relating to Plants

The present study shows that climate change impacts not only the biotic components in agriculture but also a variety of abiotic factors, such as water, soil, air, and light. This theme has three subthemes: drought, heat stress, and flooding. Different microbial and fungal communities have been discovered to play a critical role in an ecosystem. Berg et al. (2018) further emphasized the significance of soil moisture for the effective functioning of these communities in enhancing an ecosystem's overall performance. As demonstrated in the research of Mukherjee et al. (2018) and Fahey et al. (2018), climate change frequently influences soil moisture content, resulting in droughts that damage the overall performance of these communities and contribute to poor agricultural outcomes 2020. In addition, the climate changes brought on by the excessive production of carbon dioxide and other greenhouse gases contribute to heat stress, which hinders the overall agricultural performance of the system and causes food insecurity (Janni et al., 2020). This has stressed the promotion of various genetic engineering technologies to create plants that can withstand extreme heat stress due to ongoing climate change (Ihsan et al., 2019).

It has been noted that multiple natural disasters, such as floods and cyclones, have been exacerbated by a rise in climate change (Loreti et al., 2016). In the past decade, floods have significantly impacted most Asian nations, affecting not just their agricultural sectors but also their economic performance (Wright et al., 2015). Over the years, floods have disrupted the general infrastructure of communities, affecting the economic and social well-being of the affected people (Kaur et al., 2020).

3.3 Climate Change Impacts on Agriculture and Food Security

This research demonstrated that climate change negatively influences agricultural sustainability and food security. This viewpoint was further reinforced by Chandio et al. (2020), who stated that extensive carbon emissions relate to precipitation, land area, and energy consumption, hence fostering climate changes that negatively impact agricultural yields. Moreover, due to a sustained rise in population, governments in various nations are exerting pressure on agricultural sectors to maintain food security. According to the effects of Jat et al. (2016) and others, as the climate continues to change, a variety of food security vulnerabilities are being exacerbated, resulting in a lack of natural agricultural reserves (Connolly-Boutin et al. 2016). In addition, the increase in greenhouse gas emissions over the past two decades has damaged global food security, raising the worries of numerous professionals and academics (Arora, 2019). To overcome these challenges, numerous researchers have stressed the promotion of various mitigation measures, which could effectively encourage the development of resilient plants that can endure them. In this regard, Malhi et al. (2021) advocated using various genetic engineering techniques to facilitate the production of climate-resilient plants. Other mitigation measures in this regard are technology concentrating on water-smart practices and nutrient-smart practices. These tactics have also proven to be useful in enhancing agricultural sustainability. In the past, however, such mitigation techniques have not received much attention, so future studies can focus on them to assure food security, given the urgency.

4. CONCLUSION

Globally, climate change has become a key problem for numerous industries. However, the agricultural sector is most impacted by climate change's impact on global food security. In the past, numerous studies have examined the relationship between climate change and the agricultural industry, providing a variety of pertinent challenges. This research is primarily a review of previous studies on climate change and agricultural issues. A bibliometric study was undertaken on 29 journal articles from 2013 to 2022 that were picked from several internet databases proposed for this purpose. As a result of this analysis, three critical themes were developed: (a) climate change impacts on biotic factors relating to plants (it is further categorized into different sub-themes including drought, flooding, and heat stress); (b) climate change impacts on abiotic factors relating to plants (it is further categorized into different sub-themes including pollinators, soil beneficial plant microbes, climate change effects on insect pests and weed); and (c) climate change impacts on biotic factors relating to Thus, this study concludes that climate change has a detrimental effect on agricultural outcomes, resulting in food insecurity and other social and economic difficulties. The impact of climate change on the ecosystem is also detrimental to agricultural sustainability.

To promote agricultural sustainability, several mitigation techniques must be prioritized. Prior research has not primarily centered on adaptation and mitigation techniques that could increase agricultural sustainability. Thus, future research must concentrate on such mitigation techniques. In addition, future research in the context of genetic engineering technologies for the breeding of resilient plants would effectively mitigate the detrimental effects of climate change on agricultural sustainability.

5. CONTRIBUTIONS AND IMPLICATIONS

This research contributes to our understanding of the effects of climate change on agriculture. Even though numerous research papers in the past have focused on the relationship between climate change and agriculture, this study will effectively convey these findings in a unified manner through bibliometric analysis. This study will also concentrate on the various effects of climate change on crops. The present study's contribution to such adaption techniques may also improve the understanding of many farmers and other stakeholders regarding the significance of sustainable strategies, encouraging them to implement these strategies to enhance the overall agricultural environment. In addition, this research study will contribute to the body of knowledge on sustainable development and natural reserves. However, the present study's examination of digital technologies in the context of climate change, agriculture, and sustainability will offer new avenues for future research in this area. This will be an excellent strategy for relating digital technologies to sustainability in the agriculture industry. Almost no prior research has been conducted on the use of sustainable digital technologies in the agriculture sector to mitigate the effects of climate change; therefore, the present study will effectively contribute to this aspect of sustainable digital technologies, encouraging future researchers to focus on a variety of climate change mitigation strategies.

In addition, our research will effectively promote various practical measures to mitigate the adverse effects of climate change on agriculture. It has been observed that population growth has exerted a great deal of pressure on the agriculture industry. However, the deteriorating climate change has also impacted agriculture, prompting farmers and other involved parties to take significant measures to mitigate the detrimental effects of climate change on agriculture to secure food security for the world population. This report will effectively persuade farmers and agricultural sectors to adopt measures to mitigate global warming. This study will convince them to employ more sustainable digital technology to mitigate the effects of climate change on crops. Thus, the use of climate-resilient technology can be increased with the aid of this study, as it will encourage farmers and other relevant stakeholders to develop and execute various mitigation and adaptation measures. In this context, rural farmers' education and training will be promoted to achieve successful results. In addition, this research study will be effective in persuading various governments and policymakers to develop and implement significant agricultural policies, with a focus on the promotion of sustainable digital technologies and other related mitigation strategies in the agricultural sector, to improve food security and ensure the public's health and safety.

6. FUTURE RESEARCH WORK

This investigation was limited to the effects of climate change on agricultural elements. It has also been observed that most of the prior research evaluated in this context focused on the relationship between the agriculture industry and climate change. In contrast, accompanying mitigating strategies received minimal attention. Therefore, future studies might be conducted to close the gap in knowledge regarding mitigation techniques to lessen the impact of climate change on crops. Modern climate-smart breeding technologies, carbon-smart technologies, water-smart technologies, weather-smart technologies, nutrient-smart technologies, and knowledge-smart technologies are among these tactics. However, continuing advances in biotechnology have also spurred the development of various biotechnological strategies for plant breeding. These technologies have proven effective in the development of climate-tolerant, climate-resilient plants. Future quantitative and qualitative research can be conducted to contribute originality to future studies and knowledge of climate change mitigation and adaptation techniques in the agricultural industry.

In addition, nearly no prior research has focused on mitigation techniques that can mitigate the harmful effects of climate change on agricultural sustainability. Thus, future research can effectively examine these tactics. Future studies can concentrate on various water-smart practices, such as raised-bed planting, micro-irrigation, direct seeded rice, crop diversification, rainwater harvesting, and laser-land leveling, etc.; weather-smart practices, such as ICT-based agro-meteorological services and stress-tolerant varieties, etc.; and nutrient-smart techniques, such as leaf color charts, nutrient application, crop-residue management, The encouragement of carbon dioxide emissions is, nonetheless, one of the most significant challenges noted in the context of agricultural sustainability. In this connection, future research may examine various technologies for carbon-smart practices (including legumes, zero tillage, management of crop residue, etc.). In this regard, it is also necessary to expand the knowledge of farmers and other connected stakeholders, which can be done with various technologies encouraging knowledge-smart practices, such as agricultural extensions. This may increase capacity-building efficiency.

Future research can also focus on alternative genetic engineering technologies in addition to these mitigation techniques. In addition, the agricultural sector is implementing climate-forecasting technologies to prevent any harmful effects of climate change on crops. These solutions can also inspire future research advocating mitigation and similar technologies to enhance the agriculture sector's overall sustainability. This can effectively ensure global food security.

7. LIMITATIONS

Even while the current research study successfully examined the effects of climate change on several aspects of agriculture, it also has some flaws that can be addressed in future research. This study's assessment of a minimal number of journal papers from several internet databases is one of its drawbacks. Due to researcher bias, this study was also restricted to the association between climate change and agricultural parameters. In this context, the mitigation techniques received little attention. Due to ease of availability, there was also a short window for selecting articles (from 2013 to 2022). Thus, future research can address these limitations. Future research may contain numerous journal articles within the context of the topic at hand. In this sense, future research must incorporate additional conference papers and journal articles for a more comprehensive approach. Consequently, in future research, mitigation techniques in the context of climate change and agricultural sustainability can also lead to more effective outcomes. Therefore, 20 to 30 years can be chosen to collect the necessary data for future investigations.

References

Administration, N. O. a. A. (2021). Climate change impacts. Retrieved from https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts

Agency, U. S. E. P. Climate Impacts on Agriculture and Food Supply. Retrieved from https://climatechange.chicago.gov/climate-impacts/climate-impacts-agriculture-and-food-supply#ref3

Agriculture, U. S. D. O. Biotechnology and Climate Change. Retrieved from https://www.usda.gov/topics/biotechnology/climate

Agriculture, U. S. D. O. Biotechnology Frequently Asked Questions (FAQs). Retrieved from https://www.usda.gov/topics/biotechnology/biotechnology-frequently-asked-questions-faqs

Ahima, R. S. (2020). Global warming threatens human thermoregulation and survival. *The Journal of Clinical Investigation*, 130(2), 559-561. doi: https://doi.org/10.1172/JCI135006

Ali, S., Liu, Y., Ishaq, M., Shah, T., Abdullah, Ilyas, A., & Din, I. U. (2017). Climate Change and Its Impact on the Yield of Major Food Crops: Evidence from Pakistan. *Foods*, 6(6), 39. Retrieved from https://www.mdpi.com/2304-8158/6/6/39

Andrew, T. (2019). Biotechnology as a new techno-economic paradigm that will help drive the world economy and mitigate climate change. *Research Policy*, 48(4), 858-868. doi: https://doi.org/10.1016/j.respol.2018.10.001

Arora, N. K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *Environmental Sustainability*, 2(2), 95-96. doi: https://doi.org/10.1007/s42398-019-00078-w

Bank, T. W. (2021). Climate-Smart Agriculture. Retrieved from https://www.worldbank.org/en/topic/climate-smart-agriculture

Bardgett, R. D., Manning, P., Morriën, E., & De Vries, F. T. (2013). Hierarchical responses of plant–soil interactions to climate change: consequences for the global carbon cycle. *Journal of Ecology*, 101(2), 334-343. doi: https://doi.org/10.1111/1365-2745.12043

Berg, A., & Sheffield, J. (2018). Climate change and drought: the soil moisture perspective. *Current Climate Change Reports*, 4(2), 180-191. doi: https://doi.org/10.1007/s40641-018-0095-0

Brando, P., Macedo, M., Silvério, D., Rattis, L., Paolucci, L., Alencar, A., . . . Amorim, C. (2020). Amazon wildfires: Scenes from a foreseeable disaster. *Flora*, 268, 151609. doi: https://doi.org/10.1016/j.flora.2020.151609

Chandio, A. A., Jiang, Y., Rehman, A., & Rauf, A. (2020). Short and long-run impacts of climate change on agriculture: empirical evidence from China. *International Journal of Climate Change Strategies and Management*, 12(2), 201-221. doi: https://doi.org/10.1108/IJCCSM-05-2019-0026

Change.Gov, G. Impacts on Society. Retrieved from https://www.globalchange.gov/climate-change/impacts-society

Classen, A. T., Sundqvist, M. K., Henning, J. A., Newman, G. S., Moore, J. A., Cregger, M. A., . . . Patterson, C. M. (2015). Direct and indirect effects of climate change on soil microbial and soil microbial-plant interactions: What lies ahead? *Ecosphere*, 6(8), 1-21. doi: https://doi.org/10.1890/ES15-00217.1

Clements, D. R., & Jones, V. L. (2021). Rapid evolution of invasive weeds under climate change: present evidence and future research needs. *Frontiers in Agronomy*, 3, 664034. doi: https://doi.org/10.3389/fagro.2021.664034

Connolly-Boutin, L., & Smit, B. (2016). Climate change, food security, and livelihoods in sub-Saharan Africa. *Regional Environmental Change*, 16(2), 385-399. doi: https://doi.org/10.1007/s10113-015-0761-x

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285-296. doi: https://doi.org/10.1016/j.jbusres.2021.04.070

Fahey, C., Koyama, A., Antunes, P. M., Dunfield, K., & Flory, S. L. (2020). Plant communities mediate the interactive effects of invasion and drought on soil microbial communities. *The ISME Journal*, 14(6), 1396-1409. doi: https://doi.org/10.1038/s41396-020-0614-6

Forum, W. E. (2019). AGRICULTURE, FOOD AND BEVERAGE. Retrieved from https://www.weforum.org/agenda/2019/09/here-s-how-we-can-use-agriculture-to-fight-climate

Giannini, T. C., Costa, W. F., Borges, R. C., Miranda, L., da Costa, C. P. W., Saraiva, A. M., & Imperatriz Fonseca, V. L. (2020). Climate change in the Eastern Amazon: crop-pollinator and occurrence-restricted bees are potentially more affected. *Regional Environmental Change*, 20(1), 1-12. doi: https://doi.org/10.1007/s10113-020-01611-y

Giannini, T. C., Costa, W. F., Cordeiro, G. D., Imperatriz-Fonseca, V. L., Saraiva, A. M., Biesmeijer, J., & Garibaldi, L. A. (2017). Projected climate change threatens pollinators and crop production in Brazil. *PLoS One*, 12(8), e0182274. doi: https://doi.org/10.1371/journal.pone.0182274

Gómez-Ruiz, E. P., & Lacher Jr, T. E. (2019). Climate change, range shifts, and the disruption of a pollinator-plant complex. *Scientific Reports*, 9(1), 1-10. doi: https://doi.org/10.1038/s41598-019-50059-6

Gonzalez, V. H., Cobos, M. E., Jaramillo, J., & Ospina, R. (2021). Climate change will reduce the potential distribution ranges of Colombia's most valuable pollinators. *Perspectives in Ecology and*

Conservation, 19(2), 195-206. doi: https://doi.org/10.1016/j.pecon.2021.02.010

Habib-ur-Rahman, M., Ahmad, A., Raza, A., Hasnain, M. U., Alharby, H. F., Alzahrani, Y. M., . . . EL Sabagh, A. (2022). Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. *Frontiers in Plant Science*, 13. doi: https://doi.org/10.3389/fpls.2022.925548

Heshmati, H. M. (2022). Impact of Climate Change on Life. In Environmental Issues and Sustainable Development. Retrieved from https://books.google.ae/books?hl

Hsiang, S., & Kopp, R. E. (2018). An economist's guide to climate change science. *Journal of Economic Perspectives*, 32(4), 3-32. doi: https://doi.org/10.1257/jep.32.4.3

Ihsan, M. Z., Daur, I., Alghabari, F., Alzamanan, S., Rizwan, S., Ahmad, M., . . . Shafqat, W. (2019). Heat stress and plant development: role of sulphur metabolites and management strategies. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, 69(4), 332-342. doi: https://doi.org/10.1080/09064710.2019.1569715

Janni, M., Gullì, M., Maestri, E., Marmiroli, M., Valliyodan, B., Nguyen, H. T., & Marmiroli, N. (2020). Molecular and genetic bases of heat stress responses in crop plants and breeding for increased resilience and productivity. *Journal of Experimental Botany*, 71(13), 3780-3802. doi: https://doi.org/10.1093/jxb/eraa034

Jansson, J. K., & Hofmockel, K. S. (2020). Soil microbiomes and climate change. *Nature Reviews Microbiology*, 18(1), 35-46. doi: https://doi.org/10.1038/s41579-019-0265-7

Jat, M. L., Dagar, J. C., Sapkota, T. B., Govaerts, B., Ridaura, S., Saharawat, Y. S., . . . Hobbs, H. (2016). Climate change and agriculture: adaptation strategies and mitigation opportunities for food security in South Asia and Latin America. *Advances in Agronomy*, 137, 127-235. doi: https://doi.org/10.1016/bs.agron.2015.12.005

Karimi, V., Karami, E., & Keshavarz, M. (2018). Climate change and agriculture: Impacts and adaptive responses in Iran. *Journal of Integrative Agriculture*, 17(1), 1-15. doi: https://doi.org/10.1016/S2095-3119(17)61794-5

Kaur, G., Singh, G., Motavalli, P. P., Nelson, K. A., Orlowski, J. M., & Golden, B. R. (2020). Impacts and management strategies for crop production in waterlogged or flooded soils: A review. *Agronomy Journal*, 112(3), 1475-1501. doi: https://doi.org/10.1002/agj2.20093

Kogo, B. K., Kumar, L., & Koech, R. (2021). Climate change and variability in Kenya: a review of impacts on agriculture and food security. *Environment, Development and Sustainability*, 23(1), 23-43. doi: https://doi.org/10.1007/s10668-020-00589-1

Lladó, S., López-Mondéjar, R., & Baldrian, P. (2017). Forest soil bacteria: diversity, involvement in ecosystem processes, and response to global change. *Microbiology and Molecular Biology Reviews*, 81(2), e00063-00016. doi: https://doi.org/10.1128/MMBR.00063-16

Loreti, E., van Veen, H., & Perata, P. (2016). Plant responses to flooding stress. *Current Opinion in Plant Biology*, 33, 64-71. doi: https://doi.org/10.1016/j.pbi.2016.06.005

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, 13(3), 1318. doi: https://doi.org/10.3390/su13031318

Marshman, J., Blay-Palmer, A., & Landman, K. (2019). Anthropocene crisis: climate change, pollinators, and food security. *Environments*, 6(2), 22. doi: https://doi.org/10.3390/environments6020022

Moral-Muñoz, J. A., Herrera-Viedma, E., Santisteban-Espejo, A., & Cobo, M. J. (2020). Software tools for conducting bibliometric analysis in science: An up-to-date review. *Profesional de la Información*, 29(1), 1-20. doi: https://doi.org/10.3145/epi.2020.ene.03

Mukherjee, S., Mishra, A., & Trenberth, K. E. (2018). Climate change and drought: a perspective on drought indices. *Current Climate Change Reports*, 4(2), 145-163. doi: https://doi.org/10.1007/s40641-018-0098-x

Nations, F. a. A. O. o. t. U. Climate Smart Agriculture Sourcebook. Retrieved from https://www.fao.org/climate-smart-agriculture-sourcebook/concept/module-a1-introducing-csa/a1-conclusion/en/

Parajuli, R., Thoma, G., & Matlock, M. D. (2019). Environmental sustainability of fruit and vegetable production supply chains in the face of climate change: A review. *Science of the Total Environment*, 650(Part 2), 2863-2879. doi: https://doi.org/10.1016/j.scitotenv.2018.10.019

Ramesh, K., Matloob, A., Aslam, F., Florentine, S. K., & Chauhan, B. S. (2017). Weeds in a changing climate: vulnerabilities, consequences, and implications for future weed management. *Frontiers in Plant Science*, 8, 95. doi: https://doi.org/10.3389/fpls.2017.00095

Raza, A., Razzaq, A., Mehmood, S. S., Zou, X., Zhang, X., Lv, Y., & Xu, J. (2019). Impact of climate change on crops adaptation and strategies to tackle its outcome: A review. *Plants*, 8(2), 34. doi: https://doi.org/10.3390/plants8020034

Service, N. W. (2022). Heat Safety Tips and Resources. Retrieved from https://www.weather.gov/safety/heat

Skendžić, S., Zovko, M., Živković, I. P., Lešić, V., & Lemić, D. (2021). The impact of climate change on agricultural insect pests. *Insects*, 12(5), 440. doi: https://doi.org/10.3390/insects12050440

Sobrino, J. A., Julien, Y., & García-Monteiro, S. (2020). Surface temperature of the planet earth from satellite data. *Remote Sensing*, 12(2), 218. doi:

https://doi.org/10.3390/rs12020218

Sun, Y., Ding, J., Siemann, E., & Keller, S. R. (2020). Biocontrol of invasive weeds under climate change: progress, challenges and management implications. *Current Opinion in Insect Science*, 38, 72-78. doi: https://doi.org/10.1016/j.cois.2020.02.003

Tang, K. H. D. (2019). Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. *Science of the Total Environment*, 650, 1858-1871. doi: https://doi.org/10.1016/j.scitotenv.2018.09.316

Vahid, K., Ezatollah, K., & Marzieh, K. (2018). Climate change and agriculture: Impacts and adaptive responses in Iran. *Journal of Integrative Agriculture*, 17(1), 1-15. doi: https://doi.org/10.1016/S2095-3119(17)61794-5

Vila, M., Beaury, E. M., Blumenthal, D. M., Bradley, B. A., Early, R., Laginhas, B. B., Ibañez, I. (2021). Understanding the combined impacts of weeds and climate change on crops. *Environmental Research Letters*, 16(3), 034043. doi: https://doi.org/10.1088/1748-9326/abe14b

War, A. R., Taggar, G. K., War, M. Y., & Hussain, B. (2016). Impact of climate change on insect pests, plant chemical ecology, tritrophic interactions and food production. *International Journal of Clinical and Biological Sciences*, 1(02), 16-29. Retrieved from http://oar.icrisat.org/9735/1/Impact%20of%20climate%20change.pdf

Wright, A. J., Ebeling, A., De Kroon, H., Roscher, C., Weigelt, A., Buchmann, N., Hildebrandt, A. (2015). Flooding disturbances increase resource availability and productivity but reduce stability in diverse plant communities. *Nature Communications*, 6(1), 1-6. doi: https://doi.org/10.1038/ncomms7092

Ziska, L. H., Bradley, B. A., Wallace, R. D., Bargeron, C. T., LaForest, J. H., Choudhury, R. A., Vega, F. E. (2018). Climate change, carbon dioxide, and pest biology, managing the future: Coffee as a case study. *Agronomy*, 8(8), 152. doi: https://doi.org/10.3390/agronomy8080152